

Does Mentoring Fill the Knowledge-GAP in Applying to Graduate School in Mathematics?

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Applying to graduate school in mathematics requires both a desire to attend graduate school, but also an understanding of the application process. The more students know about the process, the more successful they are in their pursuit of admission to a graduate program. We examined mathematics majors’ knowledge of both graduate school and the graduate school application process as part of a larger study examining barriers to students applying to graduate school in mathematics. We also examined the impact of mentors on student interest in graduate school and whether having a mentor has an impact on student knowledge of graduate school. We frame and explain our results using the theory of social capital.

Keywords: Mentors, Graduate School Applications, Social Capital

In 2023, approximately 3.1 million students were enrolled in graduate-level programs and 15.2 million enrolled in undergraduate programs in the US (National Student Clearinghouse Research Center, 2024). A fraction of those 15.2 million will decide to apply to graduate or professional programs in the next few years. There are a variety of reasons for attending graduate school including increasing earning power, career options, depth and breadth of disciplinary knowledge, obtaining more satisfaction with their career and accomplishments, increasing self-esteem, access to professional leadership opportunities, being assigned more responsibilities, and intrinsic motivation for the challenge. However, Estien et al., (2023) points out that before students enter graduate school, they must overcome the obstacle of applying.

Researchers have investigated the graduate/professional admissions process in several disciplines (e.g., Chari & Potvin [Physics], 2019; Hadinger [Medical School], 2017; Landrum [Psychology], 2010; Sylvan et al. [Speech-language Pathology], 2020). Estien et al. (2023) states that researchers have found “several factors that shaped students’ experiences applying to graduate school including: financial constraints (Hadinger, 2017; Sylvan et al., 2020); concerns regarding the use of admissions criteria such as the Graduate Record Examination (GRE) scores (Sylvan et al., 2020); a lack of support, guidance, and advising from faculty members (Hadinger, 2017; Sylvan et al., 2020); and a lack of transparency due to variation in admissions requirements across graduate programs (Sylvan et al., 2020).” (p. 56). Furthermore, the National Academies of Science, Engineering and Medicine (NASEM) argues that mentorship is one way to enhance students’ graduate school aspirations (2019) and has multiple benefits for students like higher GPAs, completing more coursework each semester, stronger self-esteem and academic self-efficacy, higher career goals, less stress, better psychological health, improved attitudes, and better discipline-based skills (Luna & Prieto, 2009). We add to this by examining what mathematics majors know about the graduate school application process through the lens of the theory of Social Capital and assess the impact of mentoring on undergraduate mathematics students’ knowledge of the application process. Specifically, we seek to answer the following:

1. *What do undergraduate mathematics majors know about applying to graduate school and about graduate school itself?*

2. *Is there a difference in students' knowledge between students who do and do not have a mentor?*

Literature Review

Poock & Love (2001) identify extensive literature examining variables that influence students' choice of colleges at the undergraduate level. These studies focus on which students go to college, the process of students' choosing which colleges to apply to and which colleges they attend, but not on the application process at the undergraduate level. Similar to the limited research on the application process at the undergraduate level, there is also meager literature on students' choice of graduate school. Kallio (1995) called for further investigations into why students apply and choose to enroll (or not) in graduate school once admitted, but there is still scant literature on the application process at all levels. There is specifically little information known about students' application to and knowledge of the application process for graduate or professional school.

Chari & Potvin (2019) is the first study investigating undergraduate students' perceptions about graduate admissions in physics. Their sample of 802 physics juniors and seniors ranked letters of recommendation, prior research experience, GPA or grades in physics and mathematics classes, reputation of recommender, and prior research publications as the top five most important admission criteria respectively when applying to graduate school. They compared these rankings to physics faculty's top five most important admission criteria from a prior study (Potvin, et al., 2017): GPA or grades in physics and mathematics classes, letters of recommendation, undergraduate courses taken, GRE physics subject test, and prior research experience. They found that there were statistically significant differences between faculty and student perceptions on prior research experiences, reputation of recommenders, prior research publications, personal statements, and familiarity with the department.

