RUTGERS EDUCATION AND EMPLOYMENT RESEARCH CENTER

CAREER PREPARATION IN MATH GRADUATE PROGRAMS

2021 Survey and Interview Project

Executive Summary

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AUGUST 2021

RUTGERS
School of Management
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Transforming Post-Secondary Education in Mathematics (TPSE Math) is an initiative dedicated to enhancing math education in two- and four-year colleges. Funded by the Carnegie Corporation, the Alfred P. Sloan Foundation, and the National Science Foundation, TPSE's central vision is to prepare students with the "*mathematical knowledge and skills necessary for productive engagement in society and in the workplace*."[1] To achieve this vision, TPSE's work seeks to learn more about the strategies math faculty and their departments use to help students identify career in math and to ensure math majors are career ready.

In 2021, TPSE contracted with Rutgers' Education and Employment Research Center (EERC) to study the recruitment and admission processes of both master's and doctoral programs in math, and how those programs support their graduate students. TPSE was also interested in EERC further investigating the career preparation and advising strategies that had emerged in EERC's prior TPSE-funded research on undergraduate math programs.[2] These strategies included career advising, curriculum and learning opportunities, mentoring, internships/externships, research opportunities, and faculty development.

METHODOLOGY

The current study used a mixed-methods approach. With TPSE input, EERC developed an online survey that combined open- and closed-ended questions about the above topics. This survey was distributed to mathematics department chairs and graduate coordinators across the country. We then searched the survey responses for innovative approaches and analyzed the data for themes and patterns. Using these themes, we then developed an interview protocol and conducted interviews with a sample of survey respondents from both master's- and doctoral-level programs. Our report combines the qualitative and quantitative data and analysis from both the survey results and interviews.

SAMPLE

The final sample for our study included public and private institutions located across 30 US states and two Canadian Provinces. Both Research I and Research II institutions are represented. Survey data is based on 17 terminal master's programs and 46 doctoral programs. Interview data was collected from Zoom calls with two department chairs from terminal master's programs and seven chairs or graduate studies directors from seven doctoral programs.

The study elicited a variety of useful and relevant insights about (and for) math graduate programs.

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[1] TPSE. (n.d.) *About*. https://www.tpsemath.org/about

[2] The six briefs in the series are: *Working with Alumni*; *Revising Curriculum*; *Advising Strategies and Practices*; *Professional Development for Faculty and Staff*; *Practices and Polices for Career Readiness*; and *Partnering with Industry*. The briefs are available at https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

FINDINGS

Recruitment strategies. Departmental and college websites were found to be the common mechanisms of recruitment for both terminal master's and doctoral programs. Master's programs also relied heavily on undergraduate advisers, while doctoral programs relied more on national conferences. The need to shift to remote recruiting during Covid pandemic created challenges for many programs, but those conditions may have increased equity in both colleges' access to students (by leveling the playing field between larger, more established programs and smaller, less-known programs) and students' access to colleges (by increasing conference access for minority and underrepresented students). As part of their recruitment processes, some programs have become more intentional about fostering more personal and individualized relationships with potential applicants, e.g., writing personal follow up letters.

Admissions factors. Respondents from the majority of master's and doctoral programs surveyed indicated they planned to drop the use of standardized exams in their admissions process. Both survey respondents and interviewees raised concerns about the efficacy of exam results and equity in their use. Instead, most master's and doctoral programs emphasized applicants' prior math experience in their decision-making about admissions. Doctoral programs also heavily weighed prior research experience.

Diversity, equity, and inclusion (DEI). Focus on DEI issues in academia has significantly grown in recent years. We found that programs at both levels of graduate study have begun to engage in one or more initiatives to increase diversity and inclusion in their programs: for example, by forging relationships with Hispanic serving institutions (HSIs) and historically black colleges and universities (HBCUs) or the provision of financial support for students from historically under-represented groups. However, many respondents cited a lack of departmental resources or incentives to actually transform the makeup of their student bodies, particularly at the master's level. At the same time, several programs observed that their ability to increase recruitment of historically underrepresented students was intimately connected to having diverse faculty members with ties to HBCU's and HSI's. Further, a few programs underscored the importance of recruiting groups of underrepresented students to establish a sense of community for such students which furthered recruitment efforts.

Nevertheless, we did not hear about any systemic approach to DEI (e.g., faculty hiring, student recruitment and support, advising, or curriculum changes).

Advising strategies. Few math graduate programs represented in our study conducted any advising around career planning or employment outside of the academy. Most PhD students had to wait until they were at the candidacy level to receive such, albeit limited, career advising. Although all colleges have campus-based mental health services, many departments, especially doctoral programs, use adviser sessions, for well-being checks to identify and address student stress.

Only 25 percent of master-level programs offer peer mentor/support, however, the few that exist involve some innovative strategies including a chain advising structure. Almost half of doctoral programs offer peer mentor/support. One program indicated they specifically added advising support to address pandemic-related challenges.

Social networking/math related associations: Of note, 80 percent of respondents from doctoral programs and 60 percent of respondents from master's programs reported that *"there was a very close and interactive group"* among their students. Factors contributing to this included scheduled and ad hoc social activities. In addition, at the doctoral level, programs had established graduate seminars, provided collaborative research activities opportunities, and in one case, assigned multiple graduate students to the same office.

Further, at two fifths of doctoral campuses, students also had the opportunity to participate in math club/associations, including chapters of national organizations, e.g., the American Mathematical Society, the Association for Women in Mathematics. These groups sponsored social/recreational events, workshops/panel sessions about current student research activities, and, at times, sessions about career/employment information.

Faculty knowledge of non-academic career pathways. Survey respondents at both levels of graduate study indicated that faculty in their program are knowledgeable about careers outside of academia. However, interview informants clarified that this knowledge was typically based on the individual faculty member's specialization or prior experience in industry. More theoretical faculty are typically not as knowledgeable about these areas as those in applied math fields. In addition, many programs noted a generational divide in terms of both faculty knowledge about industry and their willingness to encourage students to pursue careers outside of academia, with younger faculty more knowledgeable and enthusiastic in these areas.

Non-academic career preparation. Curricular changes emerged as the primary way programs prepared students for non-academic careers at both the master's and doctoral level. Many programs required applied courses such as statistics or computer programming. Some programs also integrated more real-world problems into existing courses. Other common career preparation activities included career panels, internships, and establishing connections with local industry. In addition, some programs have even established industry advisory committees in their department and allow industry representatives to serve on doctoral committees. However, these activities were not widespread across the programs studied. Moreover, funding support for career exploration and advising activities remains an area of need in both master's and doctoral programs.

Career and occupational pathways encouraged by most faculty. In most cases, faculty continued to emphasize academic teaching and research jobs over careers in industry and government. This took place despite the growing trends of "adjunctification" throughout much of the academy; the decrease in job security in many postdoctoral and faculty positions; and a general decrease in student interest in academic careers as they progress through graduate programs. Master's programs seem to be more encouraging of non-academic careers than doctoral programs, a difference between these two graduate levels that should be explored further.

Professional development focused on non-academic pathways. Survey respondents at both the master's and doctoral levels indicated little professional development was offered in their program that focused on preparing students for careers outside the academy. However, many interviewees cited a need for such discussion and training. Some informants shared that they were trying to develop or expand such training and working to build stronger relationships with industry/government. At the same time, informants stated that professional development initiatives could only be successful if they were paired with larger cultural shifts in math graduate programs. In their view, while younger faculty often understood the need to expand preparation for non-academic career pathways, older math faculty were more likely to hold an attachment to an academic pathway, remaining unaffected by the reality that their students may not want to (or simply may not have the option to) pursue that career track.

RECOMMENDATIONS

Based on our survey and interview data, EERC has identified a number of recommendations for TPSE and math graduate programs. Many of these recommendations mirror the findings of our earlier TPSE study on undergraduate math programs.[3] They broadly include increased professional development opportunities for math graduate faculty around non-academic career preparation; building stronger relationships between math graduate programs and industry; and increased funding support for advising and non-academic career initiatives.

[3] See 2020 EERC study briefs at https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

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ABOUT THE EDUCATION AND EMPLOYMENT RESEARCH CENTER

Rutgers' Education and Employment Research Center (EERC) is housed within the School of Management and Labor Relations. EERC conducts research and evaluation on programs and policies at the intersection of education and employment. Our work strives to improve policy and practice so that institutions may provide educational programs and pathways that ensure individuals obtain the education needed for success in the workplace, and employers have a skilled workforce to meet their human resource needs. For more information on our mission and current research, visit smlr.rutgers.edu/eerc.

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Rutgers' School of Management and Labor Relations (SMLR) is the leading source of expertise on the world of work, building effective and sustainable organizations, and the changing employment relationship. The school consists of two departments—one focused on all aspects of strategic human resource management and the other dedicated to the social science specialties related to labor studies and employment relations. In addition, SMLR provides many continuing education and certificate programs taught by world-class researchers and expert practitioners.

SMLR was originally established by an act of the New Jersey legislature in 1947 as the Institute of Management and Labor Relations. Like its counterparts created in other large industrial states at the same time, the Institute was chartered to promote new forms of labor-management cooperation following the industrial unrest that occurred at the end of World War II. It officially became a school at the flagship campus of the State University of New Jersey in New Brunswick/Piscataway in 1994. For more information, visit smlr.rutgers.edu.

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INTRODUCTION

Transforming Post-Secondary Education in Mathematics (TPSE Math) is dedicated to enhancing math education in two- and four-year colleges "*to ensure that students and society are enriched by the power and beauty of mathematics*."[1] Funded by the Carnegie Corporation, the Alfred P. Sloan Foundation, and the National Science Foundation, TPSE's central vision is to prepare students with the "*mathematical knowledge and skills necessary for productive engagement in society and in the workplace*."[2] To achieve this vision, TPSE seeks to learn more about the strategies math faculty and their departments use to help students identify careers in math and to ensure math majors are career ready. In late 2019, TPSE contracted with Rutgers' Education and Employment Research Center (EERC) to study the career readiness strategies and programs being used by undergraduate math departments around the country. In the fall of 2020, Rutgers' findings were released in a series of six briefs and an executive summary under the heading *Preparing Math Majors for Careers*.[3]

In 2021, TPSE again contracted with EERC to study the recruitment and admission processes of both master's and doctoral programs in math, and how those programs support their students. In addition, TPSE returned to its initial interest in non-academic math careers, asking EERC to further investigate the career preparation and advising strategies that had emerged in the first study. These strategies included career advising, curriculum and learning opportunities, mentoring, internships/externships, research opportunities, and faculty development. The following is a report of EERC's findings from research conducted in response to those inquiries.

