Postdocs in Mathematics

Understanding Gender Equity and Opportunity

Postdocs in mathematics are understood to lead to desirable mathematics faculty research positions. Over the past fifteen years there has been no statistically significant change in the proportion of women in mathematics postdoc positions.

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Capstone Study

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Preface

Acknowledgements

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To my fellow leaders in STEM across the nation, you inspire me. I know we can and are improving and reforming STEM education for women and URM. I am grateful to be a part of the greater good.

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Executive Summary

The Association of Women in Mathematics (AWM) has posted on their website that as of 2017, 17% of tenured/tenure eligible math faculty are women. That fact is based upon the Annual Survey of the Mathematical Sciences by the American Mathematical Society (AMS) (Golbeck et al., 2019, Table FF.4). The percent of women achieving tenured/tenure eligible position in PhD-granting institutions stands at 12%, as of the 2017 AMS report (Golbeck et al., 2019, Table F.2). The number decreases when considering the rank of full professor. Despite tremendous efforts in STEM fields to broaden participation of women and underrepresented minorities (URM), the field of mathematics still shows evidence of decreasing numbers moving into advanced levels in higher education, with strikingly low rates of those moving into faculty positions at PhD awarding institutions.

Data from the American Mathematical Society (AMS), the National Center for Education Statistics (NCES) and the National Science Foundation (NSF) all suggest that in STEM fields, women are earning bachelor's degrees through doctoral degrees at a lower rate than men, with math being one of the lowest areas. The rates of women moving through the field of mathematics is decreasing at each higher education degree level earned (Golbeck, Barr, & Rose, 2019). An important contributing factor to earning tenure or tenure-eligible positions in mathematics at PhD granting institutions includes prior experience in mathematics research, which is strongly supported by postdoctoral positions (Academic Position, 2018; Ehrenberg & Kuh 2012; Farmer, 2009; Yang et al., 2015). This suggests that exploring postdoc positions may be an important factor influencing the women in tenure-track positions at PhD granting institutions. Understanding the rates of women in mathematical postdocs and exploring the recruitment and hiring practices of gaining mathematical postdocs were the focus of this capstone study.

Data collected by the AMS report numbers of women participating in postdoctoral mathematics positions over time. This capstone study considered the available data to analyze the rate at which women participate in mathematical postdoctoral positions. This study demonstrated that the rate of participation of women in mathematical postdocs has remained unchanging over the past fifteen years. Moreover, it was noted that women are underrepresented in tenure-track mathematics faculty positions at doctoral awarding institutions where research is expected. The mathematics postdoctoral positions are opportunities for newly minted PhDs to continue research methods, be mentored by a postdoc advisor, network and collaborate with others in the discipline, and be published in peer-reviewed journals. Each of these outcomes contributes favorably to earning top faculty positions.

Mathematical postdoctoral positions are a critical component in establishing research, obtaining grants, and increasing the number of publications. It is viewed by many as a necessary step in moving to doctoral tenure-track faculty positions at the top fifty research institutions. However, this capstone study demonstrated numbers historically are unwavering in the rates of women participating in mathematics postdocs. This impacts the opportunity for women and URM to advance into tenure track positions at PhD-granting institutions. The results of this study and current literature review in this area suggest the following: 1. The rates at which women are participating in mathematical postdocs have not significantly changed in the past fifteen years. 2. Women are significantly underrepresented in mathematical faculty positions at PhD awarding institutions (Glazer, 2019, Vitulli, 2018, AMS). 3. Research evidence and/or prior postdocs suggest a higher rate of earning positions for first time faculty positions at PhD awarding institutions. 4. Bias exists in STEM faculty when considering gender in STEM fields, including the quantitatively driven field of physics (Moss-Racusin, 2012; Eaton et al., 2019). This capstone study was undertaken to inform the work of the Association of Women in Mathematics in supporting their mission of advancing the rates of women participating in mathematical sciences. Based upon the findings from this study and the review of current literature, steps for formalizing recruitment and hiring of mathematical postdocs are recommended to ensure unbiased and consistent practices exist in the field.

Introduction

The need for inclusive practices which work to enhance programs, promote a welcoming working environment, and encourage innovative ideas in research are all part of the claims – which are justified - to promote more diverse and inclusive STEM fields. Indeed, if America is to remain competitive in its current global economy, institutions must promote environments in research and innovation which includes the participation of women and URM (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011), and promote equity and inclusion in fields which have areas of projected need (National Science Foundation (NSF), U.S. Bureau of Labor Statistics, National Academy Press, 1989). Blackburn (2017) summarizes the governmental calls to action in supporting the broadening of participation in STEM fields and mathematics which have been undertaken (*Everybody Counts*, 1989), including but not limited to the America Competes Act (2007), Educate to Innovate (2009), and America Competes Reauthorization Act (2010). It should be noted many of these programs were initiated more than ten years ago, yet the evidence of data across STEM fields continue to illustrate the loss of talent and new knowledge as numbers of women diminish throughout levels of education within these fields, including mathematics (NSF, 2019).

Organizational Context

The Association for Women in Mathematics (AWM), founded in 1971, was organized to promote equity for women in mathematics. From their website, “The purpose of the Association for Women in Mathematics is to encourage women and girls to study and to have active careers in

the mathematical sciences, and to promote equal opportunity and the equal treatment of women and girls in the mathematical sciences" (AWM, 2020). While a relatively young organization, both its name and mission clearly call for the need for diversity in mathematics across all education levels and places of work.

While the AWM supports women across all levels of mathematics, it is of particular interest to note the history of women in mathematics higher education within the context of this organization. On the AWM website, the organizational history includes the following important item: "Princeton did not start admitting women to their graduate program in mathematics until the fall of 1968. Marjorie Stein (Princeton Ph.D., 1972) was the first woman to complete her degree requirements there" (Blum, 1991). The history of the AWM organization chronicles the ground-breaking women who successfully penetrated an academic STEM field dominated by males. This information and historical perspective shines light on the lack of women participating in higher education mathematics.

The AWM fosters the growth of women across all mathematical careers and studies in conjunction with other partner organizations, including but not limited to the AMS and Society for Industrial and Applied Mathematics (SIAM). The AWM supports women through a variety of mentoring programs, research opportunities, and professional conferences. Organizational members pursue research in pure mathematics, but also inform and assist in shaping policy on current issues. Those include the lack of women in the mathematical pipeline throughout advanced levels of degree-seeking women in higher education. From their website, "AWM is working to fix the leaky pipeline for women in mathematics" (2020). The progression of women through mathematics is supported at every level by this organization. The organization's overarching goal is to increase the participation levels of women at the very highest levels of mathematics, which includes achievement of the professoriate at mathematics PhD-granting institutions. Understanding the supports and/or barriers in place for women along this progression of mathematical achievement provides the organization with information and insights to impact institutional change for increased levels of women in mathematics.

Current research by members and initiatives overseen by the AWM organization includes, but is not limited to, the AWM Mentor Network, Vitulli's (2018) attention to faculty positions earned by PhD candidates, and an NSF ADVANCE grant supporting systemic change in academia. As an affinity group dedicated to supporting the trajectory of females into mathematical sciences, the AWM promotes fair and unbiased advancement of women into and throughout academia requires both support and action.

While initiatives exist supporting women on their trajectory toward a fuller participation in mathematics, one avenue for pursuing research faculty positions remains relatively unstudied – the mathematics postdoc position**.** This capstone study sought to uncover the historical data regarding the participation levels of women who have been awarded mathematics postdoc positions, describe the significance of such positions for advancing into PhD doctoral math faculty positions, and provide initial insights into the practices of recruiting and hiring postdocs.

Further, the intent was to advance the understanding of potential barriers for women and URMs in being awarded mathematics postdoc positions, thereby supporting the important work of the AWM.

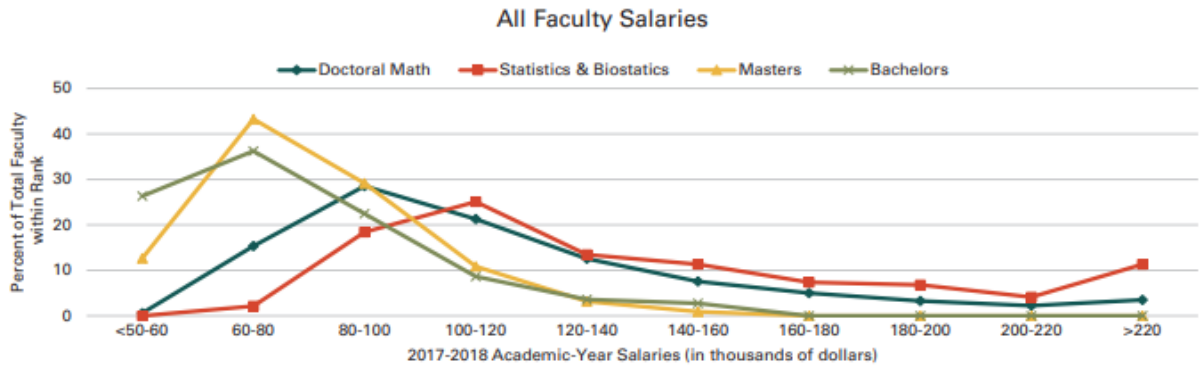
Background

Financial Equity and Opportunity

In considering the field of mathematics or statistics as careers, it is worth noting the U.S. Bureau of Labor Statistics lists those areas as two of the top fifteen for predicted occupation growth between the years of 2018-2028. Moreover, the median salaries shared in 2018 for individuals in mathematics ($101,900) and statistics ($87,780) rank in the top six of the fifteen careers provided. Careers in these quantitively driven areas may open doors to financial advantages.

Financial equity is one of the factors which highlights the importance of studying the absence of women and URM in mathematics. In investigating the lack of gender diversity in mathematics, summarized results from the 2015 and 2017 National Mathematics Survey show the decrease in women as the advancement of higher levels is reached. The numbers suggest there is a distinct drop in the number of women in mathematics throughout the pipeline in higher education. Moreover, the numbers are dramatically lower when considering those as full professors at PhD-granting institutions (Golbeck, Barr, & Rose, 2017).

Figure 1



In considering this implication for faculty salaries as well, the 2017 data from the AMS 2017-2018 Faculty Salaries Report indicate the overall increase in earnings for those in doctoral math positions, with the exception of statistics and biostatistics (see Figure 1). The earned doctorate, and further teaching at the doctoral institutions is one of financial equity and opportunity as well. The progression throughout mathematics into top positions shows a significantly lower rate of women compared to male counterparts, which suggest opportunities exist for improvement in both diversity and equity.

As the data and existing literature were explored, trends and patterns were considered. The goal was to identify potential areas to suggest evidence of what the underlying problems might be on the path toward the professoriate. A critical juncture for learning more about independent research theoretically lies in the postdoc position. Indeed, in exploring postdoctoral advancement, the National Postdoctoral Association (NPA) posits, "Many institutions understand the benefits of diversity and would like to enhance diversity among its students, faculty and staff, including postdocs. The long-term goal is to increase the diversity of STEM faculty. In order to move qualified individuals through the pipeline these primary components are essential 1) recruitment 2) retention and 3) preparation for the next phase" (NPA, 2019). For many, this progression is the move into an academic research position at an institution of higher learning.

Problem of Practice and Key Questions

Women are entering the postdoctoral field at a lower rate than men. Diversity is required for the advancement of new knowledge, and women are not present in postdoctoral studies where much of new knowledge is discovered and guided for future research as a mathematics faculty member. Understanding the factors which influence the decreasing numbers of women and URM in mathematics may also support improved opportunities and better access for financial equity and stability to others in STEM fields which are currently dominated by men. As the Smithsonian Science Education Center posts on its website, "STEM occupations out-earn non- STEM fields by 12-30% across all education levels" (2016). Women and other URM currently do not experience this advantage when their representation in the fields is lacking.

The work of van den Brink and Benschop (2014) and van Veelen et al. (2019), point out that social identity and gender identity exist as a threat to women in predominantly male fields. It may also intersect with a systemic culture of preferential bias for gender as indicated by Eaton et al (2019). This work lends to the investigation of recruiting and hiring practices focused on the mathematics postdoc appointments. The specific study attempted to illuminate the consistency and unbiased practices in place across institutions which select postdocs in mathematics.

If we understand that the move into faculty research positions expects a level of prior research and publications, then the need for a postdoc position may be accepted as a strong avenue by which to prepare for independent faculty research and thus more prestigious faculty tenure track positions. Through initial review of the literature and data on hand, little was revealed about the postdoc experience specifically in mathematics. This gap in evidence led to further questions to be explored. It is therefore important to also understand the historical trends by gender in this area, the current research on postdocs in STEM fields as it relates to mathematics, and further the understanding of the recruitment and hiring practices associated with postdoc positions in mathematics. How those practices may relate to gender were addressed. By working to understand these practices, the goal was to provide the AWM with informed research and

recommendations for supporting women from PhDs and into postdocs, with the goal of moving into tenured faculty at PhD granting institutions. This led to the following research questions to inform the capstone study and address the problem of practice for the AWM:

1. Has gender equity changed over the past fifteen years in mathematical postdoc positions?
2. What are the recruitment, selection, and hiring processes used for postdoc positions in mathematics?
3. What are the recommended norms/practices in professional organizations for selecting postdocs?

By considering these questions, this paper intends to support and further the work and mission of the AWM, thus positioning the organization to continue the necessary work of broadening participation in mathematics through their support of women and URM interested in this field.

Literature Review

Overview of Women in STEM

Science, technology, engineering, and mathematics (STEM) fields, both in the United States and globally, are traditionally highly competitive fields, which have historically been largely comprised of men. The STEM fields are similar to many other fields and workplace landscapes whose composition has been influenced by the changing demographics of society and of those attending institutions of higher education. Over time, many fields reflected an increase in the number of women and underrepresented minorities (URM) entering the workplace. However, the rate at which women and URM enter and persist in the STEM fields has been markedly different (National Science Foundation, 2017).

There is a need and a call for diversity to enhance programs, cultivate a richer working environment, and promote innovative ideas in research; these are all part of the claims justified to promote more diverse and inclusive STEM fields. Indeed, if America is to remain competitive in its current global economy, areas of education and industry must foster a rich and diverse pipeline of individuals to shore up the ability to remain competitive in research and innovation (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 2011).

Attention has also been drawn on how connections from US participation in STEM fields remains critically important to the strength of the US economy. Freeman's (2006) paper for the National Bureau of Economic Research noted, "The U.S. share of the world's science and engineering graduates at all degree levels is declining rapidly, as college enrollments have expanded in other countries. The number of S&E (science and engineering) PhDs from…US universities has stagnated" (p. 2). Freeman's paper draws attention to not only the intellectual contributions from the US, but also the job market growth potential. Freeman suggested that the data pointed toward

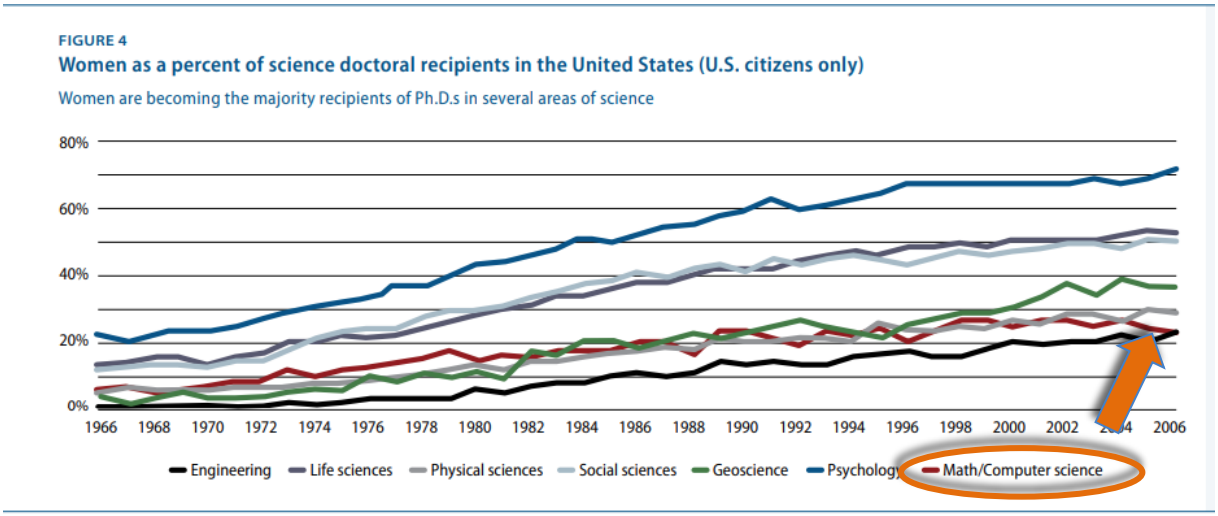
a serious concern for the lack of S&E [Science and Engineering] workforce in the US also connected to a lack of growth of PhDs in this area. If the US is not growing in research and development in academia, the entire workforce may be impacted. PhDs in the field move into industry, but many also move into academic fields - including postdoc research positions.

While industry is a part of innovation and research, higher education plays a significant contributing role to research and development. "U.S. academic institutions play a critical role in the nation's S&E enterprise by providing advanced education and training students in research practices in the areas of science, engineering, and mathematics. The nation's universities together conduct over half of the nation's basic research, thus creating new knowledge and contributing to innovation" (NSB, 2016, p. 11). More specifically in the realm of higher education, postdoc positions are critical in advancing research at universities. The role of advancing knowledge and being on the edge of innovation is a key mission for large research universities (Cantwell & Taylor, 2015). While postdocs are considered instrumental to the research work at universities, gender discrepancies remain in many of the traditional S&E fields typically held by men. As research in STEM fields is viewed as instrumental work of the university, recognizing that women are underrepresented in many STEM fields, including mathematics, is significant. Moreover, "women are underrepresented among graduates of programs that most often lead to the higher paying, higher prestige jobs. This pattern has obvious implications for efforts to address gender inequality in the STEM workforce, including academia" (Weeden, et al., 2017, p. 145). Exploring mathematical postdocs and gender equity in the field will inform opportunities for the AWM to support women in advancing new knowledge, research, and development in mathematics, as well as addressing issues of gender equity in mathematics postdocs.

Women in Advanced Academic Levels of Mathematics

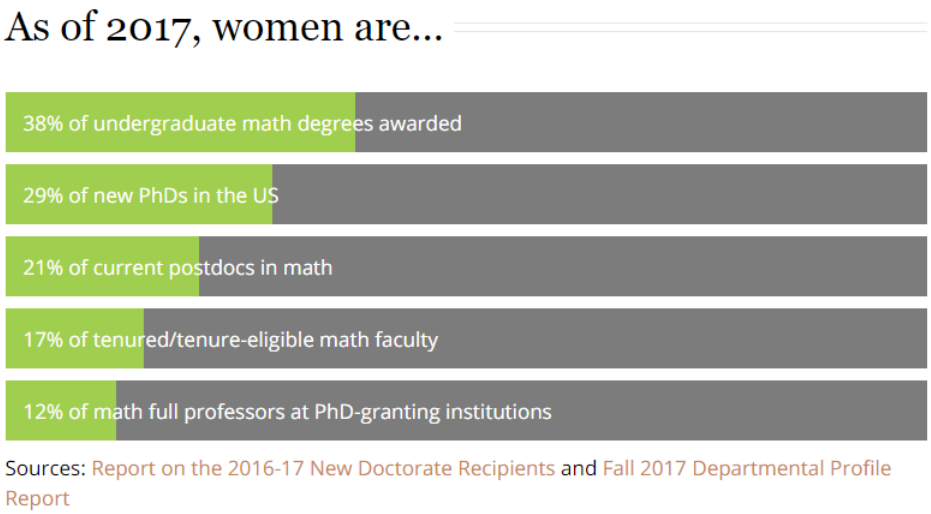
The National Science Foundation (NSF) regularly reports the data from S&E fields including data on gender and ethnicity. In a review of women in the S&E fields who earn PhDs over the time period from 1966 – 2006, data suggest a strong growth in overall fields, but the growth in mathematics (and computer science) is noticeably less by comparison over time (see Figure 2). The lack of women and URM in mathematics both in the workplace and in academia is one of equity.

Figure 2



As the evidence suggests, there are diminishing rates of women moving into PhDs and beyond in the field of mathematics. Moreover, there is stark evidence of diminishing numbers of women progressing through the field of mathematics at each level in higher education. Numbers from studies done by the American Mathematical Society (AMS), the National Center for Education Statistics (NCES) and the National Science Foundation (NSF) all suggest that in STEM fields, women are earning bachelor's degrees through doctoral degrees at a lower rate than men, with math being one of the lowest areas. The rates of women moving through the field of mathematics is decreasing at each degree level earned (Golbeck, Barr, & Rose, 2017).

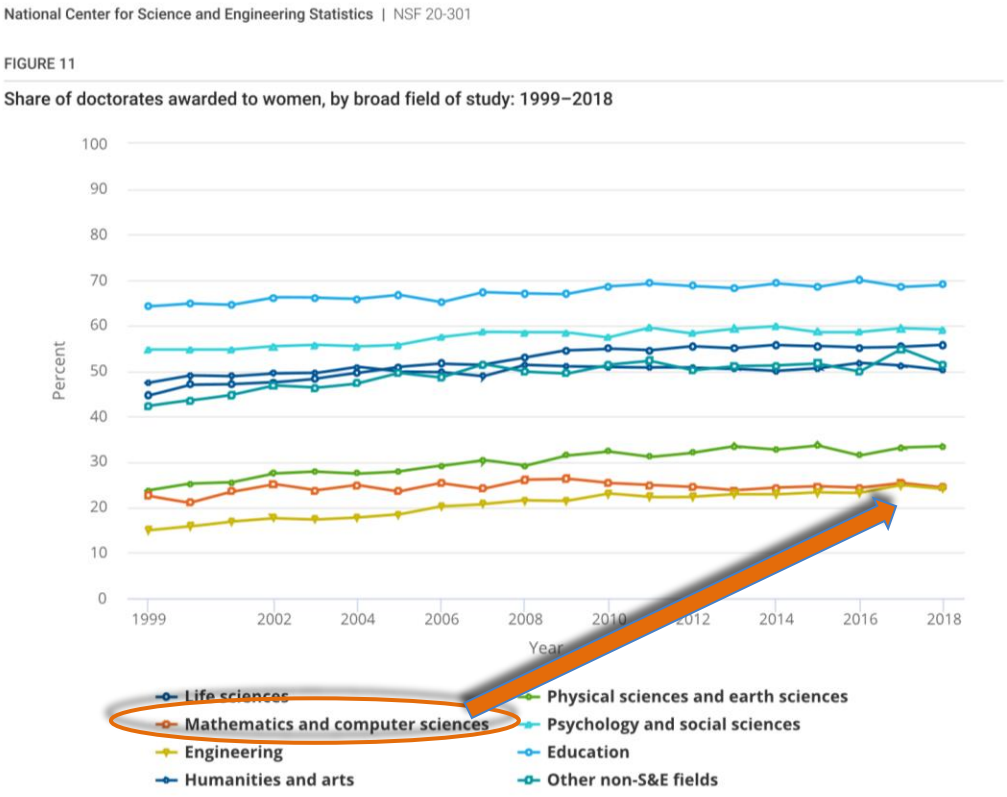
Figure 3[1]



[1] AWM (https://awm-math.org/resources/academics/data-and-research/)

The AMS is an organization which annually collects data on the profession of mathematics in academia. Their data are publicly accessible and summarized both internally and by others invested in mathematics. This source of data supports an exploration of patterns and trends of women participating in mathematics higher education. This practice includes data on race, gender, and levels of education, with some variation in the types of questions asked over the years. The AWM shared on their website the graphic (see Figure 3) which illustrates a progression over the advanced levels of study in mathematics. This graphic clearly outlines the decreasing rates of women participating in mathematics at each level of degree/position obtained. These data include the number of postdoc positions held by non-tenure track full-time doctoral faculty.