Landrum (2010) surveyed 348 students about whether they planned to apply to graduate school and knew about the application process and found that personal belief in how well they would do academically, on their preparation for graduate school, and available opportunities beyond the classroom were important factors in students' decision to apply. In addition, Sanders & Landrum (2012) surveyed undergraduate psychology majors assessing their understanding of the application process for graduate or professional school. Of the 134 students that responded, research experience, letters of recommendation, and GPA were rated as the most important components of an application for graduate school. Finally, Oakes et al. (1999) implemented a successful seminar series at Purdue University that consisted of seminars on graduate school, the General and Engineering GRE, and applying for fellowships. They found that students' understanding about graduate school increased substantially after participating in the seminars.

There is also little research on how academic advisors influence students' decisions to apply and attend graduate school. However, mentorship is a key aspect that has shown substantial impact on students' post-graduate pathways (Luna & Prieto, 2009). The literature documents different aspects of mentoring (or mentorship) that plays an important role in students' graduate school plans like faculty mentoring through research experiences (Adedokun et al., 2013; Eagan et al., 2013; Merolla and Serpe, 2013; Park et al., 2022; Pender et al., 2010), graduate school preparation programs (e.g., McNair Program [Renbarger & Beaujean, 2020] and EMERGE [Peteet & Lige, 2016]), mentoring programs (Meza et al., 2018), classroom experiences (Park et al., 2022), and faculty interactions (Espino, 2014; Hanson, et al., 2016).

Theoretical Background

We apply the theory of social capital to explore the impact of mentors on the graduate school application process. Coleman (1988) defines social capital by its function and states that it is a “variety of different entities all sharing two elements in common: they all consist of some aspect of social structures, and they facilitate actions of actors, whether persons or corporate actors, within the social structure” (p. S98). Furthermore, Coleman (1988) clarifies that “an important form of social capital is the potential for information that inheres in social relations” (p. S104). Knowledge is an essential resource necessary to apply to graduate school since students need to know it exists, why they would want to apply, and what is required to apply. In this paper, we focus on the relationships that undergraduate students have with their mentors that can provide multiple forms of resources to them because of social capital that are useful for applying to graduate school in mathematics. This social capital could be in the form of information on the graduate school application process or access to letters of recommendation. We add to the body of literature by examining what information undergraduate mathematics majors know about the graduate school application process primarily as a result of mentoring.

Methods

Instrument Development

The research team created a survey based partially on a survey developed and used to determine undergraduate physics majors’ interest in graduate school and how important they believed different aspects of the application process were (Chari & Potvin, 2019).¹ Nineteen of our survey items were adapted from that instrument. A notable difference in our survey was that we provided an opportunity for participants to express their lack of knowledge about different parts of the application process. The final survey had 57 items separated into four categories: (a) knowledge about different aspects of the application process, (b) barriers to applying, (c) interest in graduate school and what students want in programs they apply to, and (d) demographic questions. Most items were Likert scale or multiple choice, though four were open-ended and some multiple-choice items allowed participants to type in a text response.

Data Collection

The research team sent the survey to department chairs and undergraduate program directors at all undergraduate mathematics programs at U.S. colleges and universities with at least 1000 students total ($N = 985$). Initial emails were sent in Fall 2022 through Spring 2023 with follow-up emails sent to encourage a greater response rate. The research team also posted the survey on social media, listservs, and in newsletters for several professional organizations in mathematics.

Data Analysis

We received 1090 responses from students at 181 colleges and universities, with 519 complete responses. Participants could skip part of an item and still have their response marked as complete. Thus, the N s for different items are not always equal. Descriptive statistics and Chi-squared tests of association were run in IBM SPSS. To address our research questions, we analyzed responses for five survey items, where two of those items had 8 and 6 subitems respectively.

¹ The full survey is available at this link:

https://researchrepository.wvu.edu/faculty_publications/3291/

Results

Knowledge of Applying to Graduate School

Table 1 provides the overall participant knowledge of the application process for graduate school in mathematics.

Table 1. Responses to “Please rate your familiarity with the following concepts about graduate school application process.”