The report begins with a brief description of our methodology followed by a profile of the study sample. We then discuss a range of topics including recruitment and admissions; student advising; student interaction and support; and career advising and preparation. Next, we focus on faculty by exploring their knowledge of and experience in industry. This is followed by a discussion of the career pathways faculty traditionally encourage and of the employment sectors entered by recent graduates. We then turn to completed or planned faculty development activities focused on non-academic career pathways. The paper concludes with a summary of plans to further develop program capacity to prepare students for non-academic careers, followed by some suggestions for future TPSE activities.

METHODOLOGY

In collaboration with TPSE leadership, EERC designed the current study to include both an online survey and Zoom-facilitated interviews.

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[1] TPSE (n.d). *About*. https://www.tpsemath.org/about

[2] Ibid.

[3] The six briefs in the series are: *Working with Alumni*; *Revising Curriculum*; *Advising Strategies and Practices*; *Professional Development for Faculty and Staff*; *Practices and Polices for Career Readiness*; and *Partnering with Industry*. The briefs are available at https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

Online Surveys

Based on the findings from the 2020 TPSE-Rutgers study and current study goals, EERC developed an online survey for department chairs or graduate program directors of both terminal master's and doctoral programs across the country. The survey included both open and closed-ended questions and asked respondents to share current strategies in the areas identified above. We also asked respondents to indicate whether they would be available for an interview.

In mid-spring 2021, the survey was sent to TPSE's Mathematics Advisory Group and its affiliate list of four-year institutions with either a terminal master's or a doctoral program in math. This resulted in a pool of 381 potential respondents from 217 institutions. The initial survey distribution was followed by two more. Prior to each distribution, TPSE leadership sent a letter alerting the department chair or program director of the forthcoming survey. Seventeen completed surveys were received from separate master's programs. Because seven doctoral programs submitted more than one survey (e.g., the department chair, the director of graduate studies, and/or the faculty adviser completed a survey), 53 completed surveys were received from among 46 doctoral programs. In these five cases, we opted to use the survey that was most complete (e.g., included the most data-rich responses to open-ended questions).

The master's and doctoral surveys were analyzed separately to identify themes and patterns within and across the questions. In the report that follows, we will summarize and discuss the emergent themes and patterns, indicating any differences between degree-level programs.

Interviews

Five heads of terminal-master's programs and 13 heads of doctoral programs indicated a willingness to be interviewed via Zoom. The EERC team reviewed the individual surveys for these 18 individuals to identify innovative strategies or program activities, or programs which included diverse activities. Invitations for interviews were then sent out to 12 graduate program directors/department chairs, 9 of whom responded to our request.

The EERC team developed a general interview protocol that was then honed to follow up on specific items from each institution's survey. In the end, we interviewed two graduate program directors/department chairs from terminal master's programs and seven graduate program directors/department chairs from doctoral programs. With verbal consent, all calls were recorded, and an electronic transcript was created. These transcripts as well as notes taken during the calls were analyzed for themes and patterns. This report draws from our analysis of these nine interviews, providing further depth and texture to the themes and patterns that emerged from the survey responses.

SAMPLE

We received a total of 53 surveys from doctoral programs and 17 from master's programs for a return rate of 18%. After elimination of institutional duplicates, the final sample included 17 master's-level and 46 doctoral-level programs. These included two doctoral programs which did not provide any identifying information but still completed most of the survey.

The sample included public and private institutions located within 30 US states and 2 Canadian provinces. They included both Research I and Research II institutions. (See Table 1 and Appendix A for the breakdown by state). About three-quarters (76%) of terminal master's programs were located within public colleges. The proportion of doctoral programs located in public colleges was slightly lower (70%) but still represented the vast majority of responses.

Table 1: Survey Responses by Type of Institution & Degree Level

	Public	**Private**	**Unidentifiable**	**TOTAL**
Terminal master's programs.	13	4	0	17
Doctoral programs.	31	13	2	46
TOTAL	**44**	**17**	**2**	**63**

The online survey did not request information about the location and focus of the institution's graduate math department or program. Therefore, we have information about the institutional location of only two master's and seven doctoral programs. One was an applied math program located in a school of engineering. Several were located with an institution's school of arts and science. Further, several institutions had combined departments for math and statistics. In a few cases, the institution had separated their math and statistics departments. In addition, some graduate programs were described as having a pure math or applied math focus, and a few were described as a mix. There is no doubt that the above differences shaped faculty knowledge of non-academic career pathways as well as the types of programs and activities their respective departments offered to graduate students. This is an area for further study.

The survey respondents and the interview informants were a mix of department chairs and directors of graduate programs. Across master's survey respondents there were 12 chairs or program heads/directors and 5 directors or coordinators of graduate studies. Across the doctoral programs there were 12 department chairs/heads and 29 graduate studies directors/coordinators, plus 1 graduate adviser and 2 respondents who identified themselves as professors. To simplify the language in the report, we will refer to those who returned surveys as respondents and those we spoke with as interviewees or informants.

FINDINGS

Recruitment Strategies

A wide cross-section of both master's and doctoral program respondents viewed their departmental website as their principal recruitment mechanism. Other significant mechanisms for recruitments across both groups included their institution's undergraduate advisers and their institution's website.

Survey respondents from master's programs indicated that they frequently recruited directly from their undergraduate programs and from their local regions. In contrast, doctoral programs often recruited prospective students at math-focused regional, national, and international conferences. Table 2 shows the mean of the rank ordering of the recruitment strategies used by both doctoral and master's programs as reported by survey respondents.

Table 2: Principal Strategies Used to Recruit Students into Master's- and Doctoral-Level Math Programs*

	Master's (n=17)	*Doctoral (n=46)*
Choice	***Mean***	***Mean***
Departmental website.	2.33	1.50
National math conferences.	7.40	5.23
Undergraduate advisers at our college.	2.73	5.32
College website.	3.73	5.30
Math conferences/organizations focused on diversity and equity.#	6.60	6.34
Regional math conferences.	5.53	6.05
Departmental social media, e.g., Facebook page.	5.27	6.82
Outreach to Hispanic serving institutions and/or HBCUs.	6.53	7.20
Other, specify:	9.20	7.84
Math association newsletters.	7.00	7.86
International math conferences.	9.67	8.18
Other, specify:	12.00	10.93
Other, specify:		12.43

* Respondents were asked to rank order the most effective recruitment strategies (1=most frequent).

These include Latinx and Hispanics in the Mathematical Sciences (LATHISMS); Society for Advancement of Chicanos and Native Americans in Science (SACNAS); National Association of Mathematicians (NAM)

Interview informants from both master's and doctoral degree programs stated that the Covid-19 pandemic reshaped their recruitment activities. No longer able to attend conferences or invite prospective students to visit their campus, colleges turned to digital promotional tools such as websites and email communication to recruit prospective students.

While some programs indicated that they struggled with recruitment during the pandemic, others saw the pandemic bringing some benefits. One doctoral program informant noted that, "*we just saw a large increase in applicants because the job market just had these jolts.*" And a master's program informant indicated that her program *"has become much more selective because the sheer number of applications has gone up massively."* These changes underscore that bleak job markets frequently stimulate individuals to seek out further education – both undergraduate and graduate study.[4] In fact, for some individuals, graduate programs may act as a sort of lifeline during times of economic downturn. This suggests that "crises" may help identify new on-ramps to higher and continued education and expanded pathways for students interested in math.

[4] Barrow, L., & Davis, J. (2012). The upside of down: Postsecondary enrollment in the great recession. *Economic Perspectives 36*(4), 117–129.

Some graduate programs, particularly doctoral programs, noted the centrality of personal connections and communication in the recruitment process. One doctoral informant spoke about his intentionality, reporting that he launched personal correspondences with any individual who expressed an interest in applying to his program. He described the value of this process:

> *[It] is somewhat labor intensive, but it's much better than the administrative staff sending a form letter saying 'Thank you for your interest in our graduate program.' That just doesn't work. You really have to reach out. … I've tried to dissuade people of this statement: 'We don't get good applications.' Well, have we tried to get applications and actually gone out and sought them? We can't just sit back and wait for them to show up.*

He went on to underscore the need to treat graduate student recruitment the same way as faculty recruitment – by proactively looking for people that would be a good fit for the program and who would add value to the department.

During the pandemic, some programs remotely attended math conferences (e.g., Math Alliance) to recruit new students. However, informants observed that remote formats reduced their ability to develop personal connections with potential students. One informant reflected that when it came to recruiting, online math conferences were not

> *…as successful as the in-person events. I think students are afraid to come visit your virtual table. There were far fewer that participated in that format. It's just harder to have informal conversations with students if they just drop into your space on Zoom… It might be difficult especially for underrepresented groups, because when they do come here [to visit the campus], we try to get them to interact with students from similar backgrounds who are already here."*

Other informants spoke about how the pandemic impacted their ability to recruit and admit international students.

In contrast, some programs—particularly those in more remote locations—found the online formats of math conferences actually boosted their recruitment efforts. The remote format allowed them to come in contact with students who normally would not consider or even hear about their program. This new ability to connect made these programs feel as though they might be on a more level playing field with larger and more established graduate math programs. A doctoral program coordinator at a more remote school stated, *"we've had an opportunity to engage with students in the same way as other schools in large conferences. Our remote location used to hurt us."* This informant also noted that the online format of conferences may be more equitable for both programs and students, especially students who normally would not have the resources to travel to an academic conference.

These pandemic-fueled online and remote conference environments also increased the geographic range from which colleges recruited. An informant who directs a master's program indicated that, *"before, we would typically get students from small liberal arts colleges within 100 miles; now we're getting students from all over, [allowing us to] craft the class a little more selectively."* The greater reach for some master's programs fostered a more diverse student body in terms of geographic representation and the number of undergraduate programs from which students come.