Figure 4

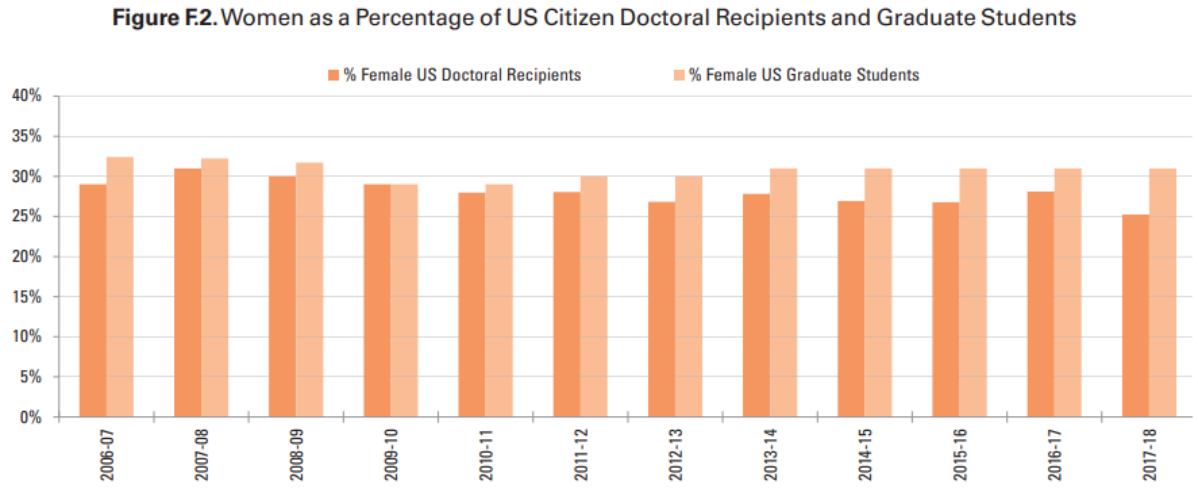


The numbers suggest there is a distinct drop in the number of women in mathematics throughout the pipeline in higher education. Continued exploration of women progressing in the field

included those of PhD level mathematicians. Data by the NSF suggests, “From 1999 to 2018, women’s share grew considerably in life sciences (from 45% to 56%), in engineering (from 15% to 24%), in physical sciences and earth sciences (from 24% to 33%), and in psychology and social sciences (from 55% to 59%). Women’s growth in mathematics and computer sciences has been modest, from 23% to 24% during this period” (NSF, 2019) (see Figure 4).

An alternate source, the AMS, tracks the overall trend for US women earning PhDs in mathematics, which includes “the percentage, over time, of US-citizen PhDs and graduate students who are women. It is notable that the percentage of women graduate students (tracked in the Departmental Profile reports of the Annual Survey) in the seven years leading up to 2017–18 has been steady at about 30%, whereas the percent of US citizen PhD recipients who are women has generally declined in this period” (Golbeck et al., 2020, p. 1204). (see Figure 5.)

Figure 5



Moreover, the numbers are considerably lower when considering professors at PhD-granting institutions. In a 1999 study, Nerad and Cerny note, “In mathematics, where substantially fewer postdoctoral positions are available, Ph.D.’s taking postdocs are more likely to obtain faculty positions, but this is true only for men” (p. 1533). This statement published twenty years ago suggests the need and importance of postdoc positions as a contributing factor to earning faculty positions. This may continue to be relevant today as data from the AMS Annual Survey Report indicate, “Women hold 15% of full-time tenured… positions in Doctoral Math departments” (Golbeck, Barr, & Rose, 2017). If women hold lower numbers of postdoc positions, it stands to reason that lower numbers of women would then also be moving into full-time faculty positions at PhD-granting institutions. Vitulli’s (2018) work on initial employment by those with pure mathematics PhD’s directly show that women have lower beginning employment not just in businesses, but also at the top universities. This is evidenced by Vitulli’s study (2018) of the 2012-2015 data from the AMS, “Similarly during 2012–2015 … the percentage of women who

were employed at Public and Private Large departments was considerably lower than for men, with the biggest difference occurring in Private Large hires" (p. 327). This evidence would suggest not much has changed from Nerad and Cerny's study before the turn of the century.

The Prerequisite Postdoc

The need for a PhD is essentially an assumed requirement for earning a position in higher education, but more specifically in a tenure-track research position in mathematics (Ehrenberg and Kuh, 2012; Yang et al., 2015). Moreover, to move into those faculty positions, some PhDs will likely progress into a postdoc position. Postdoc positions are defined to be, "A postdoctoral scholar ("postdoc") is an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing" (National Postdoctoral Association, n.d.). This position is considered as a next step in gaining research skills for moving into higher education. The Academic Position (2018) site explains:

> In many fields, a postdoc is the *de facto* next step on the academic career path after earning a PhD (hence the name.) A postdoc is a temporary position that allows a PhD to continue their training as a researcher and gain skills and experience that will prepare them for their academic career. Most postdoc positions are at a university or in industry, . . . While the vast majority of postdocs work in STEM fields.

This is evidence of the need (or perhaps almost an expectation) of a postdoc position to prepare one for a research career in academia.

A further note can be made in moving into academic positions at more prestigious research institutions. As Farmer (2009) wrote in a news article for the American Institute of Mathematics (AIM), "At high-powered research universities there is little emphasis on teaching, and many faculty teach just one or two courses each semester. Tenure and promotion at such places is mostly determined by research output" (Academic jobs section). Ehrenberg and Kuh (2012), in their book focused on the doctorate, claim there is a "need for (often multiple) postdoctoral appointments before PhD holders in many science and engineering fields can even contemplate a permanent academic position" (p. 2). Yang and colleagues (2015) further support the opportunities for postdocs, suggesting, "that a postdoc experience soon after degree completion assisted in securing employment in education, obtaining a tenure-track faculty position, and achieving higher research productivity" (p.682).

These works directly support the importance of a postdoc appointment to advance in the professoriate. If one accepts that the postdoc position is one which supports a PhD mathematician's growth in research and scholarly training in order to better prepare for a career in tenure-track research academia, an understanding of the gender composition of postdocs is of importance, as well as understanding ways in which postdocs are recruited and hired.

An analysis of men outnumbering women in STEM fields in the workplace has been studied in multiple arenas, and there are implications from these studies which may be considered relative to academic positions. Studies consider the role of women in STEM leadership fields, and what is impacting the lower number of women in those positions. Attention has been given to why women persist or elect out of roles in the workforce, many specifically in STEM fields dominated by males. The culture of the institution (Huang et al., 2019), (Barinaga, 2000), gender identity (Ibarra, Ely, & Kolb, 2013; van Veelen et al., 2019) and hiring practices (Kulik, 2014) have been a part of the body of research accumulated mainly in business organizations. Understanding these topics or barriers in the context of academia will help shape the discourse surrounding the postdoc position.

Barriers to Women in STEM Academia

Data collected over time by the AMS illustrate the pool of women which move from one level to the next in higher levels of mathematics is diminishing. This progression has been studied as to why the participation of women in mathematics lessens as one moves toward the professoriate. In a 2017 paper, Blackburn provided a thorough literature review on women in mathematics, mostly focused on undergraduate and some graduate experiences in the field. The review uncovered barriers which impede progress of women, and it also examined current practices and programs either in progress or being recommended to support women in higher education mathematics. Vitulli's (2018) work shared knowledge beyond undergraduates, where evidence of gender difference was found to exist for those in mathematics faculty positions. Vitulli posits, "Among all US-earned PhDs in mathematics, women have slightly lower initial unemployment rates than men, but their first post-PhD jobs are less likely than men's to be at top universities and in business or industry, despite the prestige of their PhD-granting department" (p. 326). Studies continue to draw attention to the diminishing numbers of women and URM participating in mathematics, which is impacting the disparate numbers of women positioned to achieve the mathematical professoriate at research institutions. A study by Yadav and Seals (2019) shared that the "majority of URM postdocs in STEM disciplines had a research-based academic position as their primary career goal, but did not feel confident in achieving it. As a result, their goals shifted towards either teaching-oriented academic positions, industrial research, or pursuing science policy in government/non-profit organizations" (p 8).

Academic Culture and Climate

Within academia, there may exist a sense of competitiveness with the need to be innovative and create new knowledge. Research is evident in institutions of higher learning and is expected for faculty to progress through tenure and promotion to achieve the full professoriate. There is a need for faculty to contribute to their field of study and its importance among colleagues (Henkel, 2005). In mathematics, a genealogy project exists online, which suggests a sort of propagation of offspring in particular fields of research, borne of particular "parents" in the discipline, namely the advisor (Mathematics Genealogy Project). The project lists on its FAQ that, "The Mathematics Genealogy Project catalogs information on individuals with doctoral degrees in mathematics. In our genealogy, one's parent(s) are his/her doctoral advisor(s)." This documentation indicates the number of "offspring" produced by a research advisor. This concept

of familial identity within mathematics may suggest a sense of proliferation and accomplishments in the field. Henkel (2005) notes, "the foundations of current individual agendas were laid down in discipline-based doctoral and post-doctoral studies and often how early specialisation [sic] and, thus, epistemic identity were established in that process" (Henkel, 2005, p. 167). Establishing a line of research and its proliferation may be regarded as one of establishing authority and identity within the field of mathematics. Henkel's (2005) work suggests:

> The dominance of the discipline, too, has come under severe challenge as organizing [sic] structure for knowledge production and transmission, as guardian of academic culture, and as nurturer of academic identity. However, it has been strongly defended by elite members and remains a powerful influence in reward systems and in the creation and maintenance of academic agendas. It remains a strong source of academic identity, in terms of what is important and what gives meaning and self-esteem. (p. 273)

The sense of pride and prestige in generating new knowledge, in advancing research in mathematics specifically, is evident. The AMS shared a statement in 2015, which stated, "In general, postdoctoral appointments in mathematics carry prestige." It is apparent the postdoc position, which is devoted to the advancement of new knowledge and research, is an avenue which is viewed as prestigious in mathematics. The fact that women obtain these positions at a significantly lower rate than men suggests those awarding postdocs view the potential contributions of men and women differently.

Additional interesting data to highlight the progression is noted by Glazer's (2019) work. Glazer's study focusing on undergraduate mathematics shared numbers of women represented at private universities (see Table 1). Glazer points out, "according to the National Science Foundation, … women earned only 25% of the Doctoral Degrees in Mathematics and Computer Sciences in 2015 (National Science Foundation) . . . Prestigious, private universities are of particular interest, because the gender gap in mathematics appears to be worse at these universities" (Glazer, 2019).

Table 1:Gender Breakdown of Mathematics Departments at Five Group I Private Institutions

	Number			Percentage Women		
	Bachelor's	**PhD**	**Senior Faculty**	**Bachelor's**	**PhD**	**Senior Faculty**
Harvard	245	58	25	20%	12%	4%

	Number			Percentage Women		
	Bachelor's	PhD	Senior Faculty	Bachelor's	PhD	Senior Faculty
MIT	663	139	51	28%	20%	8%
Yale	176	31	17	26%	16%	6%
Princeton	209	85	41	15%	13%	7%
Brown	113	42	24	27%	21%	8%

The above table reports the number of bachelor's and doctoral degrees conferred in mathematics between AY09-10 and AY14-15 and the number of senior faculty members at institutions surveyed in the National Mathematics Survey. It also reports the percentage of these degree recipients and faculty members that are women. Degree data comes from the Integrated Postsecondary Education Data System (IPEDS); a collection of annual surveys administered by the U.S. Department of Education's National Center for Education Statistics. Faculty data comes from each institution's mathematics department website as of November 2016. Senior faculty members include Full Professors, Professors Emeriti and anyone listed under Senior Faculty on the department website (note: at Harvard this also includes Professors of the Practice.[2]

Glazer's work focused on understanding experiences of women in undergraduate large private universities, which as Table 1 suggests, have below average rates of women in mathematics across these categories. (This is of interest when considering the responses of data collection within this capstone study.) A note of interest would be to consider which of these women are tenured - full professor faculty in mathematics. This work is further supported by an in-depth analysis of prestige segregation in higher education. Weeden and colleagues (2017) indirectly support Glazer's chart. Their study suggested, "Our results show that in most fields, the tacit assumption—that elite PhD pipelines are more male-dominated than average PhD pipelines—is on the mark" (p. 145). If the pipelines are more male-dominated for the prestigious institutions, then the possible financial equity and opportunity gap widens for women and URM, as does the potential for perpetuating the academic bias when seeking new appointments. Vitulli's (2018) work in hiring new mathematics PhD's at the doctoral degree awarding institutions may be evidence of such outcomes.

[2] Glazer, A. (2019).

In considering the diversity of roles of women and URM in the STEM fields in academia, attention has been paid to the climate for those participating in the social sciences and more recently on the lab sciences (Johnson, Widnall, & Benya, 2018; Tabak & Collins, 2011). The latter group has seen the culture and process of postdoc appointments and lab work more closely observed and reported upon in attempts to better understand the nature of postdoctoral positions and advancement (Moss-Racusin, et al., 2011; Odom, 2014). The existing culture and climate in pre-dominantly male populated fields is one of five factors which can contribute to environments where sexual harassment exists. Studies in university STEM fields have indicated sexual harassment exists on campuses experienced by undergraduates and graduate students (Johnson, Widnall, & Benya, 2018). This is a factor which may impede the progress of women successfully advancing in their chosen STEM field.

Finally, a chilly climate in STEM fields directly (Callister, 2006; Monroe et al., 2008; Settles et al., 2007; Xu, 2008) and across disciplines generally in higher education is noted as influencing the trajectory of women in academia (Maranto et al., 2010). The postdoc is clearly a part of the higher education environment. "In a profession in which informal collaboration and mentoring is directly instrumental to the primary measure of success – publications – women's exclusion, however unconscious or inadvertent, constitutes a powerful barrier to achievement (Maranto et al., 2010, p. 152).

Research Fields as Gendered Spaces

It has been established that postdoc positions are critical in advancing new knowledge at institutions of higher education in the US. These premises suggest the role of the postdoc position is critical for not only advancing in research, but also networking with others, providing experience and substance in publications, and providing evidence of the ability to work independently as a critical researcher in the chosen field.

> If your career goal is to be a contender for a top-tier research group leader position in this day and age, the goal of a postdoctoral fellowship is profoundly different than that of a studentship… In a postdoctoral fellowship, success would be counted as having published leading articles (note the plural) in top-tier journals…The most reliable way to be seriously looked at as a faculty candidate is to have cold, hard proof of your research caliber. (Odom, 2014, p. 1)

These arguments put forth the importance of the postdoc position as well as the importance of diversity for advancement of research, knowledge, and innovation. The National Academy of Sciences (2017) posits that individuals in postdoc positions, "gain valuable research experience and career guidance from an accomplished researcher. They learn to develop ideas for independent research, apply for grants, and manage a lab; they cultivate professional networks and publish papers. They eventually move into tenure-track research faculty positions at leading universities" (p. 1). Thus, the position of the postdoc is a critical appointment in the career path of a research mathematician considering the role of professor at a PhD granting institution. The ability to run one's own research projects, garner grant money for research, and publish papers based upon

knowledge created is advanced in postdoc appointments and expected for advancement in the professoriate.

Part of the systemic culture is acknowledging that the field, including mathematics research, is significantly populated with men. With an eye to identity theory, van Veelen et al. (2019), note in their study that "women in STEM face double trouble: The combination of working almost solely with male colleagues (being outnumbered) and working in the technical sector (where women are negatively stereotyped) predicted the highest levels of experienced gender identity threat, particularly among women who highly identified with their gender group. Gender identity threat, in turn, negatively predicted women's work engagement and career confidence (p. 1). This evidence was found to be strong in STEM fields, where many women may feel judged more so by their gender than by their ability in areas which have significantly more men than women. Because we understand that mathematics is a field populated with men, acknowledging the potential of how that impacts a woman's engagement and confidence in the field of mathematics must be considered. Moreover, in referring to Weeden and colleagues' (2017) work, women were more likely to self-elect out of programs from their own confidence, as well as factors which may include geography, family, etc., but the reasons for opting out of mathematics were not due to the women's ability to perform mathematically.

Evidence of Unconscious Bias in STEM Faculty

Evidence of barriers in academia within the literature was explored within the STEM fields. In a 2012 study by Moss-Racusin et al., the foundation was laid for the critical need for women in STEM fields and in the professoriate in particular. The claim made by the authors was that the persistence in the gap of women in advanced levels of higher education may… suggest(s) that the problem will not resolve itself solely by more generations of women moving through the academic pipeline but that instead, women's advancement within academic science may be actively impeded" (p. 16474). In exploring this potential for bias, the authors investigated how men and women undergraduates were treated by both male and female faculty in biology and physical science. Moss-Racusin et al.'s "study is unique in investigating subtle gender bias on the part of faculty in the biological and physical sciences. It informs the debate on possible causes of the gender disparity in academic science by providing unique experimental evidence that science faculty of both genders exhibit bias against female undergraduates" (Moss-Racusin et al., 2012, p. 16477). This study is important in understanding the potential for unconscious bias in STEM faculty. The Moss-Racusin and colleagues' study showed evidence of men and women faculty in the sciences rating female students in the sciences as less capable and less likely to be hired over male students. This study is significant in that it demonstrates evidence of bias existing in both men and women faculty and how their implicit bias influenced their responses toward students studying in the STEM fields.

While this evidence is neither directly in math or in postdocs, it may suggest the potential for hidden biases in how graduate mathematics students or women with PhDs are viewed and treated. This finding relates to the broader work of McNeely and colleagues (2018). In their review of literature relating to the gaps in participation by URM, women, and those with disabilities in the

STEM fields, the authors focus on the relationships and roles among those in the majority and in positions of power as part of the broader scenario in expanding participation in the sciences. McNeely and colleagues (2018) posit, “Disparities in representation and participation do not just happen; they are the result of complex processes reflecting broader social conditions and dynamics (McNeely, 2015; McNeely & Schintler, 2016)” (p. 556). This call to broadening participation suggests a wider perspective of systemic structures in place which may, even unknowingly, produce barriers to women and URM achieving advanced positions in mathematics.

Along with the challenge of keeping women in STEM programs, barriers also exist for women and URM continuing into advanced degree attainment and moving into higher education PhD faculty awarding positions. A report by Bennett and colleagues (2020) indicates, “The prevalence of bias and lack of inclusion extends beyond the instructional space to affect collegial relationships and decision-making, including the recruitment, hiring, and retention of faculty from diverse, underrepresented backgrounds” (p. 17). These decisions may include the recruitment and hiring of postdoc positions which involve collegial relationships. Postdocs in mathematics are listed by the AMS under the heading of nontenure-track appointments. This is to suggest that the time in the postdoc position is finite and will not end in tenure in the current assignment. Calls to look into recruitment and hiring practices in postdocs are limited, but newer studies have emerged. For example, a 2019 study by Eaton et al., on the hiring of physics and biology postdocs, suggests hidden barriers and biases may be evident in academia. This study sheds light on postdoc recruitment and hiring tendencies by faculty in the sciences. The study consisted of faculty reviewing identical postdoc files; however, the names were manipulated to suggest race and gender when the files were reviewed and ranked by the faculty. Results indicated:

> Faculty in physics exhibited a gender bias favoring the male candidates as more competent and more hirable than the otherwise identical female candidates. Further, physics faculty rated Asian and White candidates as more competent and hirable than Black and Latinx candidates, …An interaction between candidate gender and race emerged for those in physics, whereby Black women and Latinx women and men candidates were rated the lowest in hireability compared to all others. (p. 127)

This study is critical in the literature review as it speaks directly to the influential decisions of hiring made by faculty in the sciences. The focus here is on the outcomes in physics as a more quantitatively powered field, as compared to biology in the life sciences. The study of physics is more similar to mathematics, which may suggest the potential for similar outcomes could be found. The authors indicate a potential weakness in the study in that none of the files were exemplars; however, each file had previously been ranked as an above average applicant. (Eaton et al.). While this study may have potential weaknesses, it suggests that as women and URMs move through academia, their identities as mathematicians may be not only challenged, but perpetuated as those individuals are overlooked. Moreover, this finding is important in that the perception of hiring of postdocs positions is typically viewed as a position overseen by the

advisor, PI, or other similar individual who selects the postdoc. The NASEM 2020 report indicates the context of bias in hiring postdocs is important "because such hiring decisions are often made by individual principal investigators with little administrative oversight and formal monitoring" (p. 42). The selection of postdocs is critically important as it supports time to advance and improve research and publication opportunities, widely expected of tenure-track faculty in doctoral PhD positions.

It is clear that the numbers of women in mathematics moving into PhDs and beyond are extremely low. Reports in STEM fields and by professional organizations acknowledge that little information is known in the area of postdocs. As more information is sought on understanding the recruitment and hiring of postdocs, understanding the importance of those positions and considering what is known helps paint the landscape of what can be for those in academia. It is to be noted that this capstone study largely focused on academic postdocs. While other postdoc positions exist, as the National Academy of Science (2014) posits, "academic postdoctoral researchers . . . are by far the largest component of the population" of those in postdoc positions. (p. 3). This is further supported by the AMS, which in its 2016 Annual Report shared that 60% of postdocs hired were in academia.

"As of Fall 2017, … women make up only 19% of full-time faculty in doctoral math departments.

This number is only 12% if one restricts to tenured faculty at the top 50 research institutions"

~www.awm.org

(See Figure 3)

Postdoc Hiring Practices

Ultimately, reviewing hiring practices is a key area for potential unconscious bias against women and URM in mathematics postdocs. One area of recruitment work in a tangential science field, specifically for postdocs in clinical psychology and clinical neuropsychology, has been explored by Bodin and colleagues (2018). This paper suggests the methods by which candidates are selected in the health psychology fields is currently inconsistent across institutions (Bodin et al., 2018, p. 80). Due to limited information available on hiring postdocs, insights into human resource management methods were therefore explored.

Evidence of hiring practices in human resource management consistently describes the processes involved in recruitment and hiring. Hargis and Bradley (2011) state, "Effective human resource management practices, including properly developed employee recruitment and selection plans…have been linked to higher employee performance." (p. 107). Within the human resource framework, all levels of the onboarding and retaining of employees are discussed; however, for the purposes of this paper, the focus remains on recruitment and hiring.

Hargis and Bradley (2011) further posit recruitment strategies may be limited to resources, and that selection of the candidates from a pool of applicants is significant. Having a pool of candidates which meets clear criteria is an important consideration in the hiring process (Valantine, 2018). Hargis and Bradley (2011) indicate, "The most valid selection procedures help

a business consistently and accurately evaluate whether a job applicant has the knowledge, skills, and abilities that align with the core competencies a business relies on to create a competitive advantage" (p. 108).

Based upon findings in human resource management literature, recommended hiring processes for postdoc candidates were explored through professional organizations including the National Postdoctoral Association (NPA) and the National Institutes of Health (NIH). The latter organization has a public presentation and toolkit available (for purchase) for practices which attend to diversity in the recruitment and hiring at institutions of higher education. Valantine (2018) posits, "Recruitment candidates should be vetted objectively, using the same criteria, after assembling an initial diverse list" (Slide 12). The list should be generated from an unbiased search for candidates. This point is important with the noted potential for hidden bias as "studies show for instance how the ideal academic is gendered; the constructed ideal encompasses masculine characteristics and therefore women academics are expected not to fit the ideal" (Herschberg, Benschop, & van den Brink, 2018, p. 305). The NIH presentation further underscores the pervasiveness of bias in not just science fields, but in academic science as well (Valantine, 2018). The NIH went on to state that the criteria for the position must be fully and clearly articulated prior to conducting a search. An assessment tool for the fair and objective evaluation of each candidate should be used to minimize bias and promote fair selection. They further suggest that the selection committee be a diverse group and that anonymous voting be utilized as appropriate (Valantine, 2018).

Conceptual Framework

The current review of literature has well established the significance of the lack of diversity in academia and its potential impact on the creation of new knowledge. The need for diversifying postdocs in mathematics involves enhancing research, achieving grants, and increasing the number of publications, each of which are critical steps in leading to doctoral faculty positions. As postdoctoral work is a significant pathway of generating new knowledge in mathematics, understanding the lack of gender diversity is critical. This paper has shared evidence of research connected to the lack of persistence in the field; however, current literature has expressed little evidence of hiring practices that have explored the potential for gender bias in this area. As hiring practices in this study were researched in postdoctoral programs, exploration of the practices will be broadly considered via the literature on hiring and selection best practices, as well as through the lens of social network theory.

Social network theory suggests "an individual's network structure – measured by variables such as breadth, number and type of ties, centrality, and influence within a network – influences selection for and influence in leadership" (van Esch, Assylkhan, & Bilimoria, 2017, p. 137). This network view of understanding success in career trajectories, including in academia, where the

relationships among those in the work environment may either impede or advance opportunities for others, may explain the lack of gender diversity in mathematical postdocs (Daly, 2010).