<u>Sub-Item</u>	<u>N</u>	<u>Never heard this before</u>	<u>May have heard this before</u>	<u>Definitely heard this before</u>
Requires a minimum GPA	586	5%	21.8%	73.2%
Requires transcripts	585	1.4%	7.5%	91.1%
Requires letters of recommendation	585	4.1%	12.1%	83.8%
Letters of recommendation should be from mathematicians	585	19.8%	35.2%	45%
Programs require application fees	585	8.2%	25.3%	66.5%
Some programs offer ways to reduce or eliminate application fees	585	26.7%	31.8%	41.5%
Often requires a personal statement	584	15.8%	23.1%	61.1%
Some doctoral programs do not require applicants to get a master's degree first	585	30.3%	18.8%	50.9%

The participants who responded “Definitely heard this before” to the sub-item asking about a minimum GPA for graduate school were then asked: “You have indicated that you heard that you need a minimum GPA to have a competitive graduate school application. What is that GPA?” The average of the responses to this follow up question was a GPA of 3.3.

There was a wide range of responses from participants depending on the sub-item. For some sub-items such as “applying to graduate school requires transcripts” nearly all participants chose the option “definitely heard of before”. For other sub-items including “the availability of application fee waivers” participants were less certain that they had “heard of this before”. Overall, most participants had heard of most of the sub-items in this item.

Knowledge of Graduate School

Table 2 provides the overall participant knowledge of graduate school in mathematics.

Table 2. Responses to “Please rate your familiarity with the following concepts about graduate school in mathematics”.

<u>Sub-Item</u>	<u>N</u>	<u>Never heard this before</u>	<u>May have heard this before</u>	<u>Definitely heard this before</u>
A master's degree usually takes 2 years to complete	586	3.6%	21.1%	75.3%
A doctorate usually takes between 5 to 7 years to complete	583	8.4%	25.9%	75.7%
Math graduate programs usually provide some sort of funding	584	18.2%	31.3%	50.5%
Students in doctoral programs with funding usually have tuition waivers	584	38.3%	24%	37.7%
Funded graduate students must maintain some minimum overall GPA to keep their funding	583	18.5%	40.8%	40.7%
Graduate students in some programs are unionized and are protected under a collective bargaining agreement	584	69%	13.2%	17.8%

In comparison to the previous item, participants were less likely to have heard information about graduate school itself than they were to have heard about the graduate school application process. Participants mostly knew the length of graduate school but knew less about graduate school funding structures.

Mathematical Mentors

We asked participants “Do you have someone you consider a mathematical mentor? (This is someone who has not necessarily been formally assigned to you by your institution but gives you advice on how to advance your career in mathematics.)” Of 584 participants, 327 (56%) said they had someone they consider a mathematical mentor. We used a Chi-squared test of homogeneity to see if there was an association between interest in graduate school and having a mentor.

Table 3. Responses to “Which of the following describes your interest in graduate school in mathematics?” for Students With and Without Mentors.

<u>Option</u>	<u>Mentor</u>	<u>No Mentor</u>	<u>N</u>
Not interested in attending graduate school in mathematics	46 (52.3%)	42 (47.7%)	88

Interested in earning a master's degree only	54 (54%)	46 (46%)	100
Interested in earning a master's or attending a post baccalaureate program then earning a doctorate	76 (52.4%)	69 (47.6%)	145
Interested in earning a doctorate without earning a masters or attending a post baccalaureate program first	107 (70.4%)	45 (29.6%)	152
Not sure	43 (44.3%)	54 (55.7%)	97

There was an association in which participants with mentors were more likely to say they were interested in earning a PhD than their peers without mentors $\chi^2(4, N = 582) = 19.56, p = < .001 (V = .18)$. This result had a small effect size. In addition, we ran a Chi-squared test of independence and found that participants with mentors were more likely to say they knew about the following aspects of graduate school and the graduate school application process (Table 4).

Table 4. Results for Chi-Squared on Student Knowledge For all tests $df = 2$.