Admissions

Critical factors weighed for student admissions

Survey respondents indicated that previous math coursework was the most important factor in their decision to admit a student into their master's or doctoral programs. Unsurprisingly, doctoral programs weighed research experience more heavily than master's programs. At the same time, while doctoral programs considered overall undergraduate GPAs, master's programs emphasized that factor more heavily. Other factors that had considerable weight in admission decisions were diversity, letters of recommendation, and test scores. Table 3 presents the different factors considered by master's and doctoral programs and the four factors that weigh most heavily in admissions decisions at each level.

*Table 3: The Factors that Weigh Most Heavily in Determining Admission into Master's- and Doctoral-Level Math Programs**

Master's			Doctoral		
Answer	**Percent**	**Count**	**Answer**	**Percent**	**Count**
Previous math course work.	25.0%	17	Previous math course work.	25.0%	46
Overall college GPA.	20.69%	14	Research experience.	19.0%	35
Other, specify:	13.2%	9	Overall college GPA.	13.6%	25
Undergraduate student at your institution.	7.4%	5	Area of study.	9.2%	17
Other, specify:	5.9%	4	Other, specify:	9.2%	17
Research experience.	5.9%	4	Diversity--race/ethnicity, gender, sexual orientation, social class, disability, etc.	8.3%	15
Test scores (e.g., GRE).	4.4%	3	Test scores (e.g., GRE).	7.6%	14
Diversity.	4.4%	3	Essay.	4.5%	8
Essay.	4.4%	3	Internships/externships.	1.6%	3
Area of study.	2.9%	2	Other, specify:	1.1%	2
International.	2.9%	2	Interview.	1.2%	2
Financial independence, i.e., student does not need financial aid.	1.5%	1	Financial independence, i.e., student does not need financial aid.	0.0%	0
Other, specify:	1.5%	1	International.	0.0%	0
Employment/work experience.	0.0%	0	Employment/work experience.	0.0%	0
Internships/externships.	0.0%	0	Undergraduate student at your institution.	0.0%	0
Other, specify:	0.0%	0	Other, specify:	0.0%	0
Interview.	0.0%	0			
TOTAL	**100%**	**68**	**TOTAL**	**100%**	**184**

*Respondents were asked to select four.

Given the historic importance of standardized exams in college and graduate admissions, we look more closely at their use below.

Use of Standardized Exams

About 60% of master's program respondents indicated they had already or had plans to soon drop the use of standardized exams in their admissions decisions. Instead, these programs were planning to rely on transcripts and letters of recommendation. Even among master's programs that planned to continue to use the GRE in their admissions decisions, GRE scores were not a heavily weighted factor when considering an applicant for admission.

In contrast to the master's programs, a majority (over 55%) of doctoral program respondents reported that their department planned to continue using the GRE, GRE Math Subject Test, or other standardized exams in their admissions decisions. However, during most doctoral programs' decision-making process, GRE scores were not a heavily weighted factor.

Even among the doctoral programs that planned to continue using GRE exams were some that questioned the exam's predictive accuracy; however, they saw the act of taking the exam as evidence that a given student was truly committed to pursuing mathematics at the graduate level.

In our interviews and on the surveys, we learned that a program's decision to discontinue use of standardized exams was the result of various factors. Some programs indicated that the decision was an equity issue; discontinuing use of the exam was part of an effort to prevent the skewing of the admission process toward historic "majority" populations. One doctoral respondent spoke to the "*known biases in the exam [that] prevent a diverse applicant pool.*" Instead, she commented, her program chose to *"put more weight in reviewing personal statements and brief video interviews."*

Other respondents wrote on their surveys that GRE scores were simply not effective indicators of preparation for (and performance in) their doctoral programs. In fact, one doctoral respondent wrote on the survey, "*GREs never really seemed that useful. Students with high GREs usually (but not always) did well, but lower scores did not tell us anything about who would succeed and who would not."*

Table 4 summarizes the breakdown of doctoral programs' plans to continue the use of standardized exams in their admissions decision-making process.

Table 4: Plans to Use National/Standard Exams for Admission Decisions in the Post-Covid Era Among Math Doctoral Programs (n=45)

Choice	Frequency	Percent
Yes	25	55.6%
No	20	44.4%
TOTAL	**45**	**100%**

Several respondents, a majority of them from PhD programs, highlighted the need for international students to successfully take the Test of English as a Foreign Language (TOEFL) and saw it as a separate issue from use of the GRE in admissions decisions. One doctoral program director, for example, commented, *"most of our [financial] support is teaching assistant support, so we're very leery about putting people in the classroom if their English skills are not documented."*

Financial Aid

Survey results indicate a clear difference in the availability of financial aid for graduate students enrolled in master's and doctoral programs. All doctoral programs indicate the availability of some even if limited, financial aid. In most cases, this funding was provided through teaching assistantships, (n=38 or 83%). In fact, departments frequently made decisions about the number of doctoral students to admit based on the number of teaching assistantships they could support. One informant stated, *"We don't want anyone competing for funding. Anyone we admit, we plan to fund."*

Moreover, about 72% of doctoral programs surveyed provided specific incentives, supports, or actions to increase diversity in their student bodies. These primarily included scholarships and fellowships targeted toward equity populations, though these funding lines existed primarily at the college level rather than at the departmental level. Other reported financial supports included summer stipends, payment for teaching seminars, and involvement in mentor programs. One doctoral program indicated they had leveraged their Association for Women in Mathematics chapter to support and mentor their women students.

Table 5: *Does your department or the college have financial aid for doctoral level students?*

Answer	Frequency	Percent
Yes, primarily teaching assistantships.	38	82.6%
Yes, fairly generous departmental and/or college-based financial resources.	4	8.7%
Other, specify:	3	6.5%
Yes, but very limited departmental and/or college-based financial resources.	1	2.2%
No departmental or college-based financial aid--only student loans.	0	0.0%
TOTAL	**46**	**100%**

In contrast to PhD programs, financial aid at the master's level seems to be weak. A majority of respondents from master's programs reported their department provided either very limited or no financial support to their students. As a result, student loans seemed to the be the primary way master's students were "supported" in math departments. This is not surprising given the scarce opportunities for research and teaching at this level. However, the lack of such support may be a factor in equity gaps at this level.[5]

Strategies to Enhance Diversity in Admissions and Enrollment

Interviews and survey responses uncovered a substantial difference in the level of attention master's and doctoral programs have given to expanding the diversity of their enrolled students. Close to 90% of responding master's programs indicated that they generally do not provide specific incentives, supports, or actions to increase diversity in their student bodies. Further, the programs that did have diversity incentives or strategies indicated they were provided through their institutions' graduate school rather than by the math department itself.

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[5] Espinosa, L. L., Turk, J. M., Taylor, M. & Chessman, H.M. (2019). Race and ethnicity in higher education: A Status report. https://1xfsu31b52d33idlp13twtos-wpengine.netdna-ssl.com/wp-content/uploads/2019/02/Race-and-Ethnicity-in-Higher-Education.pdf
Allum, J., Kirby, S.N., Sowell, R., & Gonzales, L. (2013). Completion and attrition in STEM master's programs: Pilot study findings. Council of Graduate Schools.
https://cgsnet.org/sites/default/files/Completion_and_Attrition_in_STEM_Masters_Programs_2013.pdf.

One master's-level informant noted that her college has some scholarships specifically available to African American students, for example.

At the same time, both master's-level interviewees stated that active faculty outreach and targeted recruitment have been used to enhance diversity. One informant stated, "*Most of our graduate recruitment is through faculty personal connections…[We] have contacts at places like Spellman [so] we can get students from HBCUs. We also have faculty who are explicitly interested that we recruit students from their groups.*" The other master's informant indicated that her college's success in assembling a diverse student body, including women and international students, was the result of the program's high concentration of women and international faculty who were actively involved in recruitment. Of course, one wonders about the history of such hiring practices, and the campus culture which promoted it how much campus culture is now able to impact student recruitment.

In terms of campus culture, which can impact student experience and success, one of the master's program informants indicated that her math department is currently working within a university-sponsored framework to encourage more diversity, equity, and inclusion (DEI). One of the examples she offered was the establishment of an "*anti-racist book club among the faculty.*" Two of the books read thus far are *White Fragility*[6] and *Caste.*[7]

Doctoral programs reported using a variety of strategies and initiatives to enhance diversity. Many informants from PhD programs described an intentional diversity strategy intended to spark a "*cumulative effect*." Increased diversity among their students, they reasoned, fostered their capacity to have students themselves act as advocates and validators of their respective programs. Using their social networks, these students could encourage more applicants from underrepresented populations, including women and historically underserved students. But as one doctoral informant observed, "*Part of this is getting a critical mass of people. Once you have a critical mass of women in your department, women find this to be an attractive place to apply.*"

Informants emphasized the importance of recruiting *groups* of underrepresented students rather than just one or two. The more students of similar backgrounds or identities, the easier it was for students to have access to peer support and a sense of community. An informant from a school that has established targeted fellowships for underrepresented minorities described the reason for offering more than just a handful of these fellowships: "*The argument for making that many fellowships is that we need to create a community. We don't want to just bring them in and then they feel isolated.*" Other doctoral programs also indicated that fellowships and scholarships targeted toward women and historically underrepresented groups and awarded at either at the departmental or college level were part of their institution's strategies to increase diversity.

Respondents also shared that their programs sponsor various events that target women and historically underrepresented groups. These events in turn provided opportunities to recruit participants into their programs. One respondent wrote:

[6] DiAngelo, R. (2018). *White Fragility*. Beacon Press.
[7] Wilkerson, I. (2020). *Caste*. Random House.

> *We hold a Sneak Peek event every November for prospective applicants from underrepresented minorities to visit our department, learn about graduate studies here, etc. Pretty much the same activities as our March recruiting event for admitted PhD students. Participation in Sneak Peek doesn't require applicants to formally apply to grad school; they just have to have potential interest.*

Another program hosts a large annual conference for undergraduate women in mathematics. This conference *"brings our department to the attention of many women, and probably contributes to why we get so many women to apply to our department."* Of note, the gender ratio in this specific doctoral program is about an even 50/50 split.