Social network theory has implications for women in organizations and for their own personal success within organizations. The theory and its implications have been studied extensively in the business world. Specifically, "networks (also) produce inequalities as there is ample evidence of network related unequal outcomes in status, influence, careers, information, and trust (Ibarra, 1992; Krackhardt, 1990; Podolny and Baron, 1997)" (as cited in van den Brink & Benschop, 2014, p. 461). As this theory has been further explored, an emergent understanding of homophily within social network theory surfaced, as well as a role of "gatekeepers", specifically in academia. This capstone study integrates the basic tenets of homophily and the tangential theory of gatekeepers in social network theory, shares evidence of research in parallel areas of academia, and considers the lens of these particular frameworks within social network for the study of hiring practices in mathematical postdoc positions.

Homophily is the concept of individuals seeking out others who are similar to oneself, initially suggested in social interactions. "This tendency is referred to as homophily, and it plays a fundamental role in shaping social dynamics (Blau, 1977; Kandel, 1978; Kossinets & Watts, 2009; McPherson, Smith-Lovin, & Cook, 2001). Homophily is ubiquitous as its effects can be observed in almost all kinds of social interactions such as friendship, membership in an organization, information exchange, trade and business transactions, marriage, and the like" (Yavas & Yücel, 2014, p. 354). To note, homophily as a subset of social network theory includes interactions which take place within organizations. This construct has been explored in social networks, including those influenced by gender in the workplace. Specifically, van den Brink and Benschop (2017), posit:

> Homophily suggests that there will be fewer relationships and less communication between people who are dissimilar for any reason including, but not limited to, gender, race, class, and position (McPherson and Smith-Lovin, 1987). This directly impacts women leaders as it has been shown that this lack of connection leads to decreased individual performance (e.g., Ibarra, 1992; Krackhardt and Stern, 1988; Reagans and Zuckerman, 2001). (p. 137)

This concept has been further considered in the academic arena, noting impacts in the area of women in leadership and in academic publications. This idea was recently considered in a study of research papers over time led by Barnes, Sang, and Baruch (2017). The authors wrote, "Social networks represent one of the structural barriers to women's full participation in academic life, as it 'reproduces and constitutes power in action in everyday organizational life' (as cited in Benschop, 2009, pp. 222-223). Specifically, workplaces, including academia, perpetuate inequalities through the persistent dominance of white men" (Barnes et al., 2017, p. 4). In their work, the researchers concluded, "that white men are publishing with white men. If homophily of the dominant group within academia (white men) persists then there are implications for the

progression of those who are not based in leading Western universities, those who are not white and those who are not male. As such, the composition of coauthoring teams has implications for the exclusion of marginalized academics" (Barnes et al., 2017, p. 25). This claim is further supported by Holman and colleagues. In a meta-analysis of gender and coauthoring of articles, Holman et al., (2018) determined mathematics was one of the fields where women as single authors or last authors were highly underrepresented. Parity in publication was not predicted to be reached anytime in the next several decades. Because research and publications are an important part of postdoc positions, recognizing the disparity in mathematics postdocs could improve network affiliations in research for women as well as increasing the rate of publications.

Social network theory has been identified in the literature with implications surrounding areas in fields dominated by one specific group, and it is noted that advanced positions held within mathematics are largely dominated by men. Yet, as researchers van den Brink and Benschop (2014) point out, the limitations of homophily and networking as "studies on sex differences in networks [which] concentrate on network structures and outcomes" (p. 461). Within organizations and the sciences largely dominated by men, a focus has been on the outcomes, which are largely unchanging percentages as previously noted. "With the notions of gender and networking as social practices, … a new perspective in organization network research (surfaces) that allows … insights into what people say and do in networks, in their networking activities (Shaw, 2006), and in the way that networking creates, reinforces, or counters gender inequalities" (van den Brink & Benschop, 2014, p. 465). This work specifically focuses on higher education and the appointment of the postdoc leading to the professoriate. As appointments are made within academia, van den Brink and Benschop (2014) posit that those who are in the role of overseeing recruitment and hiring - the gatekeepers of an appointment - are critically important in "how networking practices of inclusion and exclusion bring about gender inequality" (p. 466). Specifically, when a single individual or gatekeeper of appointments is considered, the work of van den Brink and Benschop highlights the role of human agency in the selection process. This goes beyond the concept of homophily and underscores the ideas of influence and choice, and how gender practices may impact professorial appointments. This study:

> sheds light on how gatekeepers practice gender in networking by (a) identifying the networking practices gatekeepers routinely use in recruitment, (b) showing how those networking practices are intertwined with gender practices, and (c) showing how those gender practices in networking produce or counter gender inequalities. (van den Brink & Benschop, 2014, p. 486)

In order to promote the AWM's support of women through advanced levels of mathematics, and ultimately into faculty positions at PhD-granting institutions, an understanding of the mathematical postdoc positions, and more specifically the recruitment and hiring for postdoc positions, became a focal point of study.

Methods and Design

As discussed, a primary purpose of this capstone study was to advance the understanding of the recruitment and hiring practices of mathematical postdoc positions. Evidence was gathered in three approaches:

1. Analyzing the literature on postdocs in related STEM fields to inform practices on recruitment and hiring of postdocs.
2. Examining existing postdoc data collected and available through the American Mathematical Society (AMS).
3. Collecting evidence of current practices recruiting and hiring practices of mathematics postdocs in higher education across the nation.

Evidence was sought to determine what are commonly used practices as potential influences regarding the state of women in mathematics. The first method listed above was provided in the literature review, and the summary analysis will be shared in the findings. The second and third approaches are described in this section, with results shared. An overall summary and analysis of the findings will be shared with recommendations on moving forward in the field of mathematics.

External Data Analysis

The AMS has a commitment to understanding the trends and numbers surrounding the practice of teaching and scholarship in the mathematical sciences. Each year the AMS conducts an annual survey of the profession, which is supported in conjunction with several other professional organizations: the American Statistical Association (ASA), the Institute of Mathematical Statistics (IMS), the Mathematical Association of America (MAA), and the Society for Industrial and Applied Mathematics (SIAM). This Annual Survey is a rich resource for the mathematical community. The data is a comprehensive undertaking to gather details on the composition of institutions, departments, and students in mathematics across the United States. The survey has changed somewhat over the years, but generally collects details on faculty and students regarding salaries, course enrollments, and degrees awarded (AMS).

This annual survey is collected from participating departments each year, and the AMS shares the tables and special summarized reports publicly on their website. This trove of information provided insights into the historical trends of postdoc positions awarded each year in mathematical sciences. An example of tables provided in the 2017 data is shared in Appendix A. This specific example is taken from the *Report on 2016-2017 Academic Recruitment, Hiring, & Attrition,* summarized and written by Golbeck, Barr, and Rose (2017). All reports are able to be accessed online, through: www.ams.org.

Within the AMS report, and each yearly report, focus was directed on the table(s) providing the total number of postdoc appointments for those who held doctorates. The information was then narrowed to provide the total number of women who held doctorates who were hired into postdoc appointments. To illustrate this information, Table R.1 is shared: Recruitment and Hiring of Faculty in the Mathematical Sciences, Fall 2017 by Department Grouping. This particular table highlights the number of doctoral math faculty in postdoctoral appointments, both those of the full faculty and those appointments held by women. To clarify the variable being studied, the description or definition of postdoc faculty found in the AMS reports is provided as, "Postdoctoral faculty includes full-time faculty who have teaching and/or research responsibilities, but for a strictly limited term of employment (i.e., those individuals who hold a temporary position primarily intended to provide an opportunity to continue training or to further research experience)" (Golbeck et al., 2017, p. 1729). The women in these positions are in fulltime postdocs, having been hired to begin in the year the report was issued. It is also noted that the variable studied focuses on doctoral full-time math postdoc appointments[3].

To clarify the analysis of data, Table R.6 from the Fall 2017 report is shared below (see Figure 6). In this table, the total of All Doctoral Full-Time Math Faculty who are in Postdoctoral appointments is 248 men and 73 women. This table is one of several used to determine the percentage of women in full-time postdoc appointments, which is found to be 22.74% for 2017. (The percentage of women earning doctoral full-time math faculty postdoc positions is calculated as ((number of women)/(number of men + number of women) *100). The spreadsheet found in Appendix B shares the data recorded from each year[4] with percentages calculated and posted.

Figure 6

Previously in postdoc	-	-	-	-	-	-	-	-	-
Non-tenure-track Hires	**136**	**104**	**87**	**129**	**33**	**30**	**36**	**41**	**519**
Doctoral hires	131	101	77	128	33	27	36	41	497
Men	97	75	54	98	28	20	23	25	372
New doctoral hires	66	44	32	75	18	12	12	12	24
Not new doctoral hires	31	31	22	23	10	8	11	13	
Postdoc appointments	79	44	23	71	16	15	8	12	248
[illegible]	16	9	23	3	4	3	4	-	58
Women	34	26	23	30	5	7	13	16	125
New doctoral hires	23	8	11	22	4	4	8	8	72
Not new doctoral hires	11	18	12	8	1	3	5	8	
Postdoc appointments	28	11	3	23	4	4	7	7	73
[illegible]	7	2	8	-	-	-	3	-	17
Nondoctoral hires	5	3	10	1	-	3	-	-	22
Men	4	1	4	1	-	-	-	-	10
Women	1	2	6	-	-	3	-	-	12
Other	-	-	-	-	-	-	-	-	-
Unfilled positions	**18**	**17**	**23**	**15**	**4**	**10**	**39**	**21**	**87**

[3] The study did not include similar positions in statistics or biostatistics, nor did it include those in masters or bachelors qualifications.

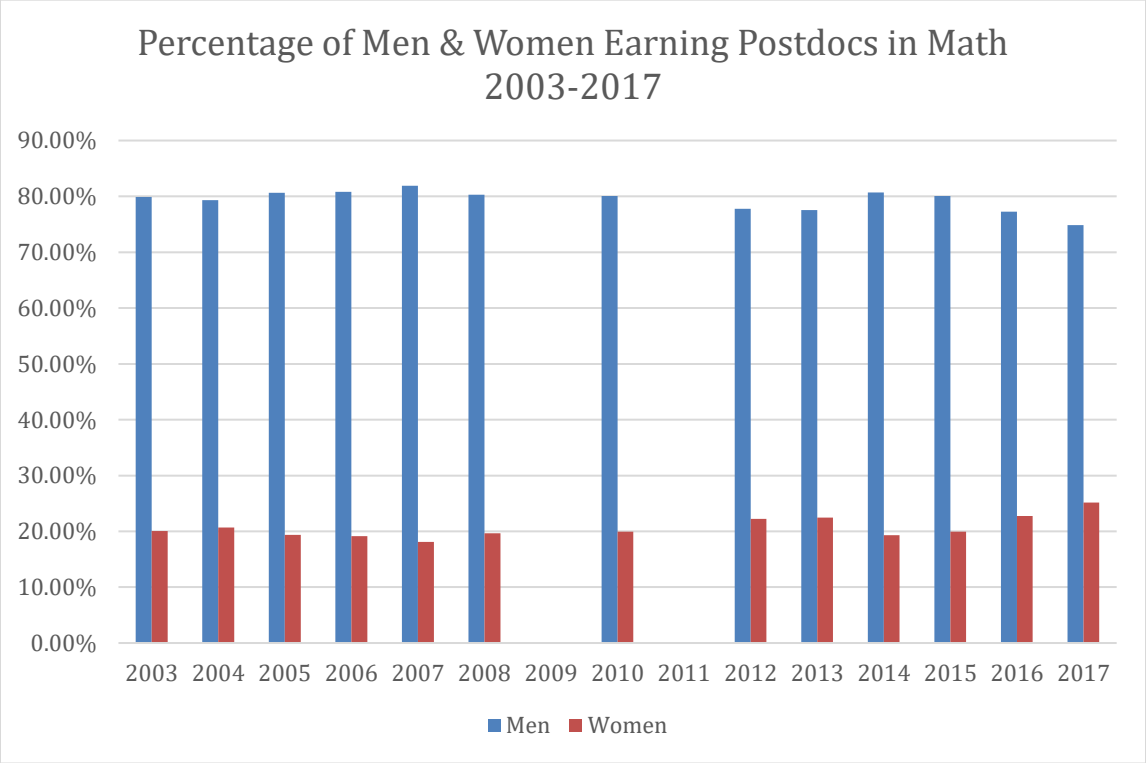
[4] The years of 2010 and 2012 have not been located and are subsequently missing in this report.

As the spreadsheets indicate, there is a significant decrease in the total numbers reported after 2009 - this is of note in the study. During the years 2003-2009, the reports summarizing the data collected from the Annual Surveys of AMS reported *all* full-time doctorate faculty *holding* postdoc positions. The AMS website reports that prior to the year 2010, the faculty profile report included some of the hiring and attrition data which was later separated out into different report formats after 2010. During the more recent years, the numbers reported identified the *new hires* in the doctoral full-time math faculty postdoc positions separately from the total. An analysis of those percentages in the "new hire" years are provided, as well as considering the overall numbers over the complete time of fifteen years is provided.

Using the data collected over the time period from 2003-2018 annual reports, a chart was made to illustrate the yearly percentages of men and women in mathematics postdoc positions. (Figure 7). Again, note that from 2010 -2018, those numbers focus only on the hires for that academic year, whereas prior to 2010, the percentages indicate all persons holding doctoral full-time mathematics postdocs, which encompasses the new hires.

In considering the visualization of the data, there appeared to be a consistent pattern of percentages of men and women over the fifteen years studied – with a modest increase in the most recent two years. With this in mind, a hypothesis test was set up in order to compare the percent of women earning postdocs over the entire fifteen years, but also over the two differently defined or recorded sets of data points.

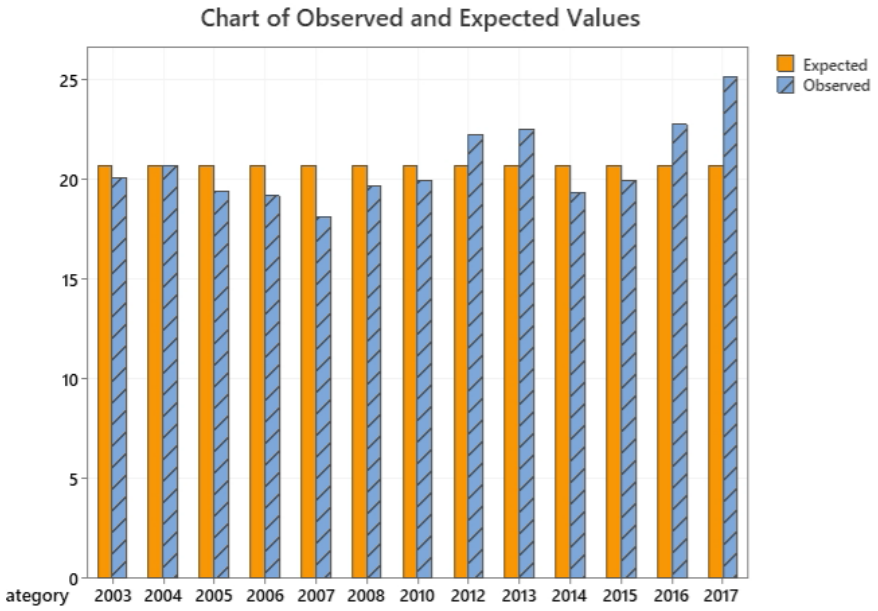
Figure 7



In considering the representation or rate of women in doctoral math full-time positions over time, the question of whether significant changes in the rate of women represented in mathematical postdocs over time is being questioned. If the rate at which women are represented in mathematical postdocs is increasing over time, we may expect to see some potential growth in the number or rate of women in doctoral math full-time positions over time. For this test, a single variable of rate of women in postdoc positions is being tested to see if the rates are all assumed to be equal (null hypothesis) or if at least one of the years is significantly different (alternate hypothesis) than the rest. A Chi-square analysis showed that there was no significant difference in the proportion of women in postdoc positions over time, X^2 (12) = 2.16, p = 0.99. (see Appendix C for complete analysis and test.)

In considering the comparison of the expected and observed values chart provided here (see Figure 8), it should be noted that there is a modest uptick in the percent of women in newly hired positions in the most recent years of data, with rates in 2016 and 2017 as 23% and 25% respectively.

Figure 8



With that recent slight upward rise, the test was repeated only over the data collected by the AMS solely on the new hires, which focuses on years 2010 – 2017.

The null and alternate hypothesis were set up again in a similar fashion for a second test. However, in this analysis the data only included the years of the AMS data which were collected and separated as *new hires* in doctoral full-time mathematics postdocs, as was provided in Figure 6. For this test, a single variable of rate of women in postdoc positions is being tested to see if the rates were all assumed to be equal (null hypothesis) or at least one of the years was significantly different (alternate hypothesis) than each of the other years. A Chi-square analysis again demonstrated that there was no significant difference in the proportion of women in postdoc positions over time, $X^2(6) = 1.19$, $p = 0.98$. (see Appendix C for complete analysis and test.) Based upon the data collected by the AMS, the results suggest there appears to be no significant change in the percentage of women who are in doctoral full-time academic mathematics postdoc positions over the past fifteen years.

It is possible that this cycle of losing talented women and URMs in mathematics will continue, as the data for the past fifteen years suggest, unless issues of hidden biases are interrupted and considered. Structures to overcome this potential toward stereotyped bias are shared by Eaton and colleagues (2019) and will be addressed in the recommendations section for the AWM.

Survey of Institutions Hiring Postdocs

The final piece of the three-pronged approach to analyzing the problem of practice involved collecting data specifically focused on the hiring and recruitment practices of mathematics postdocs. With the assistance of the then director of the AWM, a series of questions were developed to ascertain who might be hiring full-time mathematics postdocs, how the individuals were recruited, and how the applicants were vetted. The complete survey is provided in Appendix D. The objectives of the survey included the following: 1. Determine if consistencies in recruitment existed across institutions; 2. Understand the process and criteria by which mathematical postdocs were vetted across institutions; and 3. Consider if the results could inform practices related to the hiring of women in mathematical postdoc positions.

Ideally a simple random sample of postdoc hiring practices across the nation would be achievable, with the opportunity to consider consistencies, patterns, and/or protocols within this realm. This study did not intend to seek any sort of causal relationship among the processes and outcomes of recruitment and hiring. However, by reviewing the practices shared, insights into the process would hopefully be uncovered to advance knowledge of the process and perhaps suggest further avenues of researching and advising of best practices in the field.

The survey was set up in Qualtrics, with the ability to share or email the link. Through professional organizations and connections with the AWM, the link was shared via *Headlines and Deadlines,* an online news source for the mathematics professional organization. There were limitations to this process, as it would be a voluntary response and might not fully meet the

intended audience. The response rate from that posting was essentially nonexistent, which led to alternate ways of sharing the survey. After interactions with the director of AWM, connections were made with a member of the AMS reporting team for other avenues by which to survey institutions. Due to cost parameters, emailing mathematics department chairs across the US was undertaken. With the assistance of two undergraduates, searches began to identify each state for academic institutions with mathematics programs. The name of the chair and their email address were entered into Qualtrics. From that point, emails with the survey link were sent to the potential participants. (The email can be found in Appendix E).

This approach drew some responses; however, many either did not complete the entire survey or indicated they were not hiring/had not hired postdocs. Reminder emails were sent, yet the response rate remained low for representation across all institutions. At that point, searches on Mathjobs.org[5], Indeed, and Interfolio were initiated to determine who was currently advertising for math postdoc positions. After retrieving contact information for numerous hiring institutions, the survey was emailed to each contact found (see Appendix F). To get a sense of how many US academic institutions are hiring this fall (as of Sept, 2020) and who have a listing on Mathjobs.org, there were at that time approximately 35 institutions who had at least one math position posted. It is also to be noted that this number changes from year to year due for a variety of reasons, including financial support. To note, a total of 734 emails were sent to mathematics department chairs, with 59 responses started and 47 completed. Of those, a total of 18 were validated for potential postdoctoral positions who had fully completed the survey.

The final survey yielded the eighteen responses from institutions who fully completed the survey and who have recently (within the past three years) hired postdocs (see Appendix G for full results). Across the level or categorization of size of institutions[6], there is insufficient evidence with which to analyze and draw conclusions. However, it may be noted that for all of those respondents who completed the survey, we can see that Mathjobs.org is the method all use for advertising, with some others utilizing additional complementary methods.

Initial reviewing of the applicants saw responses as provided in Table 2. While no conclusions can be mathematically drawn, the responses indicate some initial review of the applicants occurs by individual screening and follow-up discussions, committee review, or by the postdoc advisor. The subsequent question was posed: "**In this initial review of applicants, a list of criteria used to describe the ideal candidate is used."** Six respondents indicated a positive response to this prompt, while eleven indicated they did not use such a list, and one did not respond to the prompt.

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[5] Mathjobs.org is sponsored by the AMS and Duke University's Dept of Mathematics.

[6] AMS categorizes mathematics degree awarding institutions. The chart is shared in Appendix H.

Table 2

Postdoctoral advisor who will be overseeing the postdoc	17.65%	3
Assistant to the postdoctoral advisor	0.00%	0
Chair of search committee for the postdoc	0.00%	0
Department Chair	0.00%	0
Administrative Assistant	5.88%	1
Multiple individuals screen files independently and later confer for agreement	47.06%	8
Committee of individuals meets and discusses each applicant	17.65%	3
Committee via electronic discussion boards or email	5.88%	1
Applicants are screened by an external reviewing company	0.00%	0
Other(s)	5.88%	1

For vetting the applicants at a second level, the responses are provided in Table 3. All 18 responses were gathered, with two indicating no second level of screening of the applicants. Eleven of the sixteen screen in committee discussion; three responded the second screening is done by one person; and for the two "other" responses, one participant indicated the applicant was screened by the whole department, while the other indicated the search committee conducted remote interviews.

Table 3

#	Answer	%	Count
1	Applicants are screened in committee discussions	61.11%	11
2	Applicants are screened by an external reviewing company	0.00%	0
3	Applicants are screened by one person	16.67%	3
4	No second level/round for narrowing the field of candidates is used.	11.11%	2
5	Other:	11.11%	2
	Total	100%	18

The next prompt immediately asked about criteria for screening at the second level. The participants were prompted with, "**Applicants are screened against a list of criteria used to describe the ideal candidate."** While sixteen reported having a second round of screening, only fourteen responded to the prompt. Of the fourteen who responded, eleven do not have such a list of criteria and three do utilize a list of criteria. There were fourteen responses when asked if onsite interviews were conducted. Two responded positively while twelve indicated they do not. It is unclear if this is typical or in light of pandemic situations currently impacting our nation.

When reviewing all categories there are two items worth noting. The first is that only one large private institution responded to the survey (those results are tabulated in with the overall responses). This detail is noted in light of the information previously shared in this paper by Glazer (2019). Several large private institutions have below average rates of women faculty. There are 24 large private universities, based upon AMS's definitions. The response rate for the category of "large public university" was considerable by comparison. There were nine out of 26 large public universities that completed the survey. This calculates to a 34.62% response rate for its category. While that appears viable, it is to be approached with caution. The size of "26" large public universities is still a small number to study in and of itself. Drawing conclusions from a limited size population is not prudent. The results of the survey from large public universities will be shared in light of what has been collected; however, those results must be treated only as information to consider.

Participants were asked to share how postdocs learned of their institution's openings. Table 4 indicated those results. They convey that the top two ways in which these respondents advertise for postdocs is on Mathjobs.org (*all nine respondents*) and/or their own institution's website. As previously indicated, Mathjobs.org is a well-known site for advertising mathematics positions of any type, including faculty positions.

Table 4

#	Answer	%	Count
1	Mathjobs.org	52.94%	9
2	Chronicle	0.00%	0
3	International sites (e.g., EMS, Nordic-math-jobs,or Academic positions)	5.88%	1
4	Jobs.sciencecareers.org	0.00%	0
5	Posting on field specific mailing list sites or listservs (e.g., DMANET or THEORYNT)	5.88%	1
6	Professional online job postings (e.g., Indeed.com, LinkedIn, or Glassdoor)	0.00%	0
7	Personal invitation (e.g., from conference talk, collaboration on paper, or knowledge of advisor)	0.00%	0
8	Posting on your institution's website	23.53%	4
9	Other (Please describe.)	11.76%	2
	Total	100%	17

Respondents were allowed to select more than one way to advertise.

