

The Price Does Not Appear the Same for Everyone: Racial Differences in Students' Perceptions of the Mathematics Graduate School Application Process

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Lack of racial diversity has been an ongoing issue in higher education. Recently, the Theory of Racialized Organizations has been used to help explain why, despite many calls for diversity, the demographics of higher education have not changed. Considering this framework, we seek to understand what aspects of the graduate