In addition to individual departments organizing their own events, survey respondents and interview informants indicated that national math conferences and math networks (e.g., Math Alliance, Joint Mathematics Meetings, Society for Advancement of Chicanos/Hispanics and Native Americans in Science, and Field of Dreams) provided opportunities to recruit students. Respondents from a number of departments also mentioned establishing relationships with HBCUs and HSIs by getting to know specific undergraduate math faculty at these institutions. In some cases, faculty alumni from such institutions have created important bridges for recruitment. In addition, several informants indicated that some HBCU and HSI institutions have established "bridge" programs that both foster and facilitate recruitment and student transition into their graduate programs.

Surveys indicated that for some doctoral programs, diversity recruitment was an embedded aspect of their application review process. One informant described how this worked at his institution:

> *[Our] strategies have generally focused on diverse, successful recruiting from the pool that apply, not on changing the pool. Those strategies include careful reading of files to identify diverse candidates who will thrive in our program; admission early in the season; fellowship offers; [and] extensive follow up from program leadership, faculty and students after offer is sent.*

Other programs similarly indicated that their diversity strategies were *"more on the back end"* or centered around ensuring underrepresented minorities were "*given full consideration"* through an intensive application review process.

General Advising & Support

Who? When?

At both the master's and doctoral levels, most programs surveyed indicated that departmental faculty served as students' primary advisers. While the majority of programs at both degree levels assigned students to an adviser during the first week of classes, there was more variation among respondents in master's programs (Table 6).

Table 6: In General, When Are Math Master's Students Assigned to a Faculty Adviser?

Choice	Frequency	Percent
First week of classes.	5	29.4%
At admission.	4	23.5%
During first semester.	3	17.7%
When student begins master's thesis.	2	11.8%
Graduate director advises until they choose a thesis adviser.	2	11.8%
Second year of program.	1	5.9%
TOTAL	**17**	**100%**

A clear majority of master's programs (70%) required students to meet with their faculty adviser once a semester. Only about one-third of master's programs lacked such a requirement.

At the doctoral level, the adviser assigned during the first week of class was typically a "preliminary" or "pre-candidacy" adviser who could assist with course selection and orientation to the program. The choice of that adviser was usually made by the graduate program director, typically based on the information students provided on their application or during the admissions process. However, one informant indicated that applicants were specifically asked whether there was a particular faculty member with whom the student wanted to work. This college allowed students to identify up to three members of the faculty to be their preliminary adviser. Once assigned an adviser, most students had the option to change their adviser if the match was not a good one. The majority of interview informants indicated that the director/coordinator of graduate studies typically followed up with students to ensure that their adviser is a good fit. Around 51% of doctoral programs required pre-candidacy students to check in with their adviser at least once a semester.

In general, candidacy/research advisers were selected after students passed their qualifying exams or initiated a research project. However, one informant indicated that her department tried to encourage students to seek out a candidacy/research adviser prior to reaching candidacy:

> *[My department is] encouraging faculty to accept students (at least in a preliminary way) sooner because this is a big stumbling block in mathematics. Students feel (and some of the faculty explicitly say) that you have to pass all the qualifying exams before getting an adviser. So, the students just keep waiting, and this makes the time to degree very long. It's frustrating and encourages drop-out.*

The Focus of Advising

In master's programs, the principal foci of advising are course selection/registration; advising about a research project; and advising about academic and career pathways. A few departments (about 8%) indicated that they also engage in advising about internships/externships (See Table 7.) One program instituted the layered advising approach recommended in a recent report from the National Academies of Sciences, Engineering, and Medicine on STEM mentoring.[8] Under this advising framework, *"we have graduate coordinators overseeing everything, but then we have specific graduate faculty for each [concentration] area."*

Of note, over 70% of master's programs indicated their department did not provide any specific advising on career planning or employment. Table 7 identifies the three primary advising areas survey respondents identified by master's and doctoral degree programs.

Table 7: Primary Focus Areas for Advising Sessions

Master's				Doctoral			
Answer	**Percent of Answers**	**Count**	**Percent of Programs**	**Answer**	**Percent of Answers**	**Count**	**Percent of Programs**
Course selection/registration.	27.5%	14	82.4%	Course selection/registration.	41.4%	41	100.00%
Advising about research project.	11.8%	6	35.3%	Checking in about over all well-being, level of stress, support system.	18.2%	18	43.9%
Academic pathways related career advising.	9.8%	5	29.4%	Advising about research project.	11.1%	11	26.8%
Advising about a master's thesis.	9.8%	5	29.4%	Academic pathways related career advising.	9.1%	9	22.0%
Advising about further study--second master's and/or doctorate.	7.8%	4	23.5%	Advising about specific doctoral programs.	8.1%	8	19.5%
Advising about specific master's programs.	7.8%	4	23.5%	Advising about doctoral thesis.	4.0%	4	9.8%
Checking in about over all well-being, level of stress, support system.	7.8%	4	23.5%	Advising about specific master's programs.	2.0%	2	4.9%
Advising about specific doctoral programs.	3.9%	2	11.8%	Other, specify:	2.0%	2	4.9%
Career advising.	3.9%	2	11.8%	Advising about further study, e.g., second master's and/or doctorate.	1.0%	1	2.4%
Other, specify:	3.9%	2	11.8%	Career advising.	1.0%	1	2.4%
Advising about internships/externships.	3.9%	2	11.8%	Other, specify:	1.0%	1	2.4%
Other, specify:	2.0%	1	5.9%	Advising about internships/externships.	1.0%	1	2.4%
TOTAL	**99.9%#**	**51**		**TOTAL**	**99.9%#**	**99**	
Response Count		**17**		**Response Count**		**41**	

*Respondents were asked to select three. # Not equal to 100% due to rounding.

[8] National Academies of Sciences, Engineering, and Medicine. (2019). *The Science of Effective Mentorship in STEMM*. The National Academies Press. https://doi.org/10.17226/25568

Corresponding to master's programs, the primary focal areas for pre-candidacy doctoral advising were course selection/registration; checking in about overall well-being/level of stress/support system; and advising about a research project. Only about 19% of surveyed programs provided pre-candidacy doctoral advising on career planning or employment. However, this picture changed significantly at the candidacy level. Over 52% of departments indicated they provide career advising for candidacy students. While careers in higher education are the primary focus of post-candidacy advising, careers in the technology industry are not far behind.

In response to TPSE's interest in students' well-being, the survey asked whether and how departments attended to students' stress or other social/emotional issues that may affect their academic success. Survey responses indicated that math departments usually did not provide such support or intervention but instead referred students to campus-based mental health services. Most interview informants stated that faculty advisers in their programs were sensitive to such issues and made themselves available to students who felt stressed or overwhelmed. However, the degree to which students shared what was going on in their lives was largely dependent on the student and the nature of the relationship the student had with their adviser.

Table 8: Resources to Support and Assist Students in Master's- and Doctoral-Level Math Programs Who Are Experiencing Stress and/or Other Social/Emotional Issues*

Master's (n=17)				Doctoral (n=46)			
Answer	**Percent of Answers**	**Count**	**Percent of Programs**	**Answer**	**Percent of Answers**	**Count**	**Percent of Programs**
On-campus counseling center with trained/licensed mental health counselors.	66.7%	16	94.1%	On-campus counseling center with trained/licensed mental health counselors.	65.7%	46	100.0%
Other, specify:	16.7%	4	23.5%	Student peer mentors are assigned to buddy with students.	20.0%	14	30.4%
Student peer mentors are assigned to buddy with students.	8.3%	2	11.8%	List of off-campus mental health counselors.	11.4%	8	17.4%
Do not know of any counseling services/resources.	4.2%	1	5.9%	Other, specify:	2.9%	2	4.4%
List of off-campus mental health counselors.	4.2%	1	5.9%	Do not know of any counseling services/resources.	0.0%	0	0.0%
Other, specify:	0.00%	0	0.00%	Other, specify:	0.00%	0	0.00%
Other, specify:	0.00%	0	0.00%	Other, specify:	0.00%	0	0.00%
TOTAL	**100%**	**24**		**TOTAL**	**100%**	**70**	

*Respondents were asked to indicate all that apply.

Given the added stresses introduced by the Covid pandemic on doctoral teaching assistants (TA), one doctoral program hired undergraduates to help TAs with grading and other administrative tasks. Further, in addition to the availability of faculty advisers and campus mental health services, some math programs established a network of peer mentors to help support and guide students. We turn to these peer mentors below.

Peer Support/Mentors

Relatively few master's programs—only 25%—used peer mentors. Typically, the mentors are more advanced students in the same math program. These mentors orient new students to the campus and provide academic and social support as needed.

One of our master's interview informants described an innovative peer mentoring program that used a "mentor chain" model; it integrated a faculty member, an advanced graduate student, a new graduate student, and an undergraduate student into a singular network of support. The mentor chain established a range of access points for students to get information and/or support. Both informal and more formalized "full-chain meet-ups" assured that students' needs were being addressed:

> *[Mentor chains] are set up so that each ladder is separate, so that way students know where to look. But they are not necessarily linear because we have more students than faculty, so it's sometimes triangular. [. . . In sum, we] just have really caring faculty that really walk the walk.*

Nearly half (49%) of math doctoral programs surveyed provided some kind of peer mentoring program. This is a significantly higher proportion than the 25% reported among master's programs. The peer mentors within doctoral programs tended to be students who had more advanced academic standing. Their primary function was initial campus orientation as well as social support. However, peer mentoring tended to be unstructured or ad hoc, the frequency and intensity of interaction shaped by the relationship between the student and their mentor.

In response to the Covid-19 pandemic, one interviewee's doctoral program established "graduate student pods" as a system to help students cope with the academic and social challenges associated with the pandemic. These pods were facilitated through scheduled Zoom meetings, student interactions outside of class, and research:

> *They would meet weekly on Zoom to talk about things that were not math related. To just meet and build some community and social structure. For students who had family in town, they had that support. For the students who didn't have that, they lost all that structure.*

Mathematics-related Networks/Associations

Campus-Based

Some master's and doctoral programs established graduate student committees in their department. Students elected to these committees helped coordinate social events and facilitate relationships and student support. Some survey respondents also reported the existence of affinity groups within their department or across their campus that were based on research interests, gender, career interests, or international status.