The question surrounding initial review of candidates is provided here: **The initial review of applicants is typically completed by (Select one).** Four respondents indicated they had,

'Multiple individuals screen files independently and later confer for agreement.' Three respondents indicated the initial review of applicants was done by the postdoc advisor who will oversee the postdoc. One respondent replied that a committee of individuals met and discussed each applicant, and one respondent replied that the review was done by a committee via electronic discussion boards or email. (Table 5 contains the summary, while Appendix I contains full categories and responses for large public universities.)

Table 5

Postdoctoral advisor who will be overseeing the postdoc	33.33%	3
Assistant to the postdoctoral advisor	0.00%	0
Chair of search committee for the postdoc	0.00%	0
Department Chair	0.00%	0
Administrative Assistant	0.00%	0
Multiple individuals screen files independently and later confer for agreement	44.44%	4
Committee of individuals meets and discusses each applicant	11.11%	1
Committee via electronic discussion boards or email	11.11%	1

When prompted with, "**In this initial review of applicants, a list of criteria used to describe the ideal candidate is used,"** two participants responded yes and seven responded no. For the possible second level of screening the applicants, seven responded that committee discussions are used; two have screenings by one individual; and the "other" responses were, "applicants are screened by the whole department" or "remote interviews are conducted by the search committee." (see Table 6)

For the second level of screening, when prompted with: "**Applicants are screened against a list of criteria used to describe the ideal candidate,"** eight participants responded "No" and one responded "yes". Additionally, eight do not have onsite interviews and one does. A note here that this may have been answered within the context of the current health pandemic, with respondents perhaps not having onsite interviews under these circumstances.

Table 6

#	Answer	%	Count
1	Applicants are screened in committee discussions	63.64%	7
2	Applicants are screened by an external reviewing company	0.00%	0
3	Applicants are screened by one person	18.18%	2
4	No second level/round for narrowing the field of candidates is used.	0.00%	0

5	Other:	18.18%	2
	Total	100%	11

It is surprising that in academia, where new knowledge is desired and expected to advance learning, that so few institutions elected to share their voice in this survey. Speculations on what those reasons might be for a low response rate include the pandemic situation across the nation, the current political unrest in the election year, email overload, spam filters on institution email, etc. Based upon recent findings discussed in the literature review, perhaps not participating is also saying something about gender in mathematics postdocs.

Funding is yet another concern which may impact the study, as the AMS (2015) states, "much of the funding for postdocs comes from individual universities," which could be an issue in financially-constrained years. Perhaps the outlook for having postdoc positions is less tenable, but again, this is all speculation. The recommendations for the AWM will come from the data collected by the AMS, the literature review, and the limited responses which show only what those who wished to participate shared. While this study would have been improved upon by interviews or focus groups of those hiring postdoc candidates and those applying for postdoc positions, the study did uncover trends which suggest further attention to this area in mathematics is needed. The area of postdocs in mathematics is largely unexplored, and there are opportunities for future research in this area.

Nonetheless, the recommendations shared are outcomes of what has been found in the literature review and analysis of the relevant AMS data, with suggestions for future best practices to support diversity of knowledge and talent in the field of mathematics. These recommendations will be supported by evidence found in tangential STEM fields, and the recommendations will specifically focus on postdoc positions, which are opportunities to grow in research mathematics and which position one for the doctoral faculty positions at research institutions.

Findings

The rates of participation in mathematics across degree levels for women and URMs are an issue of equity. If one is to argue that the need for talent and productivity is critical in the STEM fields (including math), then a review into ways to grow the talent in these fields is expected. National growth demands have stated an anticipated need across STEM fields. Surprisingly, however, outcomes in the data suggest there has been no significant change in diversity of mathematical postdocs over the past fifteen years. This lack of diversity in the field of postdoc mathematics poses challenges for diversity of thought and approaches where it is widely accepted that new knowledge is curried.

The data analyzed over the fifteen years available suggest the rate of women specifically in postdoc mathematics positions have not significantly changed. Consider this in light of the calls for supporting women in STEM fields for more than thirty years. Even when considering these calls to action, little progress is evidenced in the postdoc realm. Review of the literature suggests evidence of unconscious bias in the way women are treated in male-dominated fields, including STEM fields in academia. Additionally, the culture and climate in STEM fields are negatively contributing factors to the continuation of women in the field. The literature has also linked a decrease in woman's confidence and performance in their profession when it is perceived that they are being judged on their gender rather than their performance. The data neither suggest nor prove these biases are intentional; however, it is sufficient to know implicit biases exist.

When considering recruitment and hiring practices, gender and race biases have been found in large university settings in postdoctoral physics, which is another quantitatively driven and male dominated field. Additionally, both men and women faculty in the sciences have ranked women science students at lower levels of competence and future hire-ability as compared to their male peers. Moreover, hidden biases have been uncovered in professional settings, and it is not unusual to have found evidence that hidden biases may exist in the academic world. Indeed human resource departments in the business realm have been moving toward practices for minimizing the potential for biases to emerge unknowingly. The NIH has called for similar actions to be taken in the STEM fields for hiring of candidates in academia, and the National Postdoctoral Association has made a recommendation to have processes in place in order to assure a diverse talent pool of candidates is available from which to select a postdoc.

In reviewing the data collected in this capstone study on formal practices and procedures into the hiring and recruitment of postdocs, the results of the contributions to the study are presented. The practices and procedures of a representative sample of those doing the hiring were limited. Due to that, patterns or consistency of how those recruiting and hiring practices are consistent among institutions cannot be scientifically concluded. This capstone study, as well as a review of the literature, suggest that no tangible evidence has yet surfaced on these practices. Bennett and colleagues (2020) support that there is no evidence to suggest clear or consistent processes are in place for the hiring of postdocs, which would include those in mathematics. Further work in this area is needed, but it is expected the recruitment and hiring practices would, or should, align with the need for equitably identifying talent when appointing postdocs in mathematics.

In considering the postdoc positions in mathematics, it is understood that a critical component to establishing research includes obtaining grants and increasing the number of publications. These are viewed by many as necessary steps to moving into doctoral tenure-track faculty positions at the top fifty institutions. However, the numbers historically are unwavering in the rates of women participating in mathematics postdocs. Until this issue of equity is addressed, it is difficult to

imagine progress in women achieving tenure-track appointments at top doctoral awarding institutions.

The literature suggests there are systemic structural changes which need to be addressed in order to equitably respond to the hiring of mathematics postdoc candidates. There is potential for hidden biases to emerge in the selection process when hiring candidates. There also exist ways to minimize the potential for bias to occur, which can be taken into consideration when vetting applicants. Barriers for women exist in male-dominated fields, as indicated in the literature. Attention and action must be taken to support postdocs in mathematics, which includes an improved, inclusive environment in the previously male dominated higher education field of mathematics (Dearo et al., 2019; Picardi, 2019). Opportunities exist to minimize and perhaps remove those barriers, supporting diverse candidates in the workplace, but especially in postdoc opportunities to advance in academia where a lack of diversity currently exists.

Recommendations

The AWM organization has listed on its website, *AWM's Priorities,* the following problem of practice: "Too few women pursue careers in the mathematical sciences" (awm.org). This is both a sobering statement and a challenging problem which serves almost as a mission statement for work undertaken by those within the organization. The organization supports policies and promotes activities which support access for women and underrepresented minorities to fully participate in the mathematical sciences. Programs undertaken by the AWM include *Sonia Kovalevsky High School Days,* focused on middle school and high school students; *Teacher Partnerships,* aimed to connect math teachers with community members in math-related fields; and *AWM Mentor Networks,* designed to connect undergraduates, graduates, and women faculty as they progress through higher education. The AWM's programs and outreach embrace and align with that mission statement, and they support women and URM in mathematical pathways, including those who are interested in pursuing faculty positions in academia.

The goal of these recommendations is for the AWM to continue its mission and strong advocacy work of supporting women in the advancement of mathematics, with a particular focus on the area of postdoctoral study. If more women advance into the math research postdoc positions, then it stands that more women will likely be included in the pool of faculty considering tenure-track positions at doctoral institutions. The AWM is therefore encouraged to consider the following:

Recommended Actionable Item 1: Call for institutions to commit to open and consistent postdoc recruitment and hiring practices (NPA, NIH, NSF, Hargis & Bradley, 2011).

Several national organizations are responding to the need for more open and transparent recruitment and hiring procedures for postdoc positions. While direct evidence of biased practices in mathematics have not been measured, there is evidence of this in tangential STEM fields (Eaton et al., 2019; Moss-Racusin, 2012). Moreover, the proportion of women progressing in advanced levels of mathematics suggests inequities exist. This inequity is certainly not being addressed by all institutions. NASEM, NPA, NIH, and the NSF all support recommendations for consistency in hiring practices of postdocs, including section 4.1 of the NPA's recommendations which states: "Have formal recruitment mechanisms in place to ensure diversity of the postdoctoral population" (n.d.) (see Appendix J).

These mechanisms should include a list of objective criteria, the sharing of files with identifying race, gender, ethnicity, etc. characteristics removed to reduce the potential for bias, the inclusion of a diverse candidate pool from which to choose, and a committee process for selecting the candidate. Based upon work done by van den Brink and Benschop (2014), there exists the potential for "… elites (to) grant access to top positions through informal relations and interactions and also how these gatekeepers legitimize their practices of granting access to some and not to others" (p. 462). This work in social network theory would suggest that not only is it important to have clear criteria in place for hiring postdocs, but also a diverse committee in place for objective vetting of the candidates.

Moreover, advertising postdoc positions in areas where women and URM may be connected is also of importance. As suggested when hiring for any academic position, "…search committees post job openings in outlets specifically targeted to women scholars" (Glass et al., 2010, p. 225). While MathJobs.org was consistently named, including other venues for advertising of positions focused on other demographics may broaden the diversity of applicants in mathematics postdocs. Glass and colleagues (2010) specifically referenced posting positions where women applicants may be more aware of opportunities. These may include posting with newsletters specific to women in mathematics, including but not limited to AWM, the Women and Mathematics Network of the Mathematical Association of America, Black Women in Science and Engineering, and Society for Industrial and Applied Mathematics. Intentional advertising should be encouraged at all PhD awarding institutions.

Recommended Actionable Item 2: Join the NPA in calling for institutions of higher learning to commit to publicly sharing data collection outcomes which describe the campus culture and the demographics of postdocs (NPA, n.d., National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2014).

Data collection would support institutions in understanding the well-being of their own postdocs, facilitating a strong and vibrant research community. As institutions explore the climate

surrounding these research opportunities on campus, data will provide actionable insights into the continued commitment to the growth of new knowledge at institutions. Ideally, these outcomes and reports would be made publicly available, allowing postdoc applicants to understand the current diversity outcomes and support at institutions (The Institute of Medicine, National Academy of Engineering, National Academy of Sciences, Engineering, and Public Policy Committee on Science, Committee on Maximizing the Potential of Women in Academic Science and Engineering, and National Academy of Engineering, 2007).

Assessing campus culture in mathematics is one area in which researchers at AWM would want to support and investigate outcomes on a regular basis. As women broadly involved in the support of these initiatives, these studies provide opportunities for AWM members to oversee research supporting a national move toward broadening the participation of women and URM in mathematics research. “Funding agencies must improve their data collection on the postdoctoral segment of the workforce” (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2014, p. 7). Support of this could be driven by the organization’s director, with a call for support across other national mathematical associations.

Recommended Actionable Item 3: Formally acknowledge the AMS as a leader in the field in their admirable work in transparent data collection, and request additional question(s) regarding mathematics postdocs be included in their annual survey.

The understanding in the progression of PhD’s hired has not been widely tracked as suggested by a review of data by Vitulli (2018). Understanding outcomes and trends for PhD recipients and postdocs would provide insights into the progression of women and URM into advanced levels of mathematics. “Professional societies should utilize their networks to collect information about career paths of their members and make this data easily available” (National Academy of Sciences, National Academy of Engineering, and Institute of Medicine of the National Academies, 2014, p. 7). The AMS, in its role of collecting data on the profession, may be open to considering questions to further serve the understanding of postdoc positions. The AWM may want to consider a task force to collectively collaborate on an appropriate question for the AMS to vet in gathering further information to inform the advancement of women in mathematical postdocs.

Recommended Actionable Item 4: Begin to initiate institutional change by educating deans, department chairs, and postdoc advisors on unconscious bias (Carnes et al., 2012; NSF).

One way this can be accomplished is by joining forces with the organizations calling for workshops to reduce gender bias. The Institute of Medicine, National Academy of Engineering,

National Academy of Sciences, Engineering, and Public Policy Committee on Science, Committee on Maximizing the Potential of Women in Academic Science and Engineering, and National Academy of Engineering call for educating, "…members of review panels, university department chairs, and agency program officers about methods that minimize the effects of gender bias in evaluation" (2007, p. 10). Moreover, there are programs such as those suggested by the NIH that have demonstrated evidence of reducing potential bias in hiring processes (Valantine, nd). Incorporating innovative and effective models which demonstrated efficacy in minimizing gender bias in faculty would be a start in supporting hiring practices in mathematical postdocs. Indeed, as social network theory posits, for change in education to occur, employing the use of networks can impact the effect of change (Daly, 2010). Utilizing networks of professional organizations to work together to impact important and widespread institutional change may reduce the barrier of unconscious gender bias previously noted in STEM fields.

Recommended Actionable Item 5: Educate women and URM early on as to the importance of research, publications, and postdoc positions as well as the importance of networking in the pursuit of faculty positions. This may be strategically linked to the ADVANCE initiative, capitalizing on current strong mentoring programs already begun by the AWM.

The AWM currently has a strong ADVANCE program showing positive outcomes in mentoring and research opportunities of women and URM in mathematics. Capitalizing on results from that initiative would provide foundational evidence of what future mentoring and research opportunities might provide for members. Strengthening this platform with targeted education on the value of research, postdoc positions, and the importance of broadening networks will advance the positioning of women and URM for achieving tenure-track positions at PhD granting institutions.

The AWM currently supports research and provides some support for women presenting their findings and attending professional conferences. Along with these current practices, more emphasis on research and collaboration may prove beneficial. In order for women to see themselves as research mathematicians, they should be educated early on about the benefits and need for research in the field. As indicated in a study by Yadav and Seals (2019):

> findings suggest that majority of URM postdocs in STEM disciplines had a research-based academic position as their primary career goal, but did not feel confident in achieving it…When asked what our participants thought were important factors in helping them achieve their primary career goal, developing an independent research plan and receiving professional development were identified as being extremely important." (p. 8)

The AWM should encourage collaboration and mentoring experiences within the realm of research and facilitate opportunities for women and URM to present their findings. As women

and URM become engaged in research opportunities, it is expected that they will be able to pursue more opportunities for advancing further research in the field as their level of education increases (Rybarczyk et al., 2016). "Findings from our study suggest that professional development can positively influence minority postdocs' self-efficacy in developing skills necessary to be successful in academia (such as grantsmanship) and also increase their confidence in pursuing academic positions" (Yadav & Seals, 2019, p. 10). This conclusion would suggest that the AWM work in ways to support women and URM growing in their research and navigating how to achieve grants, thereby increasing their confidence in these areas and beginning to identify as potential academicians.

These research experiences include opportunities to enhance one's professional network. Yang et al. (2015), posit, "The postdoc experience builds both formal and informal skills and social networks that can provide long-term outcomes" (p. 682). In work by van den Brink and Benschop (2014), the article led with the importance of networking as a study in organizations, noting the importance of being involved in networks for career advancement. Granovetter's (1973) work suggests how critical interpersonal networks are to providing career advancement opportunities. In predominantly male fields such as mathematics, women have weaker ties or network access. Utilizing those networks in meaningful ways provides opportunities for women to advance in their fields, specifically in research, publications, and postdoc positions.

Networking in itself has demonstrated its importance in careers and opportunities, and ultimately when considering change (Daly, 2010). Those studies indicate male networks provide stronger associations than those of women. In predominantly male fields such as mathematics, women have weaker ties or networking compared to men. By affording women ties to broader networks within the research community of postdocs, women can leverage opportunities for connecting with others to advance their research positions academically. Networking to advance in research and ultimately postdoc positions may then afford women opportunities for tenure-track faculty positions at PhD granting institutions. The National Science Academy encourages postdocs to seek advice and mentoring from other members outside of their direct advisor (2014). This is networking within the institution as it intersects with mentoring. While mentoring may be a link to one person and one person's network and perspectives, Granovetter (1973) posits that connecting with other networks may provide advantages in advancing beyond what is held within that initial network. Finally, as part of advice on *Finding a Postdoctoral Position in Mathematics*,

> Ideally, your letter writers would also be well-known in the academic community. (A letter from a faculty member at a research university will be weighted more heavily than a letter from a postdoc.) If you have already given research talks at conferences or seminar talks at other universities, you may know mathematicians from other universities who are experts in your area of math. If you felt that your work was well-received, you might consider asking one of these people for a letter of recommendation. Most graduating students will have research letters that all

> come from faculty at their own university – so you will stand out a bit if you have a (good) letter from a well-known mathematician who is based at another university (Williams, n.d., p. 3)

This recommendation suggests the need for networking, but also the importance of external letters of recommendation to support advancing. This can be considered as networking externally, to promote and enhance future opportunities, including those in mathematics postdoc research. While this evidence is duly noted, the concept of networking may not be widely known by women and URM advancing through the field of mathematics. Providing similar sources to women and URM, educating them at conferences, and connecting them with others in the field are all opportunities for the AWM to support the advancement of women and URM in mathematics.

Conclusion

The recommended actions and program activities support both short-term and long-term change in removing barriers for women and URM to a broader level of participation in mathematics, with a focus on the increased participation in mathematics postdoc appointments.

While there was insufficient evidence to draw firm conclusions from the initial data collected in this capstone study, the researcher would argue that raising an awareness of the concern is a critical step forward. If institutions are committed to broadening participation and growing diverse talent, then the following recommendations may be readily adopted. Gewin (2018) states, "Creating an inclusive culture is not about one-off initiatives — it's about ongoing support, mentorship, governance and a clear narrative that building diversity is crucial for success" (p. 151). The recommendations may be incorporated as evidence to all applicants that institutions are committed to unbiased hiring practices as they seek to train the next generation of math research faculty. A better understanding of the pathway toward achieving the professoriate, especially at PhD-granting institutions, is important for women and URM mathematicians. An important avenue in achieving such positions involves participation in postdocs. Providing support to those not currently evident in that trajectory is important work of the organization (Bennett et al., 2020).

There is evidence the AMS, as a nationally-recognized organization, wishes to continue their belief in all that the mathematics postdoc position holds for the future of mathematics. From the AMS postdoc position statement, "Postdocs bring a youthful vitality and fresh perspective to mathematical sciences departments, while enhancing the quality of research and teaching. These facts are familiar to mathematicians, but might be less so to scholars from other disciplines" (2015). This statement aligns with the broader perspective on advancing diversity in the field. A

welcome and inclusive culture on campuses and in departments, which includes an openness and respect for new and different perspectives should positively impact teaching and research. (Campbell-Whatley et al., 2015). These beliefs overlap and suggest an internal commitment to supporting different perspectives and approaches to research. There are many AWM members whose membership also intersects with the AMS. It is perceived then that both organizations believe fresh approaches to mathematics will enhance research, which can be expected by diversifying the pool of individuals being awarded mathematics postdoc positions. An openness to diverse perspectives and approaches is one which should be applauded in all mathematical programs.

The National Science Foundation (NSF) has recently supported initiatives to support URM faculty in STEM fields, including, "the Association of Public and Land-grant Universities (APLU) INCLUDES project, funded by the National Science Foundation, examined university efforts supporting access to, retention in, and progress to the professoriate for URG STEM faculty aspirants" (Bennett, et al, 2020, p 5). This study included a survey across faculty participation levels, leading to recommendations needed for systemic change to occur across the academy to enhance and support the broadening of participation in STEM fields. The NSF has also instituted a CAREER program, awarding junior faculty funding for engaging in research and teaching. The caveat here is that the institution or colleagues must nominate the junior faculty, again focusing on providing an inclusive and supporting environment in which the junior faculty may grow. Economically, this alignment of research and teaching of the junior faculty with the institution suggests greater profitability (here in terms of new knowledge), supporting the advancement of woman and URM into research in the field. As these other broad initiatives are moving forth in STEM, AWM is poised to be a positive nation-wide contributor in this arena, with the focus on advancing women and URM in mathematics postdoc positions as the research-based recommendations in this paper suggest.

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Appendix A

Full report and listing of tables can be found at

http://www.ams.org/profession/data/annual-survey/2017Survey-DepartmentalProfile-Report.pdf

Annual Survey of the Mathematical Sciences
www.ams.org/annual-survey

Table R.1: Recruitment and Hiring of Faculty in the Mathematical Sciences, Fall 2017 by Department Grouping

	Math Public Large Group	Math Public Medium Group	Math Public Small Group	Math Private Large Group	Math Private Small Group	Applied Math Group	Statistics Group	Biostatistics Group	Total Doctoral Math	
Recruited Doctoral Positions Total Number (% of Total)	**198**	**193**	**184**	**175**	**60**	**51**	**126**	**105**	**861**	
Standard Error	7	8	8	12	12	6	10	10	20	
Tenured or tenure-track	52	81	90	45	26	23	75	60	317	
Open to new doctoral recipients	38	62	76	19	18	15	59	52	228	
Open to assoc/full level	16	16	14	19	4	12	37	15	81	
Non-tenure-track	146	112	94	130	34	28	51	45	544	
Open to new doctoral recipients	143	107	91	129	34	28	49	38	532	
Temporary 1-year appointments	35	28	56	2	5	10	24	-	136	
Reported Hires for Above Total number (% of Total Recruited in Group)	**180 (91%)**	**176 (91%)**	**161 (88%)**	**160 (91%)**	**56 (93%)**	**43 (84%)**	**87 (69%)**	**84 (80%)**	**776 (90%)**	
Tenured or tenure-track Hires	**44**	**72**	**74**	**31**	**23**	**13**	**51**	**43**	**287**	
Doctoral hires										
Men	36	52	57	26	13	10	43	22	194	
New doctoral hires	2	2	3	1	-	-	18	7	8	
Not new doctoral hires	34	50	54	25	13	10	25	15	186	
Previously in non-tenure-track	8	6	10	1	5	1	4	1	31	
Previously in postdoc	23	32	38	15	6	4	3	11	118	
Women	8	20	17	5	10	3	8	21	63	
New doctoral hires	1	7	4	-	1	-	4	4	13	
Not new doctoral hires	7	13	13	5	9	3	4	17	50	
Previously in non-tenure-track	1	-	-	-	1	-	-	5	2	
Previously in postdoc	5	9	7	3	6	3	-	9	33	
Other	-	-	-	-	-	-	-	-	-	
New doctoral hires	-	-	-	-	-	-	-	-	-	
Not new doctoral hires	-	-	-	-	-	-	-	-	-	
Previously in non-tenure-track	-	-	-	-	-	-	-	-	-	
Previously in postdoc	-	-	-	-	-	-	-	-	-	
Non-tenure-track Hires	**136**	**104**	**87**	**129**	**33**	**30**	**36**	**41**	**519**	
Doctoral hires	131	101	77	128	33	27	36	41	497	
Men	97	75	54	98	28	20	23	25	372	
New doctoral hires	66	44	32	75	18	12	12	12	247	
Not new doctoral hires	31	31	22	23	10	8	11	13	125	
Postdoc appointments	79	44	23	71	16	15	8	12	248	
1-year appointments	16	9	23	3	4	3	4	-	58	
Women	34	26	23	30	5	7	13	16	125	
New doctoral hires	23	8	11	22	4	4	8	8	72	
Not new doctoral hires	11	18	12	8	1	3	5	8	53	
Postdoc appointments	28	11	3	23	4	4	7	7	73	
1-year appointments	7	2	8	-	-	-	3	-	17	
Nondoctoral hires	5	3	10	1	-	3	-	-	22	
Men	4	1	4	1	-	-	-	-	10	
Women	1	2	6	-	-	3	-	-	12	
Other	-	-	-	-	-	-	-	-	-	
Unfilled positions	**18**	**17**	**23**	**16**	**4**	**10**	**39**	**21**	**87**	