<u>Sub-Item</u>	<u>Mentor</u>	<u>Never</u>	<u>May have</u>	<u>Definitely</u>	<u>N</u>	<u>Values</u>	<u>p-value</u>	<u>w</u>
		<u>heard this</u>	<u>heard this</u>	<u>heard this</u>				
		<u>before</u>	<u>before</u>	<u>before</u>				
Letters of recommendation should be from mathematicians	Yes	54	86	183	585	38.82	< .001	.26
	No	59	120	80				
Often requires a personal statement	Yes	44	65	216	584	8.77	.012	.12
	No	48	70	141				
Some doctoral programs do not require applicants to get a master's degree first	Yes	85	59	182	585	7.91	.019	.11
	No	92	51	116				
Math graduate programs usually provide some sort of funding	Yes	57	82	186	584	15.41	< .001	.16
	No	49	101	109				
Students in doctoral programs with funding usually have tuition waivers	Yes	109	80	134	584	7.95	.019	.12
	No	115	60	84				

There were no associations ($p > .05$) for all other sub-items in Tables 1 and 2 that were not reported in Table 4. For the five sub-items in Table 4, participants with mentors were more likely to respond that they had “definitely heard this before”. The effect size is small for all sub-items

(all w 's between 0.1 and 0.3), but the effect size for “letters of recommendation should be from mathematicians” is approaching the upper bound for a small effect size.

Discussion

Overall, we found significant variability in student knowledge of applying to graduate school and graduate school itself. Some sub-items, such as the requirement for transcripts, were nearly universally known by our participants. Other sub-items including “students in doctoral programs usually have tuition waivers” were largely unknown to our participants. Some programmatic requirements and structures were more common to be well known, including the length of degree programs and parts of the application. However, the financial aspects of graduate school including funding and tuition waivers were less well known. This is problematic for students from low-income backgrounds, because they may believe they cannot afford to apply to or attend graduate school even though they may know how to apply.

Almost half of our participants did not have someone they considered a mathematical mentor. We found that students who had mentors were more likely to state that they were interested in directly earning a PhD in mathematics compared to their peers without a mentor. Since students who want to go to graduate school may be more likely to seek a mentor, we cannot say this association is necessarily causation. Still, participants with mentors were more likely to know more about specific aspects of the application process and graduate school than their peers without mentors. They were more likely to know about the norms in applying to graduate school in mathematics such as letters of recommendation should be from mathematicians and that you can be admitted to a doctoral program directly after undergraduate school. They were also more likely to know about norms in graduate student funding, including that mathematics graduate students are usually funded and receive tuition waivers. All these factors are items that faculty mentors, mathematicians with advanced degrees, are knowledgeable about given their own experiences in graduate school. The results of our study show that the social capital that mentors can and do provide benefit students seeking to apply to graduate school, especially through access to knowledge about the application process.

That said, there were a few aspects of the application process and graduate school that were not well known by our participants and having a mentor was not associated with increased knowledge for these. The two we believed were most important are the availability of application fee waivers and the graduate school GPA requirement to maintain funding. It is the case that not all programs may have something in place like fee waivers, so this piece of information may not be as readily available to mentors. In a previous study on this data set, we found that minoritized students were more likely to view application fees as a barrier to applying to graduate school (McEldowney et al., 2024). Therefore, mentors not knowing about or talking to students about application fee waivers is especially problematic for marginalized students. In addition, giving mentees an advanced warning of graduate school GPA requirements could help ensure that more students succeed after being admitted to graduate school.

An important consideration for these results is sampling bias. While we attempted to obtain a representative sample, participants were students who chose to take a relatively long survey. Thus, we can reasonably assume that the average mathematics major knows less about graduate school than our results indicate.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant Number 2126018. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