At the master's level, 90% of respondents indicated their programs did not have a departmental math club. But a few master's programs reported affinity-like groups based on students' research interests or international status. Some master's-level respondents also indicated their programs were committed to building a departmental community. As such, their departments sponsored events such as social/recreational activities, career/employment information sessions, and sessions about student research activities. Informants from both master's and doctoral programs emphasized, however, that community-building initiatives, whether a club or social event, needed to be organic and student-driven, or there would not be significant student interest or participation.

Across doctoral programs, a key to building community was the establishment of graduate seminars. Graduate students frequently were the organizers of such seminars, and some were designed for students only such that no faculty could attend. In discussing these students-only seminars, one informant commented that students "*want a place that is just for them where there's no faculty judgment.*" Typically, graduate seminars focused on students' research projects, but one respondent from a doctoral program noted that their students also used their seminars to host job talks and industry panels.

External Associations/Campus Chapters

About 41% of doctoral programs surveyed had some kind of on-campus doctoral student math club/organization, such as chapters of the American Mathematical Society, the American Statistical Association, the Society for Industrial and Applied Mathematics, or the Association for Women in Mathematics. The activities or functions sponsored by these organizations principally involved social/recreational events, workshops/panel sessions about current student research activities, and sessions about career/employment information. Some of these organizations also sponsored workshops on tech skills such as Python. Most of the activities associated with these chapters, however, focused on industry projects or internships.

Social Networking Among Students

One of the interests of TPSE was to learn about the level of interaction and community experienced by master's and doctoral students. While the EERC survey did not involve students, 80% of respondents from doctoral programs and 60% of respondents from master's programs reported that "*there was a very close and interactive group*" among their students. Asked what factors contributed to this strong sense of community, respondents and informants stated that regularly scheduled social events such as game nights, barbeques, picnics, soda socials, and holiday parties encouraged interaction among graduate students. Of note was that many programs worked hard to continue such events remotely via virtual formats during the Covid pandemic.

One informant discussed how the simple act of assigning multiple graduate students to the same office encouraged community among the student body:

> *It helps to put graduate teaching assistant cohorts in the same office. . . . With any kind of adverse or challenging situation, if you have a group of people that you can trust, it really helps strengthen that bond very quickly. That physical proximity is very important.*

Informants also shared that student-faculty collaborative research projects helped build community. However, such collaborative opportunities were generally dependent on grant funding. According to one informant from an applied math doctoral program, faculty in their department, *"have been super great at getting grants that can support multiple students. So those students do end up working together on research, but that is a really small minority of the students."*

Career/Occupational Advising & Preparation

A major interest of TPSE was learning about the degree to which both master's and doctoral programs prepared students to be successfully employed outside the academy. To that end, EERC's survey included a series of questions about job preparation and the pathways faculty encouraged students to pursue. The next sections discuss our findings on those topics.

Given significant differences in career and employment opportunities for individuals who earn master's-level versus doctoral-level degrees,[9] we separately discuss career advising and preparation by degree level. For each level, we set the context by indicating what the survey respondents reported about their program faculty's knowledge of or experience with non-academic careers. This is followed by the strategies and activities respondents' departments used to prepare their students for work outside the academy. We then look at the career pathways faculty encouraged students to explore and compare these with the employment patterns of graduating students reported by respondents.

Terminal Master's Programs

Faculty knowledge about non-academic careers: We asked survey respondents if the faculty in their departments were knowledgeable about industries and careers outside of academia. Out of 17 master's respondents, 11 (65%) said yes, 3 (18%) said no, and 3 (18%) did not know. A few survey respondents reported that their applied mathematics, statistics, and even some of their pure math faculty had the industry background necessary to advise students about non-academic careers. Some had worked or were working in *"real jobs"* outside academia. Of those, some worked in industry and some were industry consultants.

[9] Carnevale, A. P., Rose, S. J., & Cheah, B. (2011). *The college payoff: Education, occupations, lifetime earnings.* Georgetown University Center on Education and the Workforce. https://repository.library.georgetown.edu/bitstream/handle/10822/559300/collegepayoff-complete.pdf?sequence=1&isAllowed=y

We then asked survey respondents two related, but somewhat different questions – what, if any, ***activities*** their program sponsored or hosted to prepare students for employment, and what faculty ***do*** to help students prepare.

Departmental activities to prepare students for employment (Table 9). Nearly three-quarters of master's program respondents indicated their department provided research experiences (n=12; 71%). Fewer hosted presentations or seminars on careers (n=8; 47%) or sponsored internships (n=7; 13.5%). Only five (29%) indicated that their programs helped prepare students through collaborations with industry partners or non-profits or through curriculum content such as hands-on learning by solving real-world problems.

Table 9: What Activities Does Your Department Sponsor or Host to Prepare Master's Students for Employment?*

Answer	Percent of Answers	Count	Percent of Programs
Research experiences.	23.1%	12	80.0%
Presentations/seminars, etc.	15.4%	8	53.3%
Internships.	13.5%	7	46.7%
Work on problems with non-profits.	9.6%	5	33.3%
Hands-on learning/real-world problem-solving.	9.6%	5	33.3%
Work on problems with industry partners.	9.6%	5	33.3%
Partnerships with employers/industry.	7.7%	4	26.7%
Inter-departmental partnerships.	7.7%	4	26.7%
Externships (short-term shadowing).	1.9%	1	6.7%
Other, specify:	1.9%	1	6.7%
Other, specify:	0.0%	0	0.0%
TOTAL	**100%**	**52**	
Response Count		**15**	

*Respondents were asked to indicate all that apply.

Faculty strategies to prepare students. Table 10 shows the responses to the related question, "What do faculty do to prepare students for jobs outside the academy?" There was some repetition of options with some minor variability in responses (e.g., the number who checked off externships). The most common strategy was requiring students to take courses in statistics or computer programming (n=9; 56%). Another relatively common strategy was to use curriculum to both inform students about non-academic jobs (n=6; 38%) as well as to give them real-world problems to work through (n=5; 31%).

About a third of respondents (n=5; 31%) indicated their programs connected students with local employers, and only three (19%) reported their programs connected students with employers for the purpose of an externship. Of note, respondents from only five programs (31%) indicated the use of career panels or even the use of career boards, with only one respondent commenting that their program invited industry speakers to campus. In thinking about these findings, it is important to recognize that the EERC survey was focused on the math department, so it is conceivable that additional career-related activity happened but was centralized in a campus-wide career office.

Table 10: What Do Faculty Do to Prepare Master's Students for Jobs Outside the Academy?*
N=16

	Count	Percent Of Choices	Percent of Programs
Require statistics and/or computer programming.	9	19.6%	56.35%
Integrate curriculum content on non-academic jobs in math.	6	13.0%	37.5%
Connect students with local employers.	5	10.9%	31.3%
Assign real-world problems in courses.	5	10.9%	31.3%
Sponsor career panels.	5	10.9%	31.3%
Set them up with externships.	3	6.5%	18.8%
Set them up with local employers to work on a project.	3	6.5%	18.8%
Establish a jobs' board.	2	4.4%	12.5%
Always have employers as part of the advisory board advising on curriculum.	2	4.4%	12.5%
Other, specify:			
▪ *CAMCOS projects.*	1	2.2%	6.3%
▪ *Invite industry speakers.*	1	2.2%	6.3%
▪ *Informal advising.*	1	2.2%	6.3%
I do not know.	3	6.5%	18.9%
TOTAL	**46**	**100%**	

*Respondents were asked to indicate all that apply.

One of the two master's program directors we interviewed reflected on the use of curriculum to prepare students for non-academic employment:

> *I think one of the things we don't do well enough is that, when our students are looking for jobs, employers will ask them what they've done. They'll typically respond by saying, "well, I can write wonderful proofs." That's great if they are applying for a PhD program, but it doesn't really help them get jobs in industry and other places. This is really my opinion, but many of my colleagues agree that we need a lot more emphasis on computational math in all of our courses.*

The same program director went on to add the following:

> *We need to move into the twenty-first century, and that's going to mean making some changes. I think math people have a difficult time staying up to date with the technology. We definitely use the technology but asking us to change the way we teach in a major way—we respond very slowly.*

One survey respondent mentioned that undergraduates and graduate students can enroll in a Preparation for Industrial Careers in Mathematical Sciences (PIC) math class.[10] Another interview informant spoke to us about their program's increasing use of experiential learning. While some of these classes are not specifically math classes, they give students an opportunity to *"work with faculty on local issues."* For example, *"students work with faculty on local issues like flooding . . . [or] with local cities to look at the data."* This informant believed experiential learning was *"something we need to do more of."* It may be worth nothing that this informant works at a college that values such work within its *"tenure promotion policies."*

Research opportunities. Given the much shorter period of master's studies compared with doctoral work, research opportunities may be more difficult to establish at the master's level. However, 80% (n=12) indicated they offered some type of research experience, "*as a culminating experience*." Many times, this opportunity was related to a required master's thesis. A few survey respondents indicated that funded faculty members sometimes offered research experiences to their students. At one college, "*courses include (research) projects which are sometimes in collaboration with industry or non-profit partners."* A respondent from another college reported that their Center for Applied Math, Computation, and Statistics gave students a chance to engage in research with industry partners.

Internships and externships. Internships and externships frequently provided students with rich opportunities to both apply new knowledge and skills as well as to learn new ones in a real-world setting. Internships were available at 7 of the 17 surveyed master's programs. Three programs also offered externships. One survey respondent wrote, "*We advertise many internships, and many students successfully do them."* Another respondent wrote, *"We have an internship committee that coordinates activities with industry partners. We . . . encourage internships facilitated by alumni contacts."*

An interview informant noted that data science students at his college often participated in internships. Further, students in his department had the ability to develop internships in conjunction with their master's math project course. Of note, the other master's program informant spoke about internships his department offered some of their international students specifically to help them fulfill certain visa requirements. This program also provided non-international students with internship opportunities at regional banks.

Industry Partnerships. In addition to research and internship opportunities, a few respondents noted that career preparation in their department came in the form of industry partnerships. In some programs, industry partners participated on advisory boards, gave classroom presentations, or sat on career panels. However, these practices did not seem to be widespread.