Mathematical and Statistical Sciences Annual Survey

www.ams.org/annual-survey

Table F.1

Total Faculty, Fall 2017

	Math Public Large	Math Public Medium	Math Public Small	Math Private Large	Math Private Small	Applied Math	All Doctoral Math	Masters	Bachelors	All Math	Statistics	Biostatistics	Statistics & Biostatistics Combined	Total All Groups
Total full-time faculty	**2360**	**2166**	**2463**	**1159**	**868**	**660**	**9666**	**4335**	**9253**	**23254**	**1398**	**980**	**2378**	**25632**
Standard error	*43*	*22*	*56*	*25*	*25*	*26*	*86*	*92*	*149*	*195*	*49*	*55*	*55*	**237**
Tenured	1223	1073	1295	567	485	288	4931	2261	4888	12080	744	361	1105	13185
Full Professors	986	742	801	505	335	200	3569	1371	2836	7776	537	256	793	8569
Other	237	331	494	62	150	88	1362	890	2052	4304	207	105	312	4616
Tenure-eligible (without tenure)	208	291	339	93	114	70	1115	635	1646	3396	242	218	460	3856
Non-tenured-track	929	802	829	499	259	302	3620	1439	2719	7778	412	401	813	8591
Postdoctoral appointments	429	277	100	369	79	74	1328	32	98	1458	116	57	173	1631
Renewable appointments	474	448	649	83	151	141	1946	1113	2169	5228	254	342	596	5824
Fixed-term appointments	17	76	51	47	28	84	303	202	390	895	25	1	26	921
Other appointments	9	1	29	0	1	3	43	92	62	197	17	1	18	215
Doctoral full-time faculty	**2233**	**1962**	**2116**	**1150**	**812**	**614**	**8887**	**3332**	**7443**	**19662**	**1330**	**909**	**2239**	**21901**
Standard error	*37*	*20*	*54*	*25*	*24*	*25*	*29*	*50*	*66*	*87*	*45*	*46*	*48*	*94*
Tenured	1223	1072	1289	567	485	288	4924	2210	4671	11805	743	361	1104	12909
Full Professors	986	742	799	505	335	200	3567	1351	2760	7678	537	256	793	8471
Other	237	330	490	62	150	88	1357	859	1911	4127	206	105	311	4438
Tenure-eligible (without tenure)	208	291	337	93	114	70	1113	618	1556	3287	242	217	459	3746
Non-tenured-track	802	599	490	490	213	256	2850	504	1216	4570	345	331	676	5246
Postdoctoral appointments	429	277	100	369	79	74	1328	32	98	1458	116	57	173	1631
Renewable appointments	355	287	346	82	107	97	1274	368	883	2525	192	272	464	2989
Fixed-term appointments	9	34	29	39	26	83	220	65	210	495	20	1	21	516
Other appointments	9	1	15	0	1	2	28	39	25	92	17	1	18	110
Nondoctoral full-time faculty	**127**	**204**	**347**	**9**	**46**	**46**	**779**	**1003**	**1810**	**3592**	**68**	**71**	**139**	**3731**
Standard error	*10*	*8*	*27*	*3*	*5*	*6*	*26*	*50*	*66*	*87*	*6*	*50*	*77*	*94*
Tenured	0	1	6	0	0	0	7	51	217	275	1	0	1	276
Full Professors	0	0	2	0	0	0	2	20	76	98	0	0	0	98
Other	0	1	4	0	0	0	5	31	141	177	1	0	1	178
Tenure-eligible (without tenure)	0	0	2	0	0	0	2	17	90	109	0	1	1	110
Non-tenured-track	127	203	339	9	46	46	770	935	1503	3208	67	70	137	3345
Renewable appointments	119	161	303	1	44	44	672	745	1286	2703	62	70	132	2835
Fixed-term appointments	8	42	22	8	2	1	83	137	180	400	5	0	5	405
Other appointments	0	0	14	0	0	1	15	53	37	105	0	0	0	105
Total part-time faculty	**176**	**406**	**501**	**74**	**126**	**117**	**1398**	**2061**	**4789**	**8248**	**121**	**134**	**255**	**8503**
Standard error	*19*	*22*	*33*	*11*	*13*	*14*	*49*	*169*	*197*	*260*	*13*	*47*	*47*	*273*

Table FF.1: Total Women Faculty, Fall 2017

	Math Public Large	Math Public Medium	Math Public Small	Math Private Large	Math Private Small	Applied Math	All Doctoral Math Combined	Masters	Bachelors	All Math Combined	Statistics	Biostatistics	Statistics & Biostatistics Combined	Total All Groups Combined
Total Women full-time faculty	**479**	**864**	**748**	**179**	**195**	**127**	**2292**	**1822**	**3410**	**7224**	**407**	**391**	**798**	**8022**
Standard error	-	*11*	*23*	*8*	*5*	*4*	*27*	*36*	*70*	*83*	*13*	*28*	*28*	*98*
Tenured	165	146	264	55	70	34	734	604	1424	2762	161	101	262	3024
Full Professors	111	75	124	48	38	22	418	297	713	1428	90	60	150	1578
Other	54	70	137	7	32	12	312	284	627	1223	71	41	112	1335
Tenure-eligible (without tenure)	39	83	95	21	31	18	287	247	662	1196	63	76	139	1335
Non-tenured-track	275	335	389	103	94	75	1331	671	1324	3326	183	214	401	3663
Postdoctoral appointments	83	72	16	69	18	18	276	3	40	319	30	21	51	370
Renewable appointments	182	228	340	22	63	47	942	531	1099	2572	133	193	330	2838
Fixed-term appointments	7	35	19	12	13	10	96	85	156	337	13	-	13	350
Other appointments	3	-	14	-	-	-	17	52	29	98	1	-	1	105
Doctoral Women full-time faculty	**409**	**438**	**528**	**175**	**168**	**110**	**1828**	**990**	**2377**	**5196**	**366**	**347**	**713**	**5908**
Standard error	-	*9*	*20*	*7*	*5*	*3*	*24*	*29*	*55*	*67*	*12*	*23*	*23*	*80*
Tenured	165	145	261	55	70	34	730	581	1340	2651	161	101	262	2913
Full Professors	111	75	124	48	38	22	418	297	713	1428	90	60	150	1578
Other	54	70	137	7	32	12	312	284	627	1223	71	41	112	1335
Tenure-eligible (without tenure)	39	83	95	21	31	18	287	238	616	1141	63	76	139	1280
Non-tenured-track	205	210	172	99	67	58	811	171	421	1403	142	170	312	1715
Postdoctoral appointments	83	72	16	69	18	18	276	3	40	319	30	21	51	370
Renewable appointments	117	128	146	22	38	31	482	133	318	933	96	149	245	1178
Fixed-term appointments	2	10	5	8	11	9	45	14	59	120	9	-	9	129
Other appointments	3	-	5	-	-	-	8	19	4	31	1	-	1	38
Nondoctoral Women full-time faculty	**70**	**126**	**220**	**4**	**27**	**17**	**464**	**832**	**1033**	**2029**	**41**	**44**	**85**	**2114**
Standard error	-	*5*	*13*	*1*	*2*	*2*	*17*	*28*	*40*	*57*	*4*	*11*	*13*	*55*
Tenured	-	1	3	-	-	-	4	23	84	111	-	-	-	111
Full Professors	-	-	1	-	-	-	1	9	24	34	-	-	-	34
Other	-	1	2	-	-	-	3	14	60	77	-	-	-	77
Tenure-eligible (without tenure)	-	-	-	-	-	-	-	9	46	55	-	-	-	55
Non-tenured-track	70	125	217	4	27	17	460	500	903	1863	41	44	85	1948
Renewable appointments	65	100	194	-	25	16	400	398	781	1579	37	44	81	1660
Fixed-term appointments	5	25	14	4	2	1	51	69	97	217	4	-	4	221
Other appointments	-	-	9	-	-	-	9	33	25	67	-	-	-	67
Total Women part-time faculty	**84**	**154**	**215**	**16**	**41**	**39**	**819**	**831**	**2117**	**3467**	**39**	**57**	**96**	**3563**
Standard error	-	*7*	*13*	*3*	*2*	*4*	*16*	*37*	*78*	*93*	*4*	*12*	*12*	*96*
Doctoral	25	39	55	12	19	13	163	75	406	644	23	34	57	701
Faculty with benefits received	20	20	17	4	6	8	75	13	54	144	15	4	19	163
Other part-time faculty	5	16	38	8	13	4	84	56	336	476	7	29	36	512
Phased Retirements	-	3	-	-	-	1	4	6	14	24	1	1	2	26
NonDoctoral	29	115	160	4	22	26	356	756	1711	2823	16	23	39	2862
Faculty with benefits received	25	72	32	-	6	4	139	222	302	663	6	7	13	676
Other part-time faculty	4	43	128	4	14	22	217	532	1401	2150	10	15	25	2175
Phased Retirements	-	-	-	-	-	-	-	2	8	10	-	1	1	11

Appendix B: Women in Postdocs 2003-2017

					2008	2009	####	2011	2012 (11-12)	2013(12-13)	2014	2015	2016	2017(16-17)	2018(17-18)
Men	569	579	616	654	697	796		209		231	245	280	245	248	289
Women	143	151	148	155	154	195		52		66	71	67	61	73	97
							Missing		missing						
Totals:	712	730	764	809	851	991		261		297	316	347	306	321	386
Men	79.92%	79.32%	80.63%	80.84%	81.90%	80.32%		80.08%		77.78%	77.53%	80.69%	80.07%	77.26%	74.87%
Women	20.08%	20.68%	19.37%	19.16%	18.10%	19.68%		19.92%		22.22%	22.47%	19.31%	19.93%	22.74%	25.13%
Actual Year	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**9**	**2010**	**11**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**

Appendix C

H_0: $p_1 = p_2 = p_3 = p_4 = p_5 = p_6 \ldots = p_{15}$, where 1 represents the year 2003.
The null hypothesis is assumed that there is no significant difference in the true proportion of women who are in full-time mathematics postdoc positions from year 2003 through 2017.

H_1: The alternate hypothesis suggests there is a significant difference in at least one true proportion of women who are in full-time mathematics postdoc positions in the years 2003 – 2017.

The chi-square test of one variable was run, with twelve degrees of freedom and assumed equal proportions. The results follow:

Chi-Square Test

N	DF	Chi-Sq	P-Value
268.79	12	2.16102	0.999

The Chi-square test score was lower than the critical score would be for an alpha or significance level of 5% or 10% with twelve degrees of freedom. The resultant test score corresponds to an area under the curve, or p-value of 0.999. Since my p-value is larger than any alpha I would select, the data suggest that there is no significant difference in the true proportion of women in doctoral full-time mathematics postdoc positions in any year tested.

Second Analysis:

H_0: $p_1 = p_2 = p_3 = p_4 = p_5 = p_6 = p_7$, where 1 represents the year 2010.
The null hypothesis is assumed that there is no significant difference in the true proportion of women who are new hires in full-time mathematics postdoc positions from year 2003 through 2017.

H_1: The alternate hypothesis suggests there is a significant difference in at least one true proportion of women who are new hires in full-time mathematics postdoc positions in the years 2010 – 2017. (The data for year 2011 were not available and therefore omitted in this test.)

The chi-square test of one variable was run, with six degrees of freedom and assumed equal proportions. The results follow:

Chi-Square Test

N	DF	Chi-Sq	P-Value
151.72	6	1.18659	0.978

The Chi-square test score was again lower than the critical score would be for an alpha or significance level of 5% or 10% with six degrees of freedom. The resultant test score corresponds to an area under the curve, or p-value of 0.978. Since the p-value is larger than any alpha a researcher might select, the data suggests that there is no significant difference in the true proportion of women who are new hires in doctoral full-time mathematics postdoc positions in any year tested.

Appendix D

Current Practices and Processes for Recruiting and Hiring Postdocs in Mathematics

Start of Block: Default Question Block

Q1 You are invited to join a research study to look at formal and informal processes regarding the recruiting and hiring of postdocs[i] in mathematical sciences. This survey is part of a doctoral study at Vanderbilt University, led by Mary Majerus, a doctoral candidate in Leadership and Learning in Organizations. The decision to join in this study, or not to join, is up to you. Thank you for your time and consideration.

If you decide to participate, you will be asked if your institution provides guidance on hiring and recruiting postdocs, and if so, to provide the documentation, if possible. Documentation may likely be a URL to a website on your institution's homepage or possibly a PDF or other text document. You will also be asked at most 12 multiple-choice questions regarding the recruitment/hiring process in your department. This entire process should take no longer than 7 minutes.

This survey involves no risks to the participant. This survey will not be linked to you or your institution in any way. Final results of the study can be shared with you by contacting the researcher (see the bottom of the page).
If you are not the person involved in hiring mathematical sciences postdocs in the current or past 3 years, please forward this survey to the person serving in that capacity.

Contacts for Questions or Problems For questions regarding the study or results, contact Mary Majerus, doctoral candidate in the Leadership and Learning in Organizations at Vanderbilt University: mary.majerus@vanderbilt.edu, or her academic advisor, Dr. Tracy Armstrong: tracey.m.armstrong@vanderbilt.edu.

[i] Definition for this survey: "A postdoctoral scholar ("postdoc") is an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing" (www.nationalpostdoc.org/page/What_is_a_postdoc). ***Click on the arrow at the bottom right of each page to advance the survey.***

End of Block: Default Question Block

Start of Block: Block 7

Q25 Current norms and procedures in the recruitment and hiring processes of post-doc appointments in mathematical sciences will be explored in this study. These results will be compared across different size and degree-granting institutions. This is a cross-sectional, one-time study, to compare results across institutions.

You may opt out of this study at any time. No personal information will be collected from you. The only identifying information is of the American Mathematical Society's (AMS) classification of institutions used for their Annual Survey of the Mathematical Sciences regarding your institution. That information can be found using a link provided at the start of the survey.

All results will be held in secure, password protected cloud storage for a period of three years. The only person with access to the locked storage of these results is the investigator. No identifying criteria will be kept other than AMS classification. No direct responses or quotes will be provided which could be seen as traced back to any one individual. Aggregated data or summarized comments will be shared.

For additional information about giving consent or your rights as a participant in this study, to discuss problems, concerns, and questions, or to offer input, please feel free to contact the Institutional Review Board Office at (615) 322-2918 or toll free at (866) 224-8273.

End of Block: Block 7

Start of Block: Block 1

Q2 **My current position at my institution is that of**

- ☐ Postdoctoral Advisor (who is allowed to hire his/her own research postdoc/fellow/etc.) (1)
- ☐ Department Chair (2)
- ☐ Chair of the Postdoc Search Committee in Mathematical Sciences (3)
- ☐ Other: (4) _____

Q3 **The American Mathematical Society (AMS) classification of my institution for their *Annual Survey of the Mathematical Sciences* is _____.** (You may look up your classification by using this link and searching for your institution.)

- ○ Doctoral Math Public Large (1)
- ○ Doctoral Math Public Medium (2)
- ○ Doctoral Math Public Small (3)
- ○ Doctoral Math Private Large (4)
- ○ Doctoral Math Private Small (5)
- ○ Doctoral Applied Math (6)
- ○ Doctoral Statistics (7)
- ○ Doctoral Biostatistics (8)
- ○ Masters (9)
- ○ Bachelors (10)

Q4 **Section One: Recruitment Practices**

Q5 **Select each method used to advertise and/or recruit applicants for postdocs openings at your institution:** (More than one may be selected.)

- ☐ Mathjobs.org (1)
- ☐ Chronicle (2)
- ☐ International sites (e.g., EMS, Nordic-math-jobs,or Academic positions) (3)
- ☐ Jobs.sciencecareers.org (4)
- ☐ Posting on field specific mailing list sites or listservs (e.g., DMANET or THEORYNT) (5)
- ☐ Professional online job postings (e.g., Indeed.com, LinkedIn, or Glassdoor) (6)
- ☐ Personal invitation (e.g., from conference talk, collaboration on paper, or knowledge of advisor) (7)
- ☐ Posting on your institution's website (8)
- ☐ Other (Please describe.) (9) _____

Q6 **Section Two: First Screening of Candidates**

Q7 The initial review of applicants is typically completed by (Select one):

- ○ Postdoctoral advisor who will be overseeing the postdoc (1)
- ○ Assistant to the postdoctoral advisor (2)
- ○ Chair of search committee for the postdoc (3)
- ○ Department Chair (4)
- ○ Administrative Assistant (5)
- ○ Multiple individuals screen files independently and later confer for agreement (6)
- ○ Committee of individuals meets and discusses each applicant (7)
- ○ Committee via electronic discussion boards or email (8)
- ○ Applicants are screened by an external reviewing company (9)
- ○ Other(s) (10) _____

Q8 **In this initial review of applicants, a list of criteria used to describe the ideal candidate is used.**

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If In this initial review of applicants, a list of criteria used to describe the ideal candidate is... = No

Q9 **A list of criteria to describe the ideal candidate is used at the initial level of screening.**

- ○ Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.) (1)
- ○ Yes, but I am unable or unwilling to upload the criteria at this time. (2)

Skip To: End of Block If Ifyou answered "Yes" and have a rubric: = Yes, but I am unable or unwilling to upload the criteria at this time.

Q10 **Please upload a copy of criteria used if you are willing to share and further inform the study.**

End of Block: Block 1

Start of Block: Block 4

Start of Block: Block 2

Q11 **Section Three: Second Level of Candidate Review**

Q12 **If a second level or review of candidates exists, indicate additional method(s) involved in narrowing the field of candidates:**

- ☐ Applicants are screened in committee discussions (1)
- ☐ Applicants are screened by an external reviewing company (2)
- ☐ Applicants are screened by one person (3)
- ☐ No second level/round for narrowing the field of candidates is used. (4)
- ☐ Other: (5) _____

Skip To: End of Block If If a second level or review of candidates exists, indicate additional method(s) involved in narro... = No second level/round for narrowing the field of candidates is used.

Q13 **Applicants are screened against a list of criteria used to describe the ideal candidate.**

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If Applicants are screened against a list of criteria used to describe the ideal candidate. = No

Q14 A list of criteria to describe the ideal candidate is used at this level.

- ○ Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.) (1)
- ○ Yes, but I am unable or unwilling to upload the criteria at this time. (2)

Skip To: End of Block If A list of criteria to describe the ideal candidate is used at this level. = Yes, but I am unable or unwilling to upload the criteria at this time.

Q15 **Please upload a copy of criteria used if you are willing to share and further inform the study.**

End of Block: Block 2

Start of Block: Block 3

Q16 **Section Four: Final Selection Process**

Q17 **We typically have an onsite interview.**

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If We typically have an onsite interview. = No

Q18 **Onsite applicants are screened against a list of criteria describing the ideal candidate.**

- ○ Yes (1)
- ○ No (2)

Skip To: End of Block If Onsite applicants are screened against a list of criteria describing the ideal candidate. = No

Q19 **For onsite visits, a list of criteria describing the ideal candidate is used for screening:**

- ○ Yes, and I am willing to upload that document/criteria here. (A file upload opportunity will occur when selecting this option.) (1)
- ○ I am unable or unwilling to upload the document/criteria at this time. (2)

Skip To: End of Block If For onsite visits, a list of criteria describing the ideal candidate is used for screening: = I am unable or unwilling to upload the document/criteria at this time.

Q20 **Please upload a copy of your criteria if you are willing to share and further inform the study.**

End of Block: Block 3

Start of Block: Block 5

Appendix E: Letter to Participate

Dear Dr. ${m://FirstName} ${m://LastName},

You are invited to join a research study to look at formal and informal processes regarding the recruiting and hiring of postdocs in mathematical sciences. This survey is part of a doctoral study at Vanderbilt University, led by Mary Majerus, a doctoral candidate in Leadership and Learning in Organizations.

If you decide to participate, you will be asked if your institution provides guidance on hiring and recruiting postdocs, and if so, to provide the documentation, if possible. You will also be asked at most 12 multiple-choice questions regarding the recruitment/hiring process in your department. This entire process should take no longer than 7 - 10 minutes.

This survey involves no risks to the participant. This survey will not be linked to you or your institution in any way. Final results of the study can be shared with you by contacting the researcher (see the bottom of the page).

If you are not the person involved in hiring mathematical sciences postdocs in the current or past 3 years, I respectfully request you please forward this survey to the person serving in that capacity. This data is important to better understanding recruitment and hiring practices for postdoc positions.

Follow this link to the Survey:

${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

Contacts for Questions or Problems
For questions regarding the study or results, contact Mary Majerus, doctoral candidate in the Leadership and Learning in Organizations at Vanderbilt University: mary.majerus@vanderbilt.edu, or her academic advisor, Dr. Tracy Armstrong: tracey.m.armstrong@vanderbilt.edu.

Appendix F: Invitation for Those Currently Hiring

Dear Dr. ${m://FirstName} ${m://LastName},

You are receiving this email because your institution has a recent public posting for a mathematics postdoc position. You are invited to join a research study to look at formal and informal processes regarding the recruiting and hiring of postdocs in mathematical sciences. This survey is part of a doctoral study at Vanderbilt University, led by Mary Majerus, a doctoral candidate in Leadership and Learning in Organizations.

If you decide to participate, you will be asked if your institution provides guidance on hiring and recruiting postdocs, and if so, to provide the documentation, if possible. You will also be asked at most 12 multiple-choice questions regarding the recruitment/hiring process in your department. This entire process should take no longer than 7 - 10 minutes.

This survey involves no risks to the participant. This survey will not be linked to you or your institution in any way. Final results of the study can be shared with you by contacting the researcher (see the bottom of the page).

If you are not the person involved in hiring mathematical sciences postdocs in the current or past 3 years, I respectfully request you please forward this survey to the person serving in that capacity. This data is important to better understanding recruitment and hiring practices for postdoc positions.

Follow this link to the Survey:

${l://SurveyLink?d=Take the Survey}

Or copy and paste the URL below into your internet browser:
${l://SurveyURL}

Follow the link to opt out of future emails:
${l://OptOutLink?d=Click here to unsubscribe}

Contacts for Questions or Problems

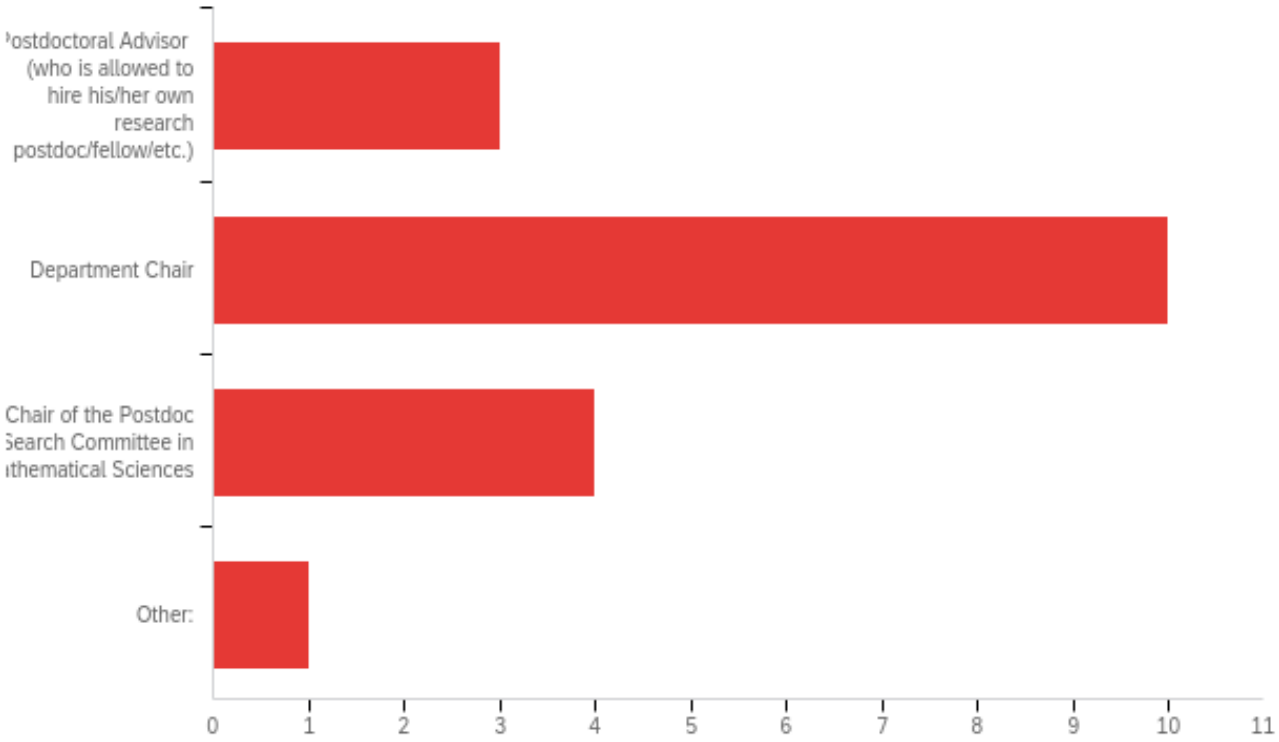
For questions regarding the study or results, contact Mary Majerus, doctoral candidate in the Leadership and Learning in Organizations at Vanderbilt University: mary.majerus@vanderbilt.edu, or her academic advisor, Dr. Tracy Armstrong: tracey.m.armstrong@vanderbilt.edu.