- Adedokun, O. A., Bessenbacher, A. B., Parker, L. C., Kirkham, L. L., & Burgess, W. D. (2013). Research skills and STEM undergraduate research students' aspirations for research careers: Mediating effects of research self-efficacy. *Journal of Research in Science teaching*, 50(8), 940-951.
- National Student Clearinghouse Research Center. (2024, January) *Current Term Enrollment Estimates: Fall 2023*, <https://nscresearchcenter.org/current-term-enrollment-estimates/>
- Chari, D., & Potvin, G. (2019). Understanding the importance of graduate admissions criteria according to prospective graduate students. *Physical Review Physics Education Research*, 15(2), 023101.
- Coleman, J. S. (1988). Social capital in the creation of human capital. *American journal of sociology*, 94, S95-S120.
- Eagan Jr, M. K., Hurtado, S., Chang, M. J., Garcia, G. A., Herrera, F. A., & Garibay, J. C. (2013). Making a difference in science education: The impact of undergraduate research programs. *American educational research journal*, 50(4), 683-713.
- Espino, M. M. (2014). Exploring the role of community cultural wealth in graduate school access and persistence for Mexican American PhDs. *American Journal of Education*, 120(4), 545-574.
- Estien, C. O., Chapman, M., Schell, C. J., Lowy, N., & Gerson, J. R. (2023). Demystifying the graduate school application process. *The Bulletin of the Ecological Society of America*, 104(1), e02029.
- Hanson, J. M., Paulsen, M. B., & Pascarella, E. T. (2016). Understanding graduate school aspirations: The effect of good teaching practices. *Higher Education*, 71, 735-752.
- Hadinger, M. A. (2017). Underrepresented minorities in medical school admissions: a qualitative study. *Teaching and learning in medicine*, 29(1), 31-41.
- Kallio, R. E. (1995). Factors influencing the college choice decisions of graduate students. *Research in higher education*, 36, 109-124.
- Landrum, R. E. (2010). Intent to Apply To Graduate School: Perceptions of Senior Year Psychology Majors. *North American Journal of Psychology*, 12(2).
- Luna, V., & Prieto, L. (2009). Mentoring affirmations and interventions: A bridge to graduate school for Latina/o students. *Journal of Hispanic Higher Education*, 8(2), 213-224.
- McEldowney, T., Townsend, E., Maldonado, D., Michaluk, L., & Deshler, J. (2024). The Price Does Not Appear the Same for Everyone: Racial Differences in Students' Perceptions of the Mathematics Graduate School Application Process. *Proceedings of the 26th Annual Conference on Research in Undergraduate Mathematics Education*.
- Merolla, D. M., & Serpe, R. T. (2013). STEM enrichment programs and graduate school matriculation: The role of science identity salience. *Social Psychology of Education*, 16(4), 575-597.

- Meza, J. I., Rodriguez, K., Trujillo, C., & Ladd-Viti, C. (2018). Helping students at the margins get into graduate school: evaluating a multifaceted mentoring program. *The Mentor: Innovative Scholarship on Academic Advising*, 20, 26-41.
- National Academies of Science, Engineering, and Medicine. (2019). The science of effective mentorship in STEMM. The National Academies Press. <https://doi.org/10.17226/25568>
- Oakes, W. C., McComb, S. A., Mulkay, E. L., Berger, E. J., Blevins, L. G., Stamber, K., & Jones, J. D. (1999). Equipping undergraduates for the graduate school process. *Journal of Engineering Education*, 88(3), 353-359.
- Park, J. J., Kim, Y. K., Lue, K., & Parikh, R. M. (2022). What's next? Soon-to-be STEM graduates on their post-graduate plans. *Research in Higher Education*, 63(8), 1343-1367.
- Pender, M., Marcotte, D. E., Domingo, M. R. S., & Maton, K. I. (2010). The STEM pipeline: The role of summer research experience in minority students' Ph. D. aspirations. *Education policy analysis archives*, 18(30), 1.
- Peteet, B. J., & Lige, Q. (2016). Beyond a bachelor's: Implementing a graduate school preparation program. *Journal of Black Studies*, 47(2), 95-112.
- Poock, M. C., & Love, P. G. (2001). Factors influencing the program choice of doctoral students in higher education administration. *Naspa Journal*, 38(2), 203-223.
- Potvin, G., Chari, D., & Hodapp, T. (2017). Investigating approaches to diversity in a national survey of physics doctoral programs: The graduate admissions landscape. *Physical Review Physics Education Research*, 13(2), 020142.
- Renbarger, R., & Beaujean, A. (2020). A meta-analysis of graduate school enrollment from students in the Ronald E. McNair post-baccalaureate program. *Education Sciences*, 10(1), 16.
- Sanders, C.E., & Landrum, R.E. (2012). The graduate school application process: What our students report they know. *Teaching of Psychology*, 39(2), 128-132.
- Sylvan, L., Perkins, A., & Truglio, C. (2020). Student experience applying to graduate school for speech-language pathology. *Perspectives of the ASHA Special Interest Groups*, 5(1), 192-205.