Funding support. Funding can make a real difference in supporting students as they prepare for employment. Yet, only about one-quarter of the 17 master's survey respondents reported

[10] PIC programs were developed by the Mathematical Association of America and the Society of Industrial and Applied Mathematics and funded by the National Science Foundation and the National Security Agency. For more information, see https://www.maa.org/programs-and-communities/professional-development/pic-math

their program received any funding related to preparing students for industry-related jobs or even academic jobs.

Table 11: Does Your Department Receive Federal or Foundation Grants to Help Master's Students Succeed and Prepare for Work?* n=17

	Count	Percent of Programs
No	13	76.0%
Yes, grants related to academic careers	2	11.7%
Yesgrants related to business, industry, or government careers	1	5.8%
Yes, other. Specify:		11.7%
▪ *Bridge to PhD programs*	1	
▪ *NOYCE, but those students are technically housed in education*	1	
TOTAL	**18**	

* Respondents were asked to indicate all that apply.

We now turn to doctoral programs.

Doctoral Programs

Faculty knowledge about non-academic careers. Over 70% of doctoral program survey respondents (31) indicated that their faculty were knowledgeable about math careers outside the academy. Just under 20% (9) indicated that their faculty were not knowledgeable about careers in math outside of academia. Nine% (4) indicated they did not know about faculty knowledge. Both survey respondents and interviewees observed real differences in the level of knowledge and experience about government and industry-related careers by the field of math specialization. Pure and theoretical math faculty tended to know far less than those involved in applied math or statistics: *"Most of our faculty is focused on pure mathematics. We do have a few exceptions. One of our faculty members has his own institute in applied mathematics and computer science."* Interview respondents also observed that older faculty tend to have less knowledge and experiences. Many are focused on help their students succeed in academic career pathways. In contrast, younger faculty often have experiences outside of academia research. Many more are open to non-academic math fields and pathways. *"The younger faculty definitely embrace that there are a lot newer (sic) opportunity out there. So, it's up to us older folks to really embrace those opportunities as well. It has really exploded now with things like machine learning, data analytics and the "data science" craze."*

Colleges are also "*…definitely making hiring decisions based on where we see the needs of students and these larger shifts.*

In terms of industry experience, interviewees spoke of faculty who had worked or consulted with Microsoft, the insurance industry, financial service companies, Bell Labs, and the US Department of Defense. One former department chair, a typologist, has worked summers with the National Security Agency.

Departmental activities to prepare students for employment (Table 12). Almost all doctoral program survey respondents (n=36; 80%) indicated their department offers presentations or seminars to help prepare graduate students for employment. Two survey respondents wrote that they hold job search seminars. One wrote that they have an industrial boot camp. Another wrote that they connect their students to the Erdos Institute,[11] a service that helps PhDs locate jobs. Several wrote that they try to connect their current students with alumni who have "*left academia*." In fact, several survey respondents indicated the use of alumni to help students better understand and link to jobs outside the academy. The value of working with alumni was also identified in EERC's earlier work with TPSE.[12]

Table 12: What Activities Does Your Department Sponsor or Host to Prepare Doctoral Students for Employment? * n=45

Answer	Percent of Answers	Count	Percent of Programs
Presentations/seminars, etc.	27.9%	36	80.0%
Research experiences.	23.4%	30	66.7%
Internships.	16.3%	21	46.7%
Work on problems with industry partners.	9.3%	12	26.7%
Other, specify:	6.2%	8	17.8%
Inter-departmental partnerships.	6.2%	8	17.8%
Hands-on learning/real-world problem-solving.	5.4%	7	15.6%
Partnerships with employers/industry.	4.7%	6	13.3%
Work on problems with non-profits.	0.8%	1	2.2%
Externships (short-term shadowing).	0.0%	0	0.0%
Other, specify:	0.0%	0	0.0%
TOTAL	**100%**	**129**	

*Respondents were asked to indicate all that apply.

Faculty strategies to prepare students (Table 13). In response to a question of what faculty do to prepare students for non-academic jobs, close to 20% of respondents stated they did not know. This gave us pause. Further, we noted some inconsistencies in respondents' answers to the questions about departmental activities and what actions faculty take. For example, no doctoral-program respondent included "externships" under departmental activity, but nine cited externships as things that faculty do. It is unclear if this means that externships are solely established by individual faculty members and are not the departmental, or if there is another reason for such different answers to the two questions.

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[11] See https://www.erdosinstitute.org/

[12] Edwards, R., McKay, H., & Michael, S. (2020). *Working with Alumni*. Rutgers University, Education and Employment Research Center. https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

Given the absence of data about the primary focus of each of the doctoral programs that responded to the survey (i.e., which focused more on pure math, applied math, statistics, data science or some mix), it is unclear to what extent the answers in Tables 12 and 13 track with applied programs or include a mix of program types.

About a third of respondents (n=13; 30%) indicated their doctoral programs sponsor career panels, but only two indicated they sponsor jobs boards. In the comments section for this question on the survey, several respondents indicated that their program offered jobs workshops to help students. Two also cited the use of Erdos Institute to help students locate employment.

As already observed with regard to master's programs, there is a significant absence of career-related services within doctoral departments despite the above activities. Again, it is not known if other campus offices are, in fact, offering employment-related information and guidance to graduate students.

Table 13: What Do Faculty Do to Prepare Doctoral Students for Jobs Outside the Academy?*
n=44

Answer	Percent of Answers	Count	Percent of Programs
Sponsor career panels.	16.1%	13	29.6%
Require statistics and/or computer programming.	14.8%	12	27.3%
Connect students with local employers.	13.6%	11	25.0%
Other, specify:	11.1%	9	20.5%
Set them up with externships.	11.1%	9	20.5%
Set them up with local employers to work on a project.	9.9%	8	18.2%
I do not know.	9.9%	8	18.2%
Assign real-world problems in courses.	4.9%	4	9.1%
Integrate curriculum content on non-academic jobs in math.	4.9%	4	9.1%
Establish a jobs board.	2.5%	2	4.65%
Always have employers as part of the advisory board advising on curriculum.	1.2%	1	2.3%
Other, specify:	0.0%	0	0.00%
TOTAL	**100%**	**81**	

*Respondents were asked to indicate all that apply

Curriculum. Over one-quarter (27%) of respondents indicated their doctoral programs required students to take statistics or computer programming as preparation for employment. Only four indicated that their programs included content about non-academic jobs in their courses. However, one respondent added in the comments section that their department offered a specific "*job search seminar*" during which faculty "*spends a great deal of time discussing non-academic jobs.*" Another respondent wrote that in their department's jobs seminar they helped students "*prepare [job] applications*." Further, one respondent wrote that their doctoral program held training workshops in programming and data science that provided opportunities for students to gain in-demand skills for the job market.

Research. Despite the fairly universal requirement of dissertation research, only 67% (n=30) of respondents indicated that research experience through their doctoral departments prepared students for jobs outside of academia. This suggests that at least a third of dissertation research was focused on theoretical issues.

Partnering with employers. Only one respondent indicated that their doctoral program always had local employers on their curriculum advisory board. At the same time, a quarter of respondents (n=12) indicated that their programs worked on problems with industry partners, but only eight (18%) indicated their programs "*set students up with local employers to work on a project.*"

Internships and Externships. Close to half of respondents (n=21; 47%) reported that their programs offered internships to students. One respondent wrote that their college is located near one of the US Department of Energy's National Labs, which gave interested students the opportunity to do a summer internship at a federal facility.

However, as noted above in response to faculty strategies, nine respondents (20%) indicated the use of externships by faculty in their program, but in answer to departmental activities, zero respondents cited externships. Perhaps our use of the term "*short-term shadowing*" confused the respondents.

Use of Alumni. Several respondents referenced connecting students to alumni who are now working in industry. A few respondents circled back to faculty's role as advisers, indicating that some, but not all, advisers at times engaged students in "*frank discussions about interests and options*."

Funding support (Table 14): The majority of respondents (77%) reported that their doctoral programs did not receive federal government or foundation funding specifically earmarked to help prepare students for work. Of those programs that reported having received funding, seven (15%) reported their funding was focused on preparing students for careers in the academy. Only three reported receiving funding to help students pursue careers outside of the academy.

Table 14: Does Your Department Receive Federal or Foundation Grants to Help Doctoral Students Succeed and Prepare for Work?* n=45

Answer	Count	Percent of Answers	Percent of Programs
No.	36	76.6%	80.0%
Yes, grants related to academic careers.	7	14.9%	15.6%
Yes, grants related to business, industry, or government careers.	3	6.4%	6.7%
Yes, other. Specify: • Graduate School of the Arts and Sciences (GSAS) Fellowship.	1	2.1%	2.2%
TOTAL	**47**	**100%**	

Career/Occupational Pathways

In this section we examine the career pathways master's and doctoral programs encourage for their students as well as the reported pathways students from each program have taken. The survey listed possible pathways and provided room for additional ones to be entered by respondents. It is important to note that we did not collect any data on the regularity and comprehensiveness of tracking students' post-graduation at respondents' institutions or the recency of the data used by respondents to complete this portion of the survey. We also do not know what proportion of any program's graduates went into any specific field. We thus report the findings about post-graduation jobs more as potential trends to consider than as data about the actual numbers being employed in any field.

To set our findings into a larger landscape and situate it within current trends, we reviewed recent research about the employment outcomes of math master's and doctoral students. One resource is the American Mathematical Society's (AMS) annual survey of doctoral recipients. AMS' 2020 report indicated that about 60% of doctoral recipients from the 2017–2018 cohorts were in some kind of academic occupation, whereas 39% were in business, industry, or government jobs. The top industries reported by respondents in non-academic occupations included financial services, software, business services, and pharmaceuticals/medical devices.[13]

Perhaps the most significant of AMS's findings to the current study is the employment status of doctoral recipients in academic vs. non-academic jobs. Although a slight majority (52%) of respondents in permanent employment relationships were in academic occupations,[14] a notable 64% of respondents in academic jobs reported that they were in a temporary employment relationship.[15] While respondents in the AMS survey are only two years out of

[13] Golbeck, A. L., Barr, T. H., and Rose, C. A. (2020). Report on the 2017–2018 new doctorate recipients. *Notices of the American Mathematical Society*, *67*(8). http://www.ams.org/profession/data/annual-survey/2018Survey-NewDoctorates-Report.pdf

[14] Ibid.