Appendix G

Final Study Part One

Current Practices and Processes for Recruiting and Hiring Postdocs in Mathematics

Q2 - My current position at my institution is that of

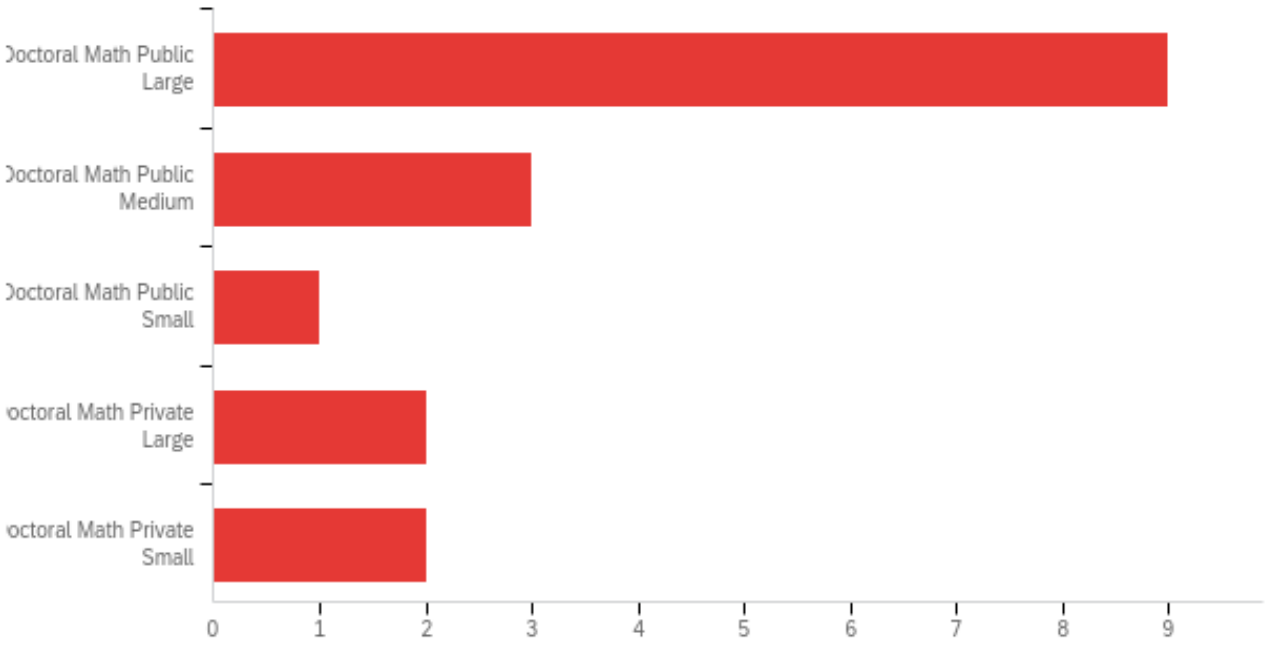


#	Answer	%	Count
1	Postdoctoral Advisor (who is allowed to hire his/her own research postdoc/fellow/etc.)	16.67%	3
2	Department Chair	55.56%	10
3	Chair of the Postdoc Search Committee in Mathematical Sciences	22.22%	4
4	Other:	5.56%	1
	Total	100%	18

Q2_4_TEXT - Other:

Other: - Text
Professor and part of the Postdoc Search Committee

Q3 - The American Mathematical Society (AMS) classification of my institution for their Annual Survey of the Mathematical Sciences is _____. (You may look up your classification by using this link and searching for your institution.)

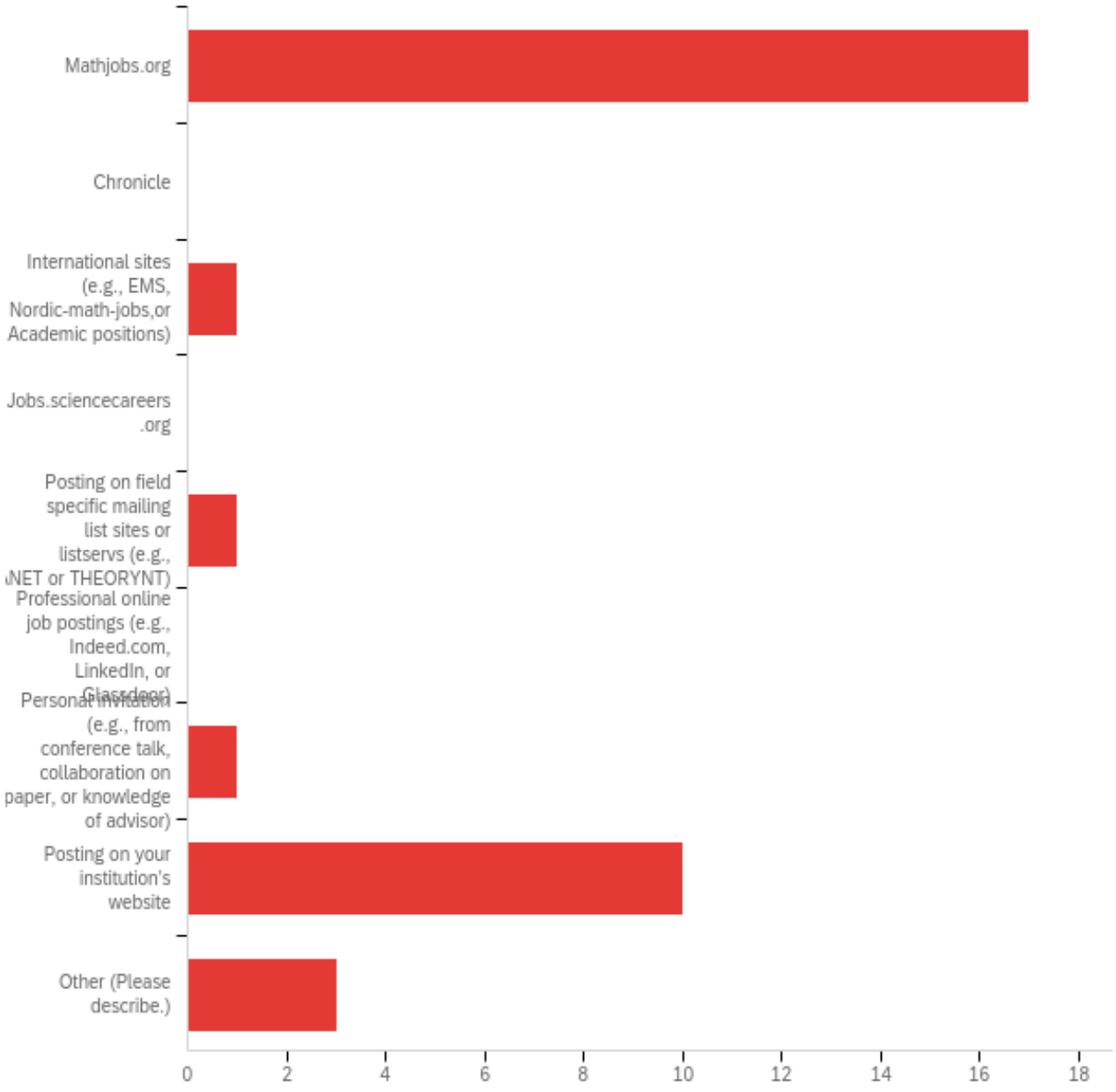


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	The American Mathematical Society (AMS) classification of my institution for their Annual Survey of the Mathematical Sciences is _____. (You may look up your classification by using this link and searching for your institution.)	1.00	5.00	2.12	1.45	2.10	17

#	Answer	%	Count
1	Doctoral Math Public Large	52.94%	9
2	Doctoral Math Public Medium	17.65%	3
3	Doctoral Math Public Small	5.88%	1

4	Doctoral Math Private Large	11.76%	2
5	Doctoral Math Private Small	11.76%	2
	Total	100%	17

Q5 - Select each method used to advertise and/or recruit applicants for postdocs openings at your institution: (More than one may be selected.)



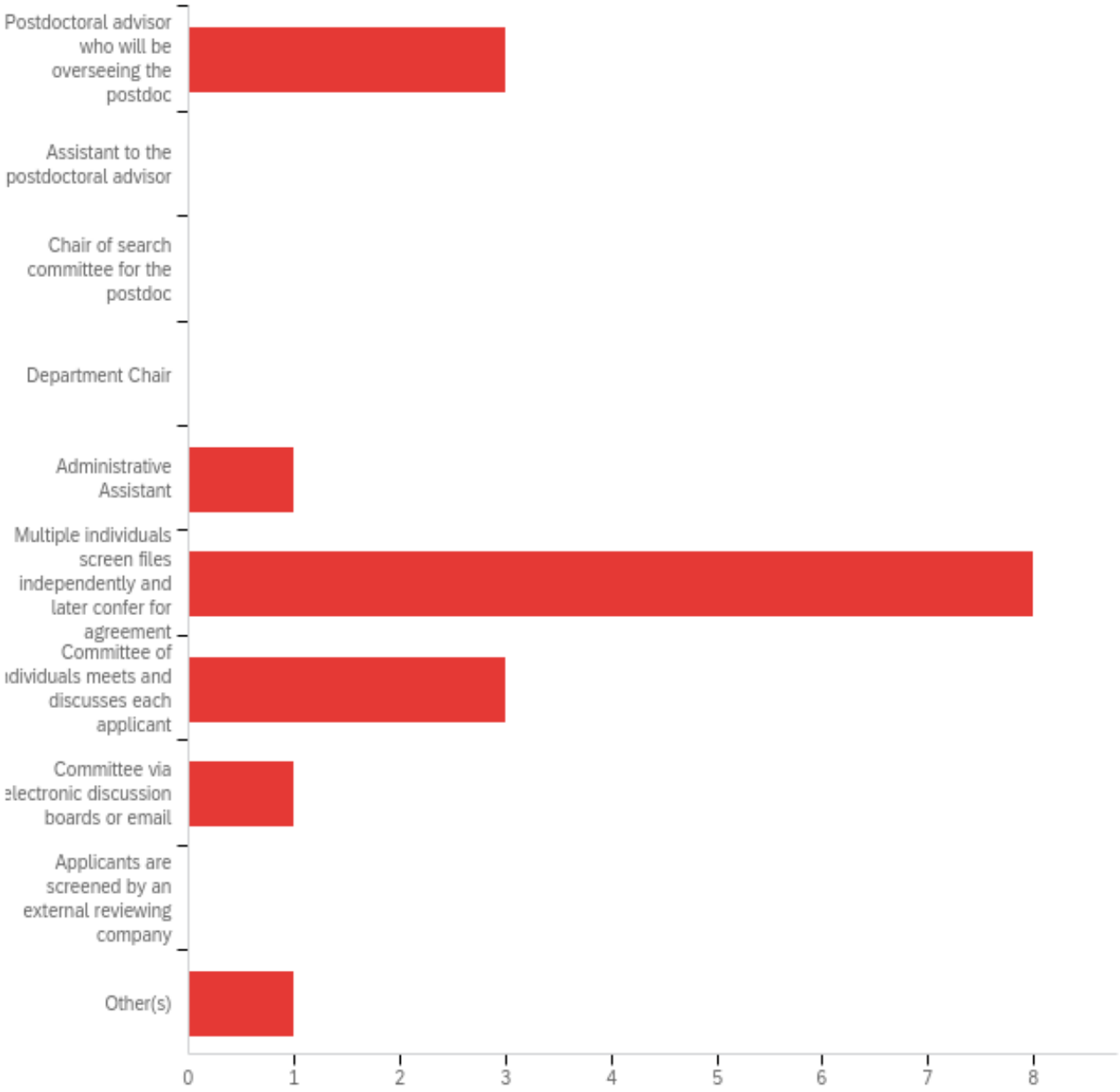
#	Answer	%	Count
1	Mathjobs.org	51.52%	17
2	Chronicle	0.00%	0
3	International sites (e.g., EMS, Nordic-math-jobs,or Academic positions)	3.03%	1

4	Jobs.sciencecareers.org	0.00%	0
5	Posting on field specific mailing list sites or listservs (e.g., DMANET or THEORYNT)	3.03%	1
6	Professional online job postings (e.g., Indeed.com, LinkedIn, or Glassdoor)	0.00%	0
7	Personal invitation (e.g., from conference talk, collaboration on paper, or knowledge of advisor)	3.03%	1
8	Posting on your institution's website	30.30%	10
9	Other (Please describe.)	9.09%	3
	Total	100%	33

Q5_9_TEXT - Other (Please describe.)

Other (Please describe.) - Text
Posting on CRM (Montreal) site
UC Recruit website
Interfolio

Q7 - The initial review of applicants is typically completed by (Select one):

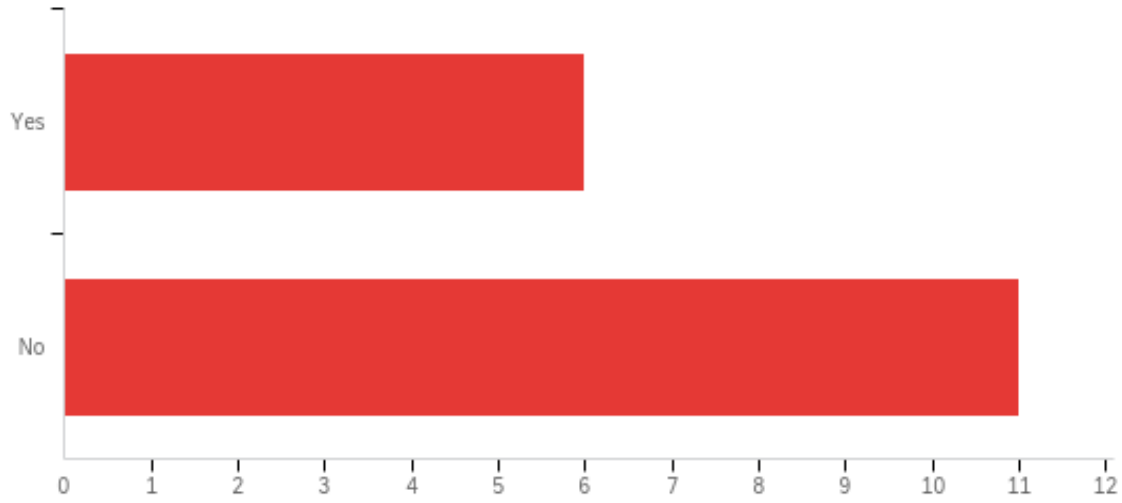


#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	The initial review of applicants is typically completed by (Select one): - Selected Choice	1.00	10.00	5.59	2.38	5.65	17

#	Answer	%	Count
1	Postdoctoral advisor who will be overseeing the postdoc	17.65%	3
2	Assistant to the postdoctoral advisor	0.00%	0
3	Chair of search committee for the postdoc	0.00%	0
4	Department Chair	0.00%	0
5	Administrative Assistant	5.88%	1
6	Multiple individuals screen files independently and later confer for agreement	47.06%	8
7	Committee of individuals meets and discusses each applicant	17.65%	3
8	Committee via electronic discussion boards or email	5.88%	1
9	Applicants are screened by an external reviewing company	0.00%	0
10	Other(s)	5.88%	1
	Total	100%	17

Q7_10_TEXT - Other(s)
Other(s) - Text

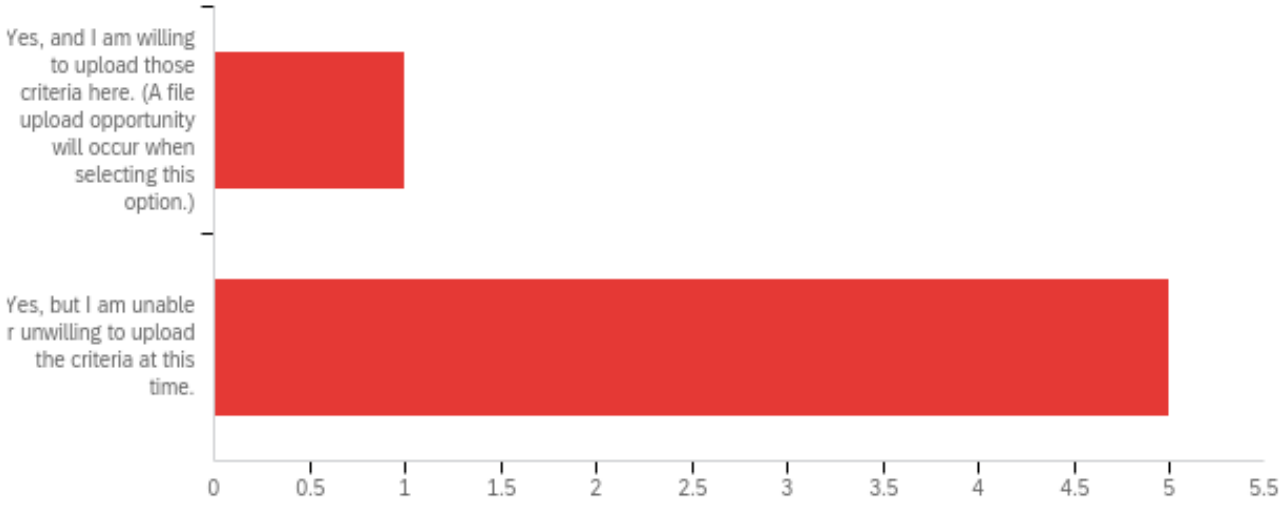
Q8 - In this initial review of applicants, a list of criteria used to describe the ideal candidate is used.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	In this initial review of applicants, a list of criteria used to describe the ideal candidate is used.	1.00	2.00	1.65	0.48	0.23	17

#	Answer	%	Count
1	Yes	35.29%	6
2	No	64.71%	11
	Total	100%	17

Q9 - Ifyou answered "Yes" and have a rubric:



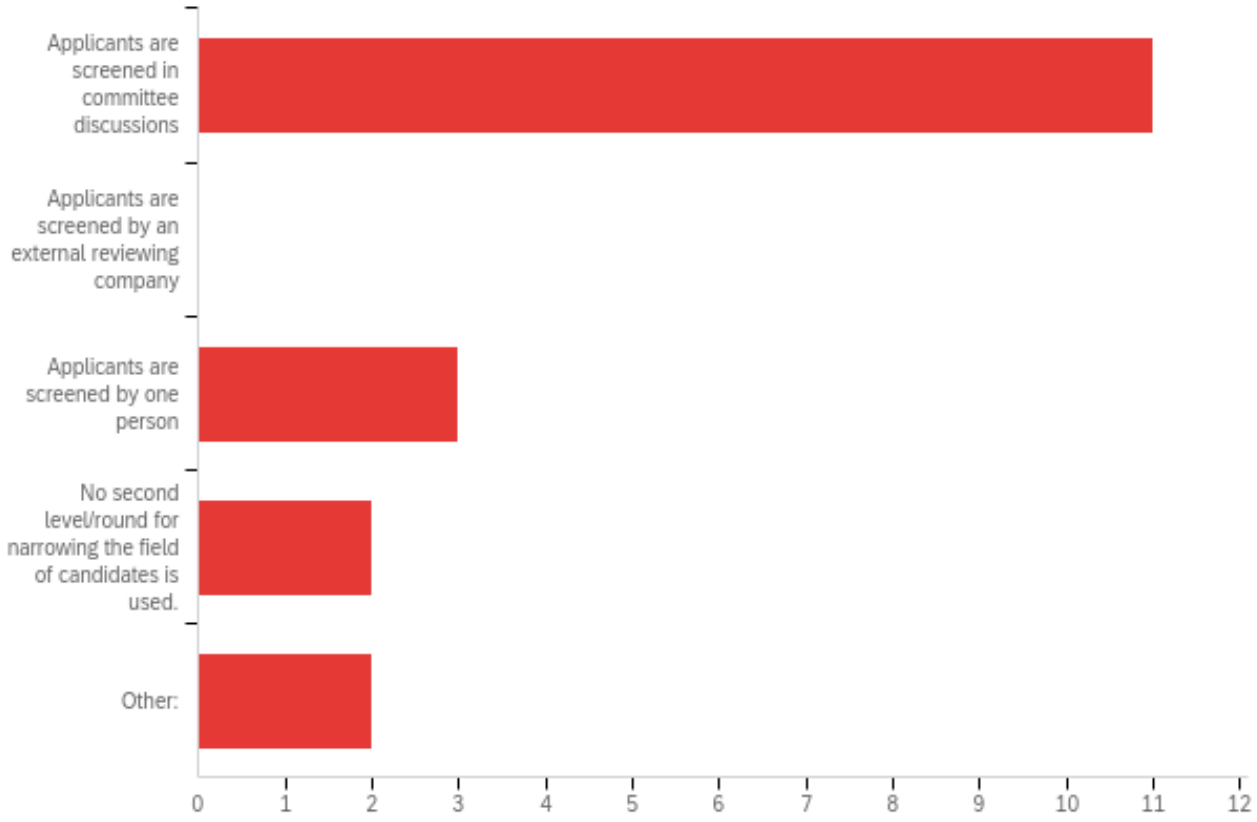
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Ifyou answered "Yes" and have a rubric:	1.00	2.00	1.83	0.37	0.14	6

#	Answer	%	Count
1	Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.)	16.67%	1
2	Yes, but I am unable or unwilling to upload the criteria at this time.	83.33%	5
	Total	100%	6

Q10 - Please upload a copy of criteria used if you are willing to share and further inform the study.

Q10_Id - Id
Please upload a copy of criteria used if you are willing to share and further inform the study. - Name

Q12 - If a second level or review of candidates exists, indicate additional method(s) involved in narrowing the field of candidates:



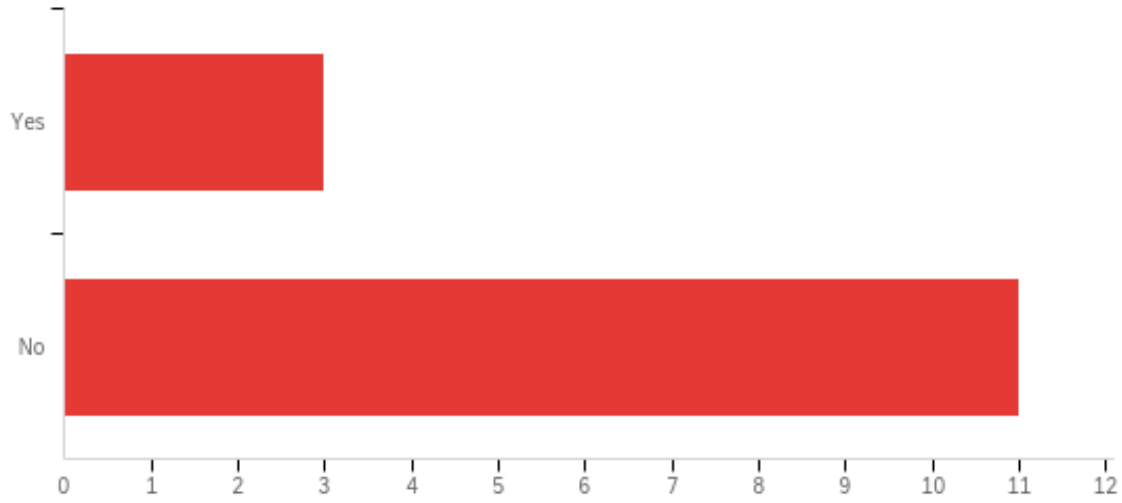
#	Answer	%	Count
1	Applicants are screened in committee discussions	61.11%	11
2	Applicants are screened by an external reviewing company	0.00%	0
3	Applicants are screened by one person	16.67%	3
4	No second level/round for narrowing the field of candidates is used.	11.11%	2
5	Other:	11.11%	2
	Total	100%	18

Q12_5_TEXT - Other:

Other: - Text

Applicants are screened by whole department
Remote interviews are conducted by the search committee

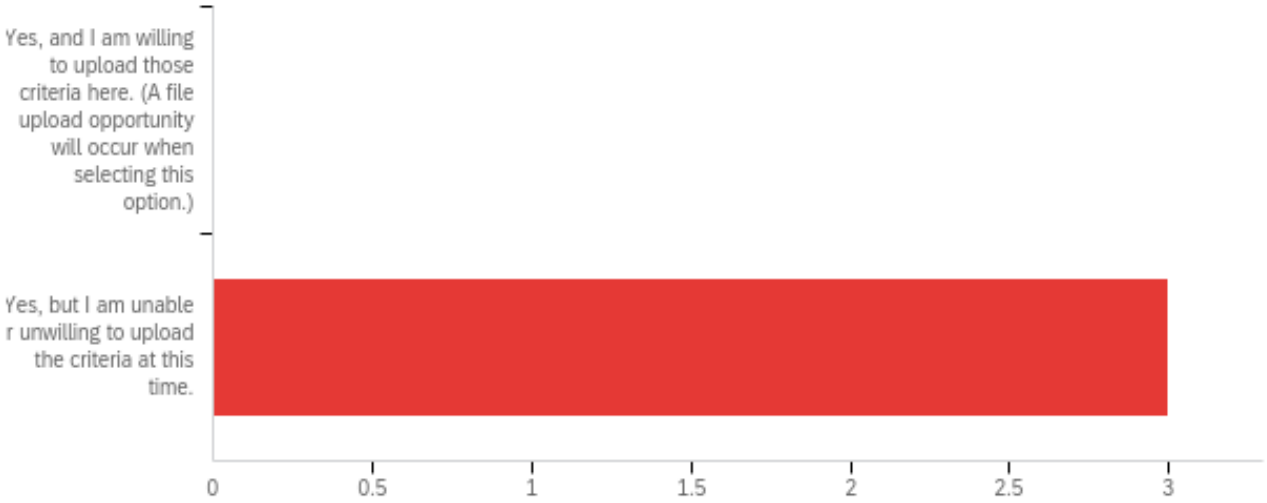
Q13 - Applicants are screened against a list of criteria used to describe the ideal candidate.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Applicants are screened against a list of criteria used to describe the ideal candidate.	1.00	2.00	1.79	0.41	0.17	14

#	Answer	%	Count
1	Yes	21.43%	3
2	No	78.57%	11
	Total	100%	14

Q14 - A list of criteria to describe the ideal candidate is used at this level.



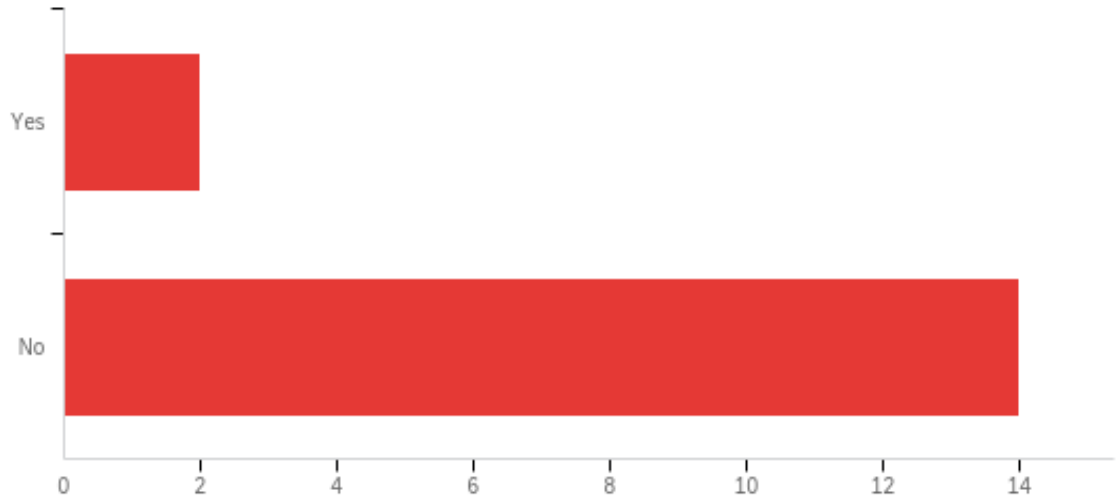
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	A list of criteria to describe the ideal candidate is used at this level.	2.00	2.00	2.00	0.00	0.00	3

#	Answer	%	Count
1	Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.)	0.00%	0
2	Yes, but I am unable or unwilling to upload the criteria at this time.	100.00%	3
	Total	100%	3

Q15 - Please upload a copy of criteria used if you are willing to share and further inform the study.

Q15_Id - Id
Please upload a copy of criteria used if you are willing to share and further inform the study. - Name

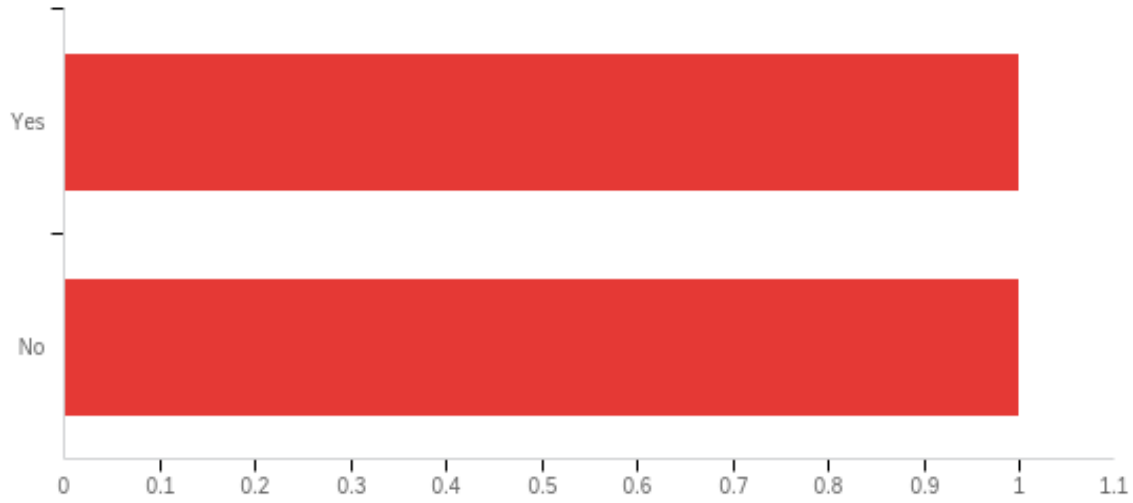
Q17 - We typically have an onsite interview.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	We typically have an onsite interview.	1.00	2.00	1.88	0.33	0.11	16

#	Answer	%	Count
1	Yes	12.50%	2
2	No	87.50%	14
	Total	100%	16

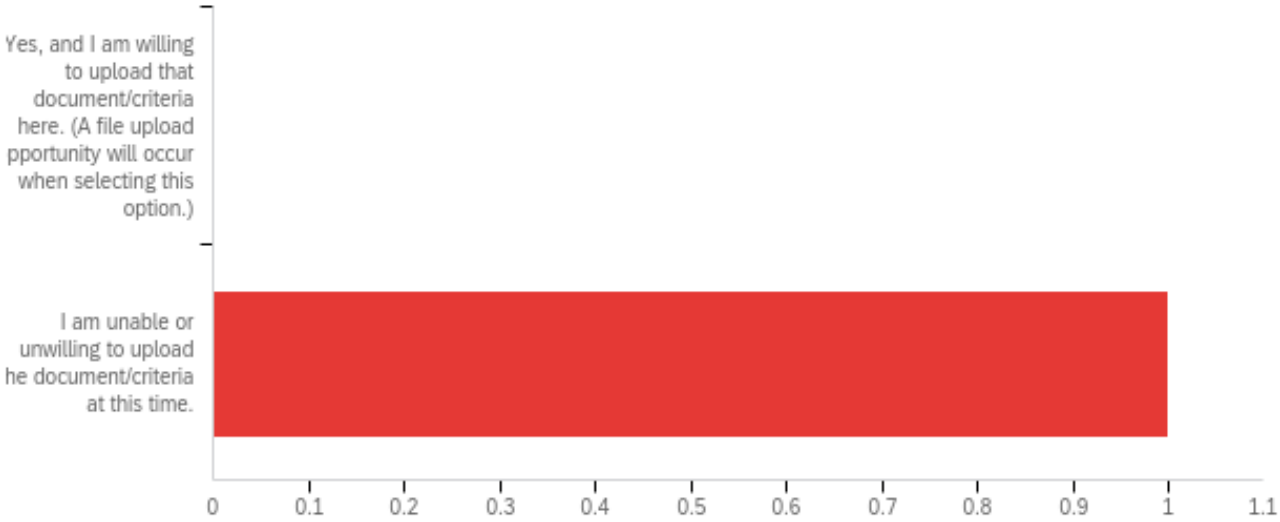
Q18 - Onsite applicants are screened against a list of criteria describing the ideal candidate.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Onsite applicants are screened against a list of criteria describing the ideal candidate.	1.00	2.00	1.50	0.50	0.25	2

#	Answer	%	Count
1	Yes	50.00%	1
2	No	50.00%	1
	Total	100%	2

Q19 - For onsite visits, a list of criteria describing the ideal candidate is used for screening:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	For onsite visits, a list of criteria describing the ideal candidate is used for screening:	2.00	2.00	2.00	0.00	0.00	1

#	Answer	%	Count
1	Yes, and I am willing to upload that document/criteria here. (A file upload opportunity will occur when selecting this option.)	0.00%	0
2	I am unable or unwilling to upload the document/criteria at this time.	100.00%	1
	Total	100%	1

Q20 - Please upload a copy of your criteria if you are willing to share and further inform the study.

Q20_Id - Id
Please upload a copy of your criteria if you are willing to share and further inform the study. - Name

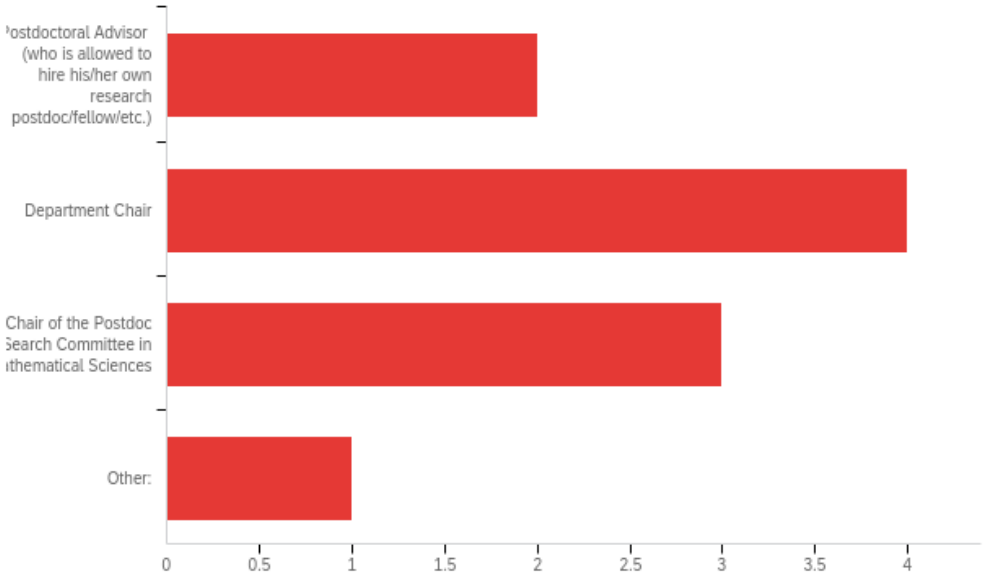
Appendix H

A department is in Group...	...when its subject area, highest degree offered, and PhD production rate p
Math Public Large	Math PhD, $7.0 \leq p$
Math Public Medium	Math PhD, $3.9 \leq p < 7.0$
Math Public Small	Math PhD, $p < 3.9$
Math Private Large	Math PhD, $3.9 \leq p$
Math Private Small	Math PhD, $p < 3.9$
Applied Math	Applied mathematics, PhD
Statistics	Statistics, PhD
Biostatistics	Biostatistics, PhD
Masters	Math, masters
Bachelors	Math, bachelors
Doctoral Math	Math Public, Math Private, & Applied Math
Stat/Biostat or Stats	Statistics & Biostatistics
Math	All groups except Statistics & Biostatistics

Appendix I

Final Study Part Two Only Large
Current Practices and Processes for Recruiting and Hiring Postdocs in Mathematics

Q2 - My current position at my institution is that of



#	Answer	%	Count
1	Postdoctoral Advisor (who is allowed to hire his/her own research postdoc/fellow/etc.)	20.00%	2
2	Department Chair	40.00%	4
3	Chair of the Postdoc Search Committee in Mathematical Sciences	30.00%	3
4	Other: [Professor and part of postdoc search committee]	10.00%	1
	Total	100%	10

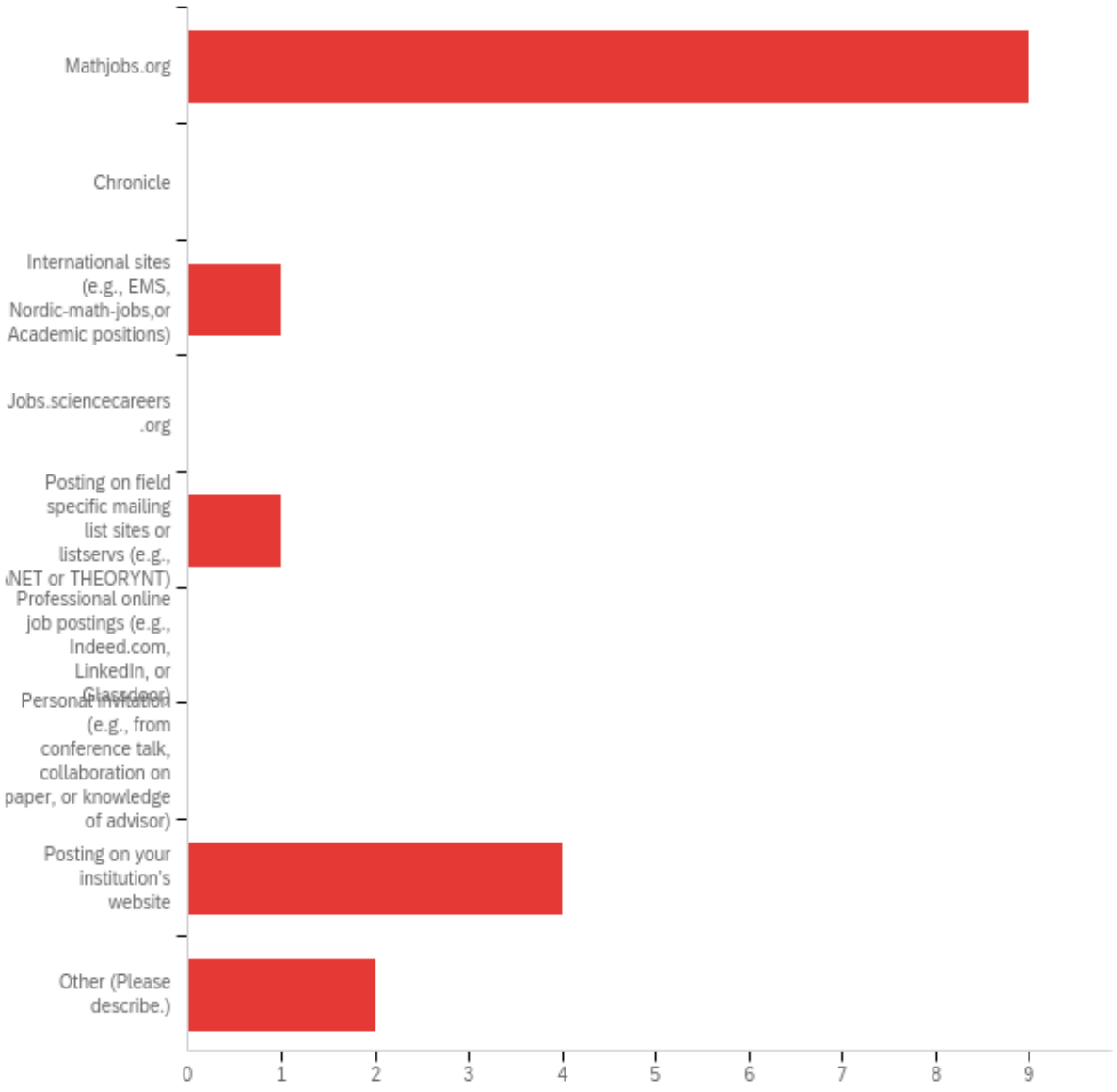
Q2_4_TEXT - Other: - Text

Professor and part of the Postdoc Search Committee

Q3 - The American Mathematical Society (AMS) classification of my institution for their Annual Survey of the Mathematical Sciences is _____. (You may look up your classification by using this link and searching for your institution.)

#	Answer	%	Count
1	Doctoral Math Public Large	100.00%	9
	Total	100%	9

Q5 - Select each method used to advertise and/or recruit applicants for postdocs openings at your institution: (More than one may be selected.)



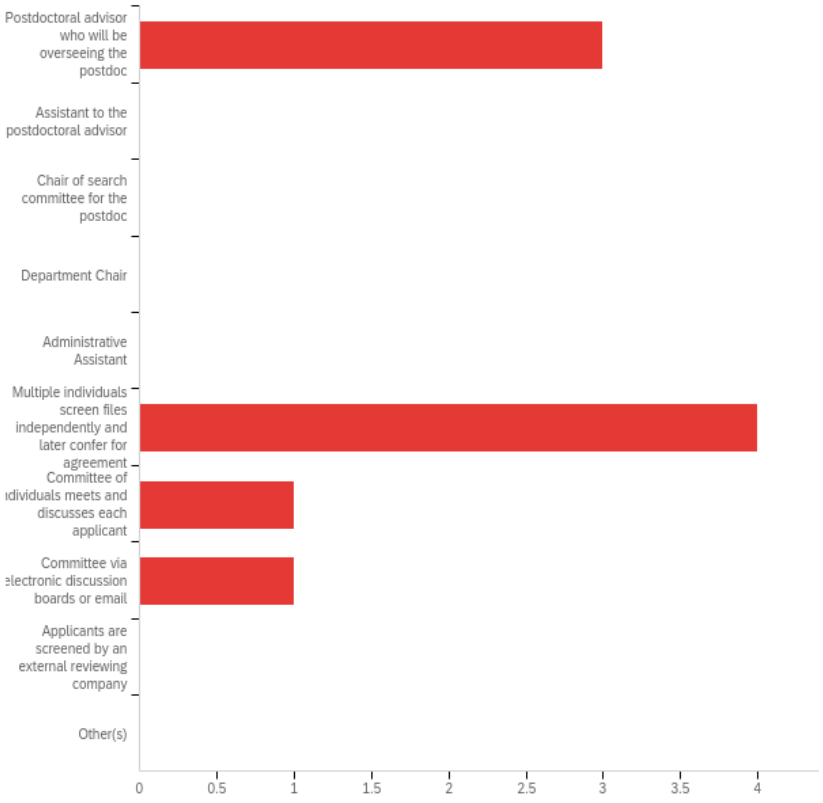
#	Answer	%	Count
1	Mathjobs.org	52.94%	9
2	Chronicle	0.00%	0
3	International sites (e.g., EMS, Nordic-math-jobs,or Academic positions)	5.88%	1
4	Jobs.sciencecareers.org	0.00%	0
5	Posting on field specific mailing list sites or listservs (e.g., DMANET or THEORYNT)	5.88%	1
6	Professional online job postings (e.g., Indeed.com, LinkedIn, or Glassdoor)	0.00%	0

7	Personal invitation (e.g., from conference talk, collaboration on paper, or knowledge of advisor)	0.00%	0
8	Posting on your institution's website	23.53%	4
9	Other (Please describe.)	11.76%	2
	Total	100%	17

Q5_9_TEXT - Other (Please describe.)

Other (Please describe.) - Text
UC Recruit website
interfolio

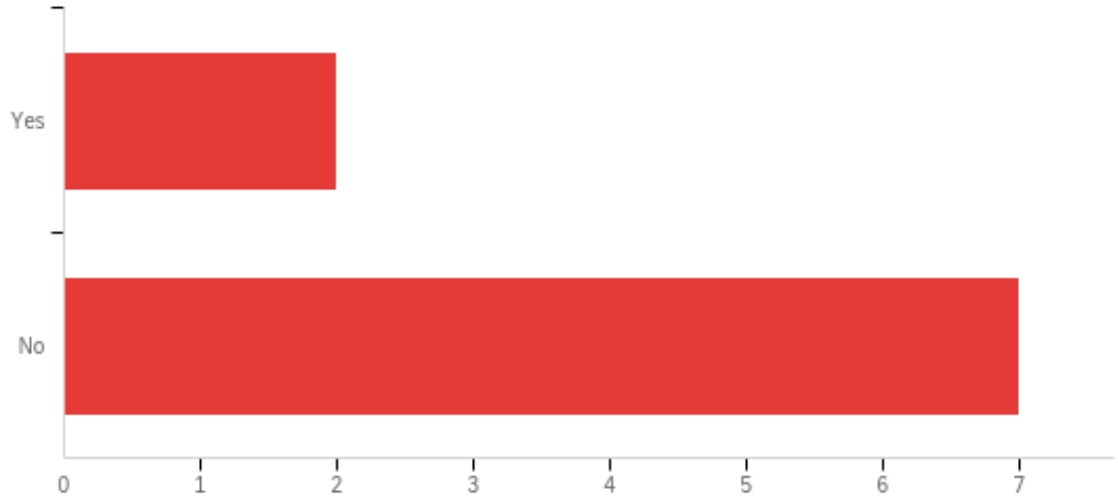
Q7 - The initial review of applicants is typically completed by (Select one):



#	Answer	%	Count

1	Postdoctoral advisor who will be overseeing the postdoc	33.33%	3
2	Assistant to the postdoctoral advisor	0.00%	0
3	Chair of search committee for the postdoc	0.00%	0
4	Department Chair	0.00%	0
5	Administrative Assistant	0.00%	0
6	Multiple individuals screen files independently and later confer for agreement	44.44%	4
7	Committee of individuals meets and discusses each applicant	11.11%	1
8	Committee via electronic discussion boards or email	11.11%	1
9	Applicants are screened by an external reviewing company	0.00%	0
10	Other(s)	0.00%	0
	Total	100%	9

Q8 - In this initial review of applicants, a list of criteria used to describe the ideal candidate is used.