[15] Ibid.

achieving their PhD, these findings demonstrate that permanent and tenured-track jobs are a rare option for at least the first few years of postdoctoral life.

Our interviews with graduate program directors and chairs confirm national trends. The traditional view of the post-baccalaureate career trajectory for math graduate students—a view that remains widely held by many tenured math faculty—is simply divorced from actual labor market conditions. Academic jobs are increasingly precarious, casualized, and underpaid, and they carry with them slim opportunities for advancement or tenure.

Our survey demonstrates that mathematics faculty at both the master's and doctoral levels continue to emphasize academic career tracks over industry and government careers despite rapidly escalating evidence that it may be outside students' best interest to do so. The harsh realities of part-time adjunct positions afflict most of the academy, including many math departments.[16] Moreover, the kinds of careers math faculty encourage may be misaligned with the occupations students are actually interested in pursuing.

Indeed, recent studies of STEM PhD students show that student interest in academic careers is declining. In a 2017 study, Roach & Sauermann found that while about 80% of STEM doctoral students entered their respective programs with an interest in an academic career, only about 55% remained interested, and 25% significantly lost interest, after three years of study. The authors argue that their results downplay the influence of academic labor market expectations on these preference shifts, but they do suggest that STEM graduate programs need to provide more hands-on learning opportunities and informational resources around non-academic occupations in addition to restructuring their programs to better accommodate anticipated career preference shifts as students' progress through their programs.[17] Despite these earlier calls from researchers, our findings demonstrate that these imperatives still need significant translation for math graduate faculty and department leaders.

Career Pathways Encouraged Compared with Reported Post-Graduation Employment

Given the very different types of opportunities available for individuals with master's or doctoral degrees, we have again separated our discussion by the two-degree levels.

Terminal Master's Programs

Before we look at career pathways at the terminal master's level, it is important to note that 88% of respondents reported that at least some of the students in their program went on to pursue a doctorate (Table 15). To what extent this affects the types of careers encouraged by master's faculty or pursued by their students remains unclear, as we did not ask what *proportion* of students in these programs go on to doctoral study. We did, however, ask respondents to

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[16] Lancaster, A. K., Thessen, A. E., & Arika, V. (2018). A new paradigm for the scientific enterprise: Nurturing the ecosystem. *F1000Research*, 7. https://doi.org/10.12688/f1000research.15078.1

[17] Roach, M., & Sauermann, H. (2017). The declining interest in an academic career. *PLOS ONE 12*(9): e0184130. https://doi.org/10.1371/journal.pone.0184130

identify the fields of study their master's students went on to pursue in doctoral programs, and we present their responses in Appendix B.

Table 15: Do Some of Your Master's Students Earn Their Master's and then Continue on into a Doctoral Program?

	Count	Percent
Yes.	15	88.2%
No.	1	5.9%
Do not know. We do not track alumni.	1	5.9%
TOTAL	**17**	**100%**

Table 16 presents a wide range of potential career pathways. Two career pathways were identified by close to 90% of master's degree survey respondents as those most likely to be encouraged by faculty: college teaching and data science. Given most four-year colleges require faculty to have a doctoral degree, it is not clear if this encouragement is to teach at a community college level or to pursue doctoral studies to prepare for university teaching. Nearly half the respondents indicated faculty in their master's program encouraged careers in K-12 math teaching (47%), and just over 40% indicated their master's faculty encouraged an academic research career. Careers in actuarial sciences, financial services, or general statistics were cited by close to a third of respondents as common recommendations of their program faculty. A quarter of respondents reported their faculty encouraged careers in general statistics. Fewer than 20% of respondents believed it was common for faculty in their program to recommend math careers in tech industries, government, defense/military, or the nonprofit sector.

Table 16: In General, What Are the Top Four Career Path(s) or Occupational Field(s) Most Encouraged by Your Master's Faculty?

Choice	Count	Percent of Programs
Data science.	15	88.2%
College math teaching.	15	88.2%
K-12 math teaching.	8	47.0%
Academic research.	7	41.0%
Actuarial sciences.	5	29.4%
Financial services.	5	29.4%
General statistics.	4	24.5%
Tech industries.	3	17.6%
Military/defense.	3	17.6%
Government.	1	6.0%
Non-profit.	1	6.0%
Health sciences.	0	0.0%
Computer science.	0	0.0%
Manufacturing industries.	0	0.0%
Other, specify:	0	0.0%
TOTAL	**67**	

Table 17 presents the jobs students from master's programs were reported to have entered after graduation. College teaching was the most common career choice, employing graduates of 71% of master's programs surveyed. Mirroring what we saw in Table 16, K-12 teaching was the next most popular reported occupation, welcoming recent graduates from almost 50% of programs. Actuarial work, however, breaks the pattern. Though respondents did not believe faculty spent much time encouraging actuarial science as a career choice, it tied with K-12 teaching as the second-most-common field for master's graduates to enter immediately upon completing their program. Non-research industry jobs and government jobs were far more commonly reported, , employing graduates of 35% of master's programs. In contrast, academic research jobs were far less common among recent graduates than the rate at which they were encouraged by faculty, employing graduates of only 29% of programs surveyed despite being encouraged by faculty at 41% of programs.

Table 17: What Are the Top Four Types of Jobs Your Students Enter After Receiving Their Master's? (n=17)

Answer	Percent of Answers	Count	Percent of Programs
College/university teaching.	22.2%	12	70.6%
Actuarial and insurance business.	14.8%	8	47.1%
K-12 teaching.	14.8%	8	47.1%
Non-research industry jobs.	11.1%	6	35.3%
Government jobs, e.g., IRS, Medicare, Bureau of the Budget.	11.1%	6	35.3%
Academic research.	9.3%	5	29.4%
Health care related jobs.	5.6%	3	17.7%
Non-governmental research jobs.	5.6%	3	17.7%
Do not know, we do not track alumni.	3.7%	2	11.8%
Other, specify:	1.9%	1	5.9%
Other specify:	0.0%	0	0.0%
TOTAL	**100%**	**54**	

As indicated above, it is not clear what time period was referenced by the respondents or how robust the data collection was. That said, the wide differences between the careers they believed their faculty encouraged compared to the jobs most graduates reportedly found is an area not only for additional research but also for departmental action.

Doctoral Programs

Not unexpectedly, doctoral faculty were most inclined to encourage career paths in academic research (100%) and college math teaching (93%) (Table 18). Of note, just over half (55%) of our respondents believed the doctoral faculty in their programs encouraged students to pursue a career in data science. Substantially fewer, however, believed their faculty encouraged students to explore job options in tech industries (41%), the government sector (39%), or financial services (32%). Less than one-third of respondents believed faculty members in their doctoral program encouraged students to pursue careers in general statistics, the actuarial sciences, or health sciences. Again, an important caveat here is that we do not know whether some doctoral programs may have had specific focus or foci that could have impacted the fields faculty encouraged their students to pursue.

Table 18: In General, What Are the Top Four Career Path(s) or Occupational Field(s) Most Encouraged by Your Doctoral Faculty? Select Four. (n=45)

Answer	Count	Percent of Programs
Academic research.	44	100%
College math teaching.	41	93.2 %
Data science.	24	43.2%
Tech industries.	18	40.9%
Government.	17	38.6%
Financial services.	14	31.8%
General statistics.	5	11.4%
Actuarial sciences.	5	11.4%
Data science.	5	11.4%
Health sciences.	4	9.0%
Manufacturing industries.	1	2.3%
Computer science.	1	2.3%
Non-profit.	1	2.3%
Military/defense.	1	2.3%
K-12 math teaching.	1	2.3%
Other, specify:	0	0.0%
Other specify:	0	0.0%
TOTAL	**177**	

The first jobs doctoral program graduates reportedly entered tracked fairly consistently with the principal career pathways their faculty likely encouraged. Table 19 shows that graduates from all or nearly all doctoral degree programs go into college teaching (100%) or into academic research (91%). These were the same two fields that respondents believed faculty members encouraged most often in their doctoral programs. Further, graduates of 40% of doctoral programs reportedly entered governmental jobs, which may directly reflect the 39% of programs in which respondents believed faculty members encouraged their students to consider government employment (Table 18).

Not all the links between faculty encouragement and eventual employment were as clear, however. For example, 40% of respondents indicated that graduates of their doctoral program entered non-research industry jobs, and 22% reported their graduates went into actuarial sciences, both of which were fields that appeared to have little support from faculty. However, again, the caveat is that we asked which occupations were represented among recent alumni but do not know the proportion of graduating students going into each of these occupations.

Table 19: What Are the Top Four Types of Jobs Your Students Enter After Receiving Their Doctorate? (n=45)

Answer	Percent of Answers	Count	Percent of Programs
College/university teaching.	26.0%	45	100.0%
Academic research.	23.7%	41	91.1%
Non-research industry jobs.	15.6%	27	60.0%
Non-governmental research jobs.	10.4%	18	40.0%
Government jobs, e.g., IRS, Medicare, Bureau of the Budget.	10.4%	18	40.0%
Actuarial and insurance business.	5.88%	10	22.2%
Other, specify:	4.1%	7	15.6%
Health care related jobs.	2.3%	4	8.9%
K-12 teaching.	1.2%	2	4.4%
Other specify:	0.6%	1	2.2%
Do not know, we do not track alumni.	0.0%	0	0.00%
TOTAL	**100%**	**173**	

Faculty Development

Professional development around topics related to non-academic careers seems to be a clear gap for programs at both the master's and doctoral levels. To date, 94% of master's survey respondents and 89% of doctoral-level respondents indicated their departments had not conducted any professional development to help faculty become more informed about careers outside of academia. That said, we saw some differences in the engagement of public and private institutions in professional development initiatives. Among the 16 master's programs that responded to this question, only 1 of the 4 private institutions (25%) had conducted professional development, while none of the 12 public colleges had conducted professional development.

Out of the 12 private doctoral programs, only two (17%) indicated that they had conducted some form of professional development around these topics; likewise, only 2 out of the 28 public colleges (6%) had done the same, representing an even smaller percentage. Respondents who indicated their program had conducted professional development activity wrote that their strategies centered on forming stronger relationships with stakeholders from business, industry, and government; applying for grant funding; and organizing more job seminars and events with alumni.