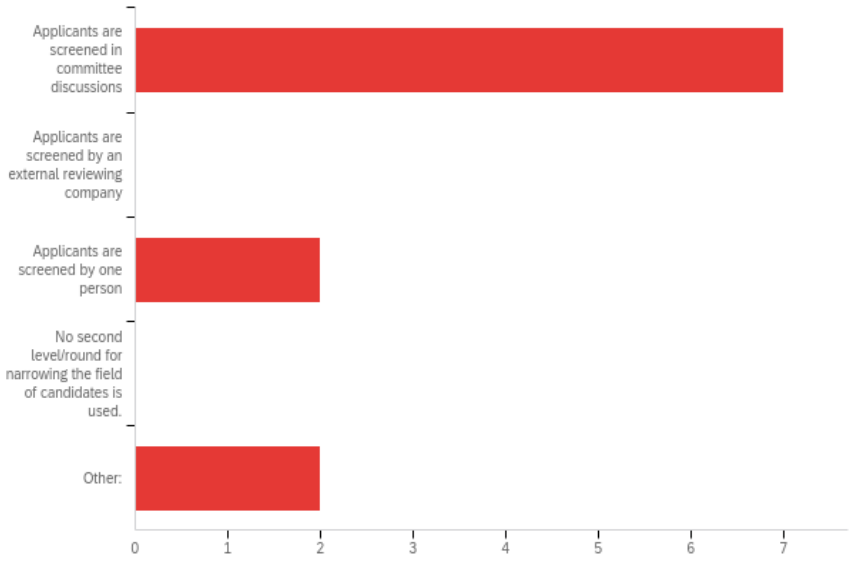
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	In this initial review of applicants, a list of criteria used to describe the ideal candidate is used.	1.00	2.00	1.78	0.42	0.17	9

#	Answer	%	Count
1	Yes	22.22%	2
2	No	77.78%	7
	Total	100%	9

Q9 – If you answered "Yes" and have a rubric:

#	Answer	%	Count
1	Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.)	0.00%	0
2	Yes, but I am unable or unwilling to upload the criteria at this time.	100.00%	2
	Total	100%	2

Q12 - If a second level or review of candidates exists, indicate additional method(s) involved in narrowing the field of candidates:

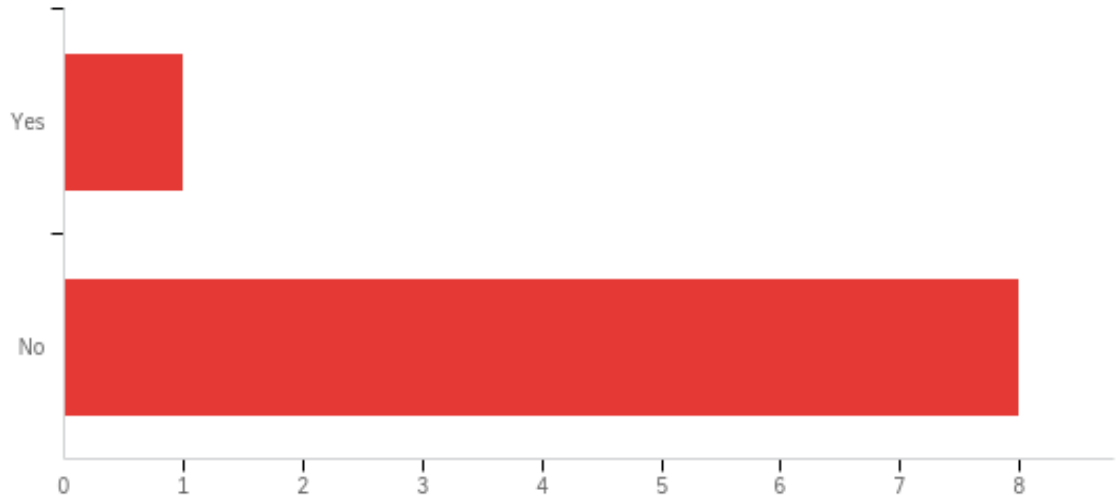


#	Answer	%	Count
1	Applicants are screened in committee discussions	63.64%	7
2	Applicants are screened by an external reviewing company	0.00%	0
3	Applicants are screened by one person	18.18%	2
4	No second level/round for narrowing the field of candidates is used.	0.00%	0
5	Other:	18.18%	2
	Total	100%	11

Q12_5_TEXT - Other:

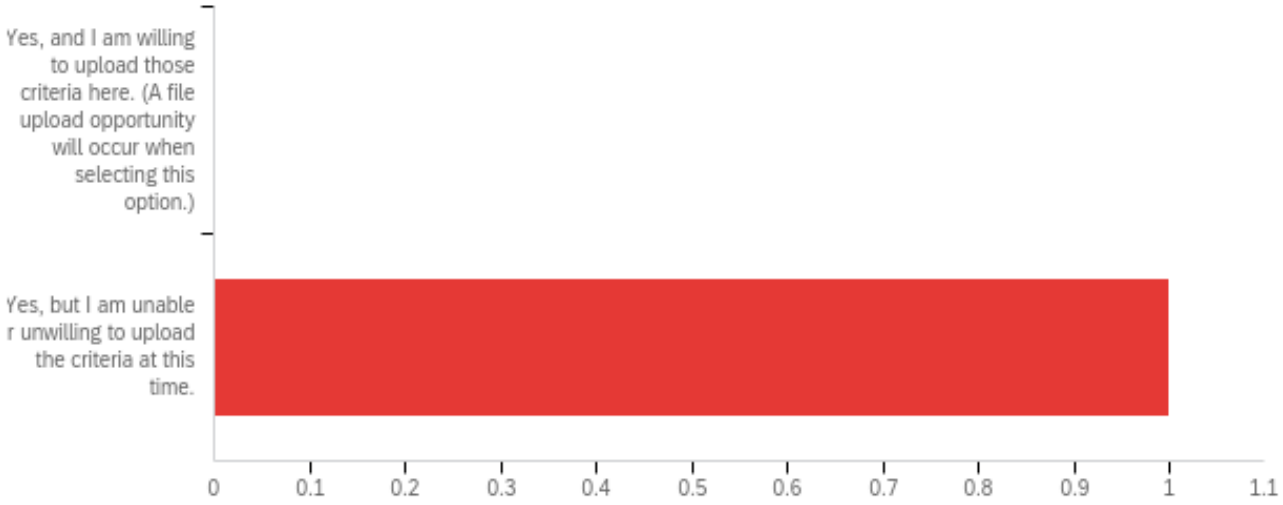
Applicants are screened by whole department
Remote interviews are conducted by the search committee

Q13 - Applicants are screened against a list of criteria used to describe the ideal candidate.



#	Answer	%	Count
1	Yes	11.11%	1
2	No	88.89%	8
	Total	100%	9

Q14 - A list of criteria to describe the ideal candidate is used at this level.



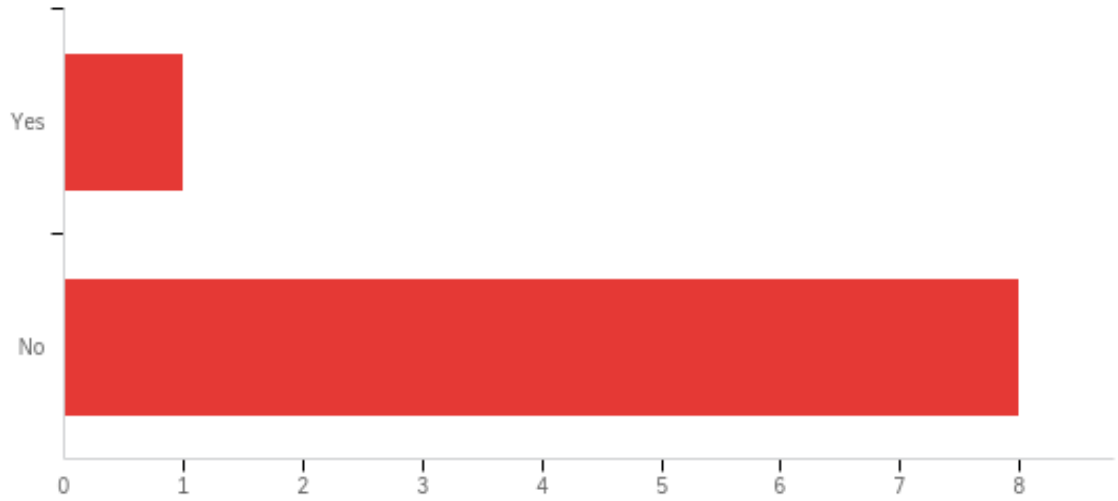
#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	A list of criteria to describe the ideal candidate is used at this level.	2.00	2.00	2.00	0.00	0.00	1

#	Answer	%	Count
1	Yes, and I am willing to upload those criteria here. (A file upload opportunity will occur when selecting this option.)	0.00%	0
2	Yes, but I am unable or unwilling to upload the criteria at this time.	100.00%	1
	Total	100%	1

Q15 - Please upload a copy of criteria used if you are willing to share and further inform the study.

Q15_Id - Id
Please upload a copy of criteria used if you are willing to share and further inform the study. - Name

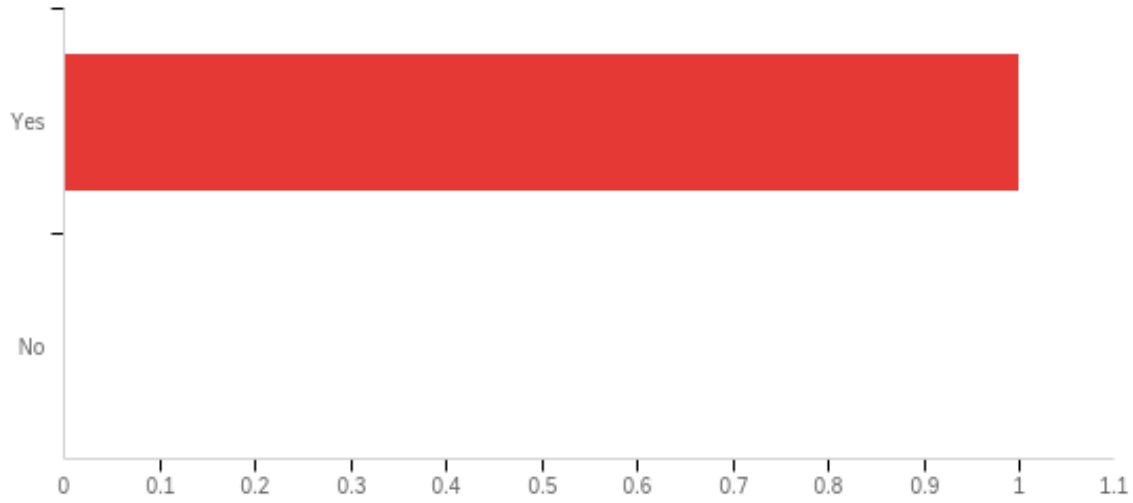
Q17 - We typically have an onsite interview.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	We typically have an onsite interview.	1.00	2.00	1.89	0.31	0.10	9

#	Answer	%	Count
1	Yes	11.11%	1
2	No	88.89%	8
	Total	100%	9

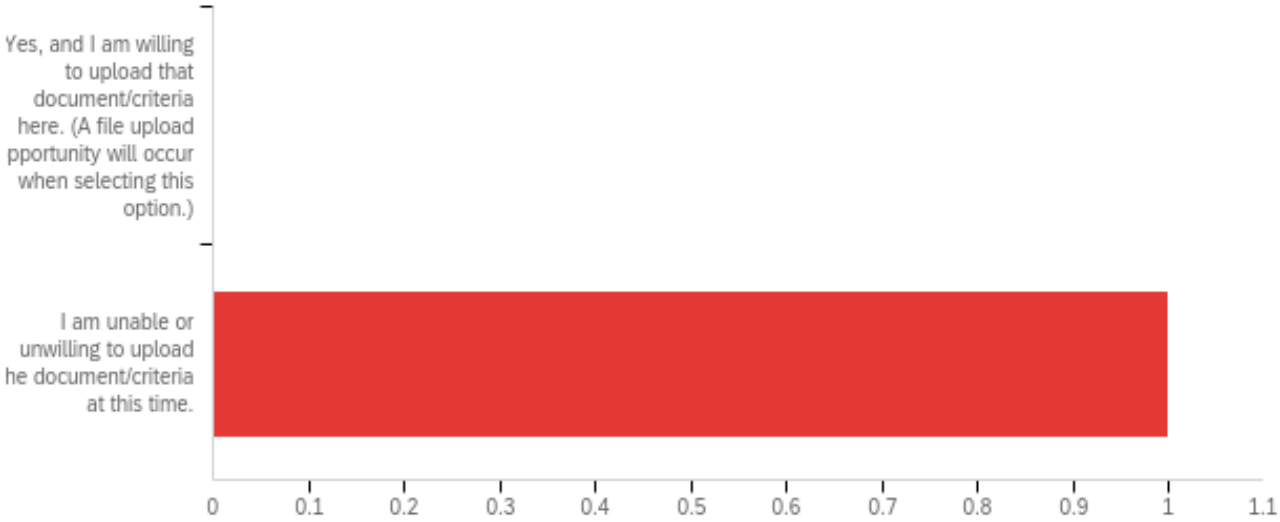
Q18 - Onsite applicants are screened against a list of criteria describing the ideal candidate.



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Onsite applicants are screened against a list of criteria describing the ideal candidate.	1.00	1.00	1.00	0.00	0.00	1

#	Answer	%	Count
1	Yes	100.00%	1
2	No	0.00%	0
	Total	100%	1

Q19 - For onsite visits, a list of criteria describing the ideal candidate is used for screening:



#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	For onsite visits, a list of criteria describing the ideal candidate is used for screening:	2.00	2.00	2.00	0.00	0.00	1

#	Answer	%	Count
1	Yes, and I am willing to upload that document/criteria here. (A file upload opportunity will occur when selecting this option.)	0.00%	0
2	I am unable or unwilling to upload the document/criteria at this time.	100.00%	1
	Total	100%	1

Appendix J

NATIONAL POSTDOCTORAL ASSOCIATION

Recommendations for Postdoctoral Policies and Practices

The National Postdoctoral Association (NPA) believes that appropriate training of the next generation of independent scientists requires that institutions set policies to encourage individual responsibility, foster effective mentoring, and recognize the value and contributions of postdoctoral scholars. This commitment to better preparation must be made at the highest levels, with institutional leaders providing: incentives and programs that promote good mentoring, an atmosphere that fosters diversity of ideas and experiences, professional development opportunities, including education on the myriad career options available to them upon graduation, appropriate recognition and compensation for postdoctoral fellows.

After considering the recommendations of stakeholders, most notably the Committee for Science, Engineering and Public Policy (COSEPUP)[1], and collecting data from over 100 institutions, the NPA recommends implementation of the following institutional policies and practices for postdoctoral training.

1. Establish a postdoctoral office/association that actively engages and represents postdoctoral scholars

1.1 Establish a Postdoctoral Office (PDO)

1.2 Establish a Postdoctoral Association (PDA)

The presence of both a postdoctoral office (PDO), staffed by permanent employees and a postdoctoral association (PDA), run by the postdocs themselves, provides an excellent mechanism to facilitate open lines of communication with the administration and gives postdocs an independent and accessible avenue to provide input to the administration. PDO's and PDA's have different roles, functions and scope The NPA provides online toolkits developed in collaboration with AAMC/GREAT to assist in the formation of PDAs, and PDOs (please visit the NPA Web site at http://www.nationalpostdoc.org/publications/toolkits for more information). If creating a postdoctoral office is not feasible (i.e., if your institution has too few postdocs to warrant such an office), an existing academic department should be given the responsibility of overseeing postdoctoral researchers, i.e. Vice-Provost for Research or Division of Graduate Studies. If the establishment of a postdoctoral association is not feasible, the appropriate office should establish defined policies to keep postdoctoral scholars engaged in planning and executing programs designed for their benefit. Additionally, the postdoctoral Office and the postdoctoral Association should strive to accomplish the goal of implementing the recommendations outlined in this document.

1.3 Setup and maintain a postdoctoral listserv and social media outlets

[1] "Enhancing the Postdoctoral Experience for Scientists and Engineers: A Guide for Postdoctoral Scholars, Advisers, Institutions, Funding Organizations, and Disciplinary Societies". National Academy of Sciences, National Academy of Engineering, Institute of Medicine, 2000. http://books.nap.edu/html/postdoctoral_experience/

The Postdoctoral Office (PDO) should establish a listserv to communicate important information to the postdocs within each institution. Additionally, the PDO should use social media outlets such as LinkedIn, Facebook and Twitter to disseminate information to current and past postdocs.

1.4 Establish a Postdoctoral Advisory Committee

The Postdoctoral Office activities and postdoctoral policies should be directed by a Postdoctoral Advisory Committee. This Committee should consist of directors of postdoctoral office/training/research programs, faculty. Administrators from the postdoctoral office, human resources, grant management, international/diversity office, and most importantly postdoctoral scholars (elected by the postdoctoral scholar community) should be included.

1.5 Ensure postdoctoral scholar representation on relevant institutional committees

Postdoctoral scholars should be represented (representatives should most preferably be chosen/elected postdoctoral scholars) on institutional committees that have operational or governance oversight of issues pertinent to the postdoctoral community.

2. Establish postdoctoral policies

An institution must recognize that its postdoctoral population has unique needs and concerns that differ substantially from those of other subsets of the university/institute population and create and implement policies that pertain specifically to postdoctoral scholars.

Postdoc-specific policies that should be clearly delineated include:

Administrative Policies

2.1 Adopt a clear definition of "postdoc" and to ascribe to each postdoc the employment categorization that they occupy--whether that is fellow, employee, or scholar

The National Institutes of Health (NIH) and the National Science Foundation (NSF) have agreed to the following definition of a postdoc:

> *A postdoctoral scholar ("postdoc") is an individual holding a doctoral degree who is engaged in a temporary period of mentored research and/or scholarly training for the purpose of acquiring the professional skills needed to pursue a career path of his or her choosing.*

The institution should have straightforward policies detailing whether postdocs are treated as employees in all cases or only in certain cases (e.g. based on source of funding). The appointment process should be uniform and ensure that postdocs are aware of the terms of their employment and that sufficient funds are available to provide financial support for the duration of their appointments. It is not necessary to create new policies for every circumstance, but institutions should clearly define which existing policies apply or do not apply to postdocs.

2.2 Identify and establish policies to deal with issues concerning postdocs

Institutions should have policies outlined regarding misconduct, grievances, authorship disputes, and concerns with regards to intellectual property. Policies should incorporate international and diversity postdoc issues and be easily accessible.

2.3 Create and disseminate a postdoctoral handbook

A handbook that includes important policy information, as well as local information, is an indispensable reference and resource for postdocs. Ideally, this handbook would be produced as a collaborative effort between the postdoctoral office, the postdoctoral association, the international scholar's office, and the human resources office. Among other resources, the handbook should contain information on the implications of funding support from training grants (individual and institutional) versus research grants; authorship and intellectual property policies; and an overview of conflict resolution and misconduct policies, with contact information for the appropriate ombudsman office. Postdocs should be provided with a hard copy of this document at the start of their training. Additionally, this document should be easily accessible online for future reference.

2.4 Utilize a centralized appointment process

A specific process for appointing postdocs should be adopted. This process will enable an institution to accurately know how many postdocs work at their institution and to evaluate the working conditions of their postdoctoral scholars. An appointment letter detailing terms of the appointment, verifying the existence of sufficient funds for the duration of employment, delineating conditions for re-appointment, detailing stipend information, and explaining benefits should be part of this process. The letter should be filed with the postdoctoral affairs office, if such an office exists, in addition to the department chair or dean.

2.5 Establish policies that give postdocs access to university facilities such as the fitness center, library, as well as career and professional development resources and university events

Providing such access is a low to no-cost way of making postdocs feel part of the community.

2.6 Conduct an orientation program for new postdocs

Providing an orientation program for new postdocs within three months of starting allows an institution to get a better understanding of the demographics of the postdocs and to ensure postdocs understand expectations, are aware of services, programs, benefits available to them, so postdocs can make the most of their appointments.

2.7 Conduct an exit interview

An exit questionnaire provides feedback regarding the success of the postdoctoral program at the institution and enables the institution to track the career pursuits of the postdocs. Maintaining such outcome data over time would inform the institution about the effectiveness of their training programs, help establish an alumni network, and enable policy decisions to be driven by data. Additionally, information from several institutions would provide valuable data regarding the scientific workforce. These interviews would ideally be conducted by the administrative body overseeing postdoctoral research at an institution but, regardless, should be conducted by an impartial entity and in such a way as to encourage honest feedback without fear of reprisal.

2.8 Conduct an annual survey of postdocs

Utilizing an annual survey provides PDAs and PDOs with valuable information regarding the needs and concerns of their postdoctoral population. The information obtained from the survey should be used to aid in determining the specific issues that are important to postdocs on an institution-specific basis.

Training policies

2.9 Provide professional development and advanced training for postdocs

The National Postdoctoral Association (NPA) has established six core competencies (www.nationalpostdoc.org/competencies) to offer guidance on relevant training for to postdocs. These competencies are meant to serve primarily as: (1) a basis for self-evaluation by postdoctoral scholars and (2) a basis for developing training opportunities that can be evaluated by mentors, institutions, and other advisors.

Given that the expressed purpose of the postdoctoral position is to receive additional advanced training in preparation for an independent career, institutions should provide guidelines and standards for this training and resources to support this training. The institution should consider that, in an era of increasing complexity for the research enterprise, postdoctoral scholars pursue professional opportunities not only in academia but also in industry, government, nonprofits, and entrepreneurship. The variety of career options available today demands a diverse array of skills, such as writing grant proposals and mastering the principles of effective resource management, that are often neglected during doctoral study and postdoctoral research. The postdoctoral experience will be more relevant to career and professional development if the scholar is offered opportunities to acquire, develop, or improve these professional skills.

2.10 Establish time frame for postdoctoral transition to independence

Institutions should define the maximum length of time an individual may be classified as a postdoc, after which they should be moved into a permanent employee position. This total should take into account the number of years previously spent at other institutions in a postdoctoral position. In cases involving family leave and other extenuating circumstances, extensions to this limit may become appropriate.

2.11 Facilitate effective mentoring and personal responsibility through career planning with an annual review

Establishing good communication between postdocs and mentors is critical for a successful relationship. The NPA recommends the use of the individual development plan (IDP), adapted as appropriate for different fields of study and to reflect any institutional guidelines. (See http://myidp.sciencecareers.org/ for more information). The IDP opens communication, identifies expectations, establishes objective criteria for success, recognizes the importance of training and service, and should be flexible to allow new opportunities to be pursued when they appear. The IDP should include defined time and resources devoted to research and career development activities independent of the mentor's research. The entrance questionnaire is an excellent opportunity to introduce the IDP and discuss particular aspects that should be included, and the exit questionnaire could be used to determine perceived and actual benefits of an IDP. An annual review of the plan and the progress made is needed to ensure that the expectations of both parties are being met and that appropriate modifications of the plan or the approach to the plan are made.

2.12 Provide career counseling and development services

Postdocs today face enormous competition and diverse career options. Mentors are unlikely to be able to provide all the necessary information and tools to facilitate transition to independence without institutional assistance. Institutions that provide career development programs and resources recognize their role and responsibility to their postdocs and help them make the most of their time at the institution. Resources could include career counseling, career exploration and panels, mentoring, lab management resources, internships or teaching opportunities, grant writing classes, access to relevant Web-based resources and small, competitive career-enhancement awards.

Benefits Policies

2.13 Establish a minimum baseline salary/stipend, plus a salary/stipend scale

Many institutions adopt the NIH National Research Service Award (NRSA) stipend scale as a minimum for departments funded through the NIH. The NRSA scale provides a baseline stipend for postdocs who have recently graduated and adjusts upwards based on the number of years of experience. While adopting this scale may be a realistic starting point for many institutions, the NPA strongly recommends a minimum baseline salary/stipend of $50,000 for a postdoc who is less than 1 year from receiving her/his Ph.D. Equal salaries should be paid to national and international postdocs.

Institutions should also provide some mechanism to ensure that guidelines recognize regional costs of living and are followed, whether through department heads, postdoctoral offices, or offices of grants and contracts administration.

2.14 Provide a comprehensive, fair, and equitable benefits package to postdocs, comparable to that which is received by standard employees whether national or international at the same institution.

Institutions should provide postdocs with a benefits package that is equitable when compared with other full-time employees at the institution. This benefits package should minimally include health and dental insurance plans for postdocs. Additionally, institutions should provide policies for vacation and sick days allowed for postdocs, as well as for family leave benefits.

2.15 Extend family-friendly benefits to all postdocs

Institutions should recognize that many postdocs are at a stage of life when establishing a family is as important as their professional development. Therefore they should extend benefits to all postdocs that are reflective of the institution's commitment to other employees. These benefits should include: adherence to the family and medical leave act for non-employees, maternity/paternity leave, access to on-site child care and/or subsidies, access to dependent coverage for health insurance, support programs for foreign spouses, and part-time status for postdocs.

2.16 Allow matched contributions to a retirement program

Given the increasing age of postdocs and length of time spent as a postdoc, the opportunity to contribute to retirement accounts is an important resource. Recognizing the temporary nature of the postdoctoral position, institutions may establish special rules for vesting by postdocs and for allowing employer-matched contributions.

3. Maintain an office for international scholar services

Postdocs who are non-U.S. citizens face unique challenges that their mentors may not be able to meet without additional assistance from elsewhere in the institution. A dedicated office for international scholars is a critical resource for both prospective scholars and those who are already at the institution. The postdoctoral office (PDO) should work closely with the office for international scholar services to ensure that the particular needs of international postdocs are being addressed. Programs to support international postdocs could include offering legal seminars or International Coffee Hours for example.

4. Establish a Diversity Office to ensure diversity and inclusion

Institutions should seek to promote diversity and ensure equal opportunity, inclusion, leadership, and activities for all postdocs, regardless of race, ethnicity, sex, disability, country of origin, field of research, socio-economic status, religion, age, marital status, sexual orientation, or gender identity.

Specifically, institutions should also:

4.1 Have formal recruitment mechanisms in place to ensure diversity of the postdoctoral population

4.2 Have support systems in place to ensure the retention and success of postdocs from under-represented and other non-traditional backgrounds

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