Interview informants saw a clear need for professional development. However, many felt the needs went further. For them, while there may be some lack of knowledge about mathematics careers in industry and government, the greater challenge was program culture. One informant explained that not all professors in their department are open to change, even if the opportunity to learn something new is presented to them:

[They] feel like academic freedom gives them the right to teach and train students the way they want. It's hard to argue with that. I try to make the point and lay out how we can have a robust program, and one of the ways we can get known is by having a good graduate program.

Other informants indicated that they had made more headway in this area, but underscored that catalyzing cultural shifts, especially among faculty, takes time. One informant described how he has tried to emphasize with faculty the importance of more work-based and experiential learning opportunities for math graduate students, especially during the summer months:

[I've tried to] change the culture a little bit in that all advisers in the department feel that it is a good idea to do a summer internship. When we first embarked on pushing this five or six years ago, there were a number of advisers who wanted students to spend the summer on their research. I think the students have found it very useful, and I think it has improved their chances at getting jobs in academia.

Departmental Plans

Most of our interview informants as well as some survey respondents described departmental or faculty activities to spark cultural change. However, we did not hear about any designated work plan with distinct goals focused on non-academic career preparation. We did hear, however, from one informant about his strategy for changing culture, which involved showing faculty the benefits of change rather than simply telling them to change:

The feeling is that if faculty see students moving on to jobs that earn more than academic jobs, they'll start to see the usefulness of the approach. The secret really is to reach out to students first and give them the skills, have workshops with industry representatives and alumni, mini bootcamps, and pay the students to spend three weeks doing an applied research project and get them prepared, and faculty will come around slowly.

We also heard that some programs are developing or planning to develop a stronger alumni network as well as better ways to track what kinds of occupations their graduate students enter.

Respondents from a number of master's and doctoral programs viewed partnerships with industry as a lifeline for their programs. They stated that internships and other work-based learning opportunities have the potential to open up new funding opportunities for students. One informant we interviewed leads a department with a doctoral program as well as a master's program with an Applied and Computational Math Emphasis that requires students to complete an internship. Some of these master's students have received funding from their internship host to pay for the remainder of their graduate studies. Consequently, this program is working to build their internship opportunities: *"We're really trying to tap into this funding source for our graduate program. . . . We've thought about using this as a way to grow our master's program."*

IDENTIFIED AREAS FOR ENHANCEMENT

EERC's previous research for TPSE[18] identified areas of potential enhancement for mathematics departments at the undergraduate level.[19] Both graduate program survey respondents and interview informants echoed many of these same areas.

Industry Partnerships

- Many interview informants and survey respondents indicated that effectively partnering with industry is an area that their department needs to work on. Some programs already have fairly well-established internship programs or industry advisory boards or may even include industry representatives on doctoral committees. However, many stakeholders with whom we spoke expressed the need to develop and expand their partnerships with industry.

Faculty development

- Professional development around non-academic careers also seems to be a critical area for development across math graduate degree programs. In our prior research, undergraduate programs identified the general lack of resources for such activities as their major barrier. However, at the graduate level, our interview informants suggested the barriers are more cultural than stemming from a lack of resources.

  Graduate faculty may have greater resources and perhaps even schedule flexibility to engage in professional development. But they may be less inclined to consider a focus on industry engagement. (Faculty working in statistics and other similar applied specializations may be exceptions to this rule.) In this regard, a variety of strategies beyond formalized professional development might be helpful, e.g., peer-to-peer training and access to empirical evidence about post-degree employment opportunities both within and outside the academy.

Use of real-world problems in curriculum

- Many respondents we surveyed and spoke to indicated that integrating real-world problems into curricula was still a work in progress in their programs. In some programs, faculty groups have formed—typically faculty in applied math—to work on this area. At times, programs bring external professionals into their classes to lead or facilitate students' work on real-world problems. Alternatively, some programs have decided not to modify existing curricula, but instead to create new courses that can help students develop industry-ready

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[18] These briefs are available at https://smlr.rutgers.edu/content/transforming-post-secondary-education-mathematics-research

[19] EERC. (2020). *Preparing math majors for careers: Executive summary.* https://smlr.rutgers.edu/sites/default/files/Documents/Centers/EERC/transforming_math_research_executive_summary.final_%20%282%29_0.pdf

skillsets, e.g., data and computer science. Another program developed a special topics class whose syllabus can be easily modified to respond to rapid technological changes in industry. Each of these approaches offers a means to stimulate faculty enthusiasm and greater buy-in for industry-oriented initiatives.

Use of Alumni

- Most of those interviewed and surveyed indicated their programs are not currently tracking alumni. Programs that have reached out to alumni to foster career exploration initiatives typically did so in an ad hoc manner and largely for career panels and other informational sessions. Few have drawn on alumni experience in the labor market to inform curriculum or even to learn about their post-degree employment experiences. Establishing more systematized professional alumni networks in math graduate departments could help connect more students with industries and careers beyond academia.

SUGGESTIONS FOR TPSE

- **Professional Development Opportunities.** According to some informants, in addition to a better understanding of the career and occupational landscape for math graduate students, faculty also need more training on the kinds of soft and professional skills students will need as they enter the labor market—skills that go beyond what it is traditionally covered in an academic graduate program. According to one informant, faculty in their department "*have this belief that if a student writes a good thesis, they will instantly get a job. They need communication and interview skills, and we need to impress on faculty that reality.*" Respondents from a vast majority of programs indicated that professional development around these topics was an area of need:
  - The Career and Occupational Landscape for Math Graduate Students Beyond Academia
  - How to Develop Strong Relationships with Industry
  - Equitable Advising Strategies that Encourage Students' Agency
  - Skills Math Graduate Students Need to Succeed in the Twenty-First Century Labor Market
  - Integrating Industry/Real-World Problems into Math Graduate Curricula
- **Facilitating Stronger Partnerships Between Math Departments and Industry.** Most informants and survey respondents indicated that, if their faculty *did* have strong relationships with industry, it was typically faculty with applied math specializations or prior experience with industry. Some respondents reported their programs had an established industry advisory board as well as dedicated staff members for career preparation—in line with previous recommendations from EERC at the undergraduate

level.[20] Many informants indicated that, even if they themselves did not have experience in industry, they were still able to get their students into industry jobs with the right kind of support and guidance. At this current juncture, it seems as if students who want to enter a non-academic career pathway need to take a lot of initiative themselves within their math graduate program. Thus, helping departments develop better and stronger relationships with industry would help ease the burden on many students, and expand student opportunities and faculty knowledge.

- **Funding Support for Non-Academic Career Initiatives.** Our survey results showed that 76% of master's programs and 80% of doctoral programs did not receive any kind of foundation, state, or federal government funding to help graduate students succeed and prepare them for work. Professional development initiatives paired with funding supports could help build departmental capacities for implementation and adoption of programming and supports aimed at employment preparation. Importantly, while not a question on our survey, only a handful of the informants we spoke to, said their programs had staff dedicated to providing career services and support for their students. Identifying funds to help departments employ even a part-time career adviser might be extremely helpful.

[20] EERC. (2020). *Partnering with industry.* https://smlr.rutgers.edu/sites/default/files/Documents/Centers/EERC/transforming_math_research_partnering_with_industry.final_.pdf

APPENDIX A

SAMPLE INSTITUTIONS BY STATE

Responding Institutions by State

Anonymous
Two colleges (doctoral)

Alabama
University of South Alabama (master's, public)
University of Alabama (doctoral, public)

Arizona
University of Arizona (doctoral, public)

California
California State University, Fresno (master's, public)
San Jose State University (master's, public)
California State University, Channel Islands (master's, public)
University of Southern California (doctoral, private)
Stanford University (doctoral, private)

Canada
University of Victoria (doctoral, public)
University of Calgary (doctoral, public)

Colorado
Colorado State University (doctoral, public)
University of Northern Colorado (doctoral, public)

Connecticut
University of Connecticut (doctoral, public)

Florida
University of Florida (doctoral, public)
Florida Atlantic University (doctoral, public)

Georgia
Georgia Tech (doctoral, public)

Hawaii
University of Hawaii (doctoral, public)

Illinois
Roosevelt University (master's, private)

Indiana

University of Notre Dame (doctoral, private)
Indiana University (doctoral, public)

Kansas
University of Kansas (doctoral, public)

Kentucky
University of Louisiana, Lafayette (doctoral, public)
Maryland
Johns Hopkins University (doctoral, private)
University of Maryland, College Park (doctoral, public)
Morgan State University (doctoral, public)

Massachusetts
Boston College (doctoral, private)
Harvard University (doctoral, private)
Tufts University (doctoral, private)

Michigan
University of Michigan, Dearborn (master's, public)
University of Michigan, Ann Arbor (doctoral, public)

Minnesota
University of Minnesota (doctoral, public)

Missouri
Washington State University, Saint Louis (doctoral, private)

Nebraska
University of Nebraska, Lincoln (doctoral, public)

New Hampshire
University of New Hampshire (doctoral, public)

New Mexico
University of New Mexico (doctoral, public)

New York
Queens College (CUNY) (master's, public)
Buffalo State College (master's, public)
Manhattan College (master's, private)
SUNY New Paltz (master's, public)
University of Rochester (doctoral, private)

North Carolina
Appalachian State University (master's, public)
Wake Forest University (master's, private)
North Carolina State University (doctoral, public)

University of North Carolina (doctoral, public)

Ohio
Youngstown State University (master's, public)
University of Dayton (master's, private)
University of Cincinnati (doctoral, public)
Ohio University (doctoral, public)

Pennsylvania
Penn State (doctoral, public)
Lehigh University (doctoral, private)

Rhode Island
Brown University (doctoral, private)

Tennessee
Tennessee Tech (master's, public)
Lamar University (master's, public)
University of Tennessee, Knoxville (doctoral, public)

Texas
University of Texas, Rio Grande Valley (master's, public)
University of Texas, Austin (doctoral, public)

Utah
University of Utah (doctoral, public)
Brigham Young University (doctoral, private)

Washington
University of Washington (doctoral, public)
Washington State University (doctoral, public)

Wisconsin
University of Wisconsin, Milwaukee (doctoral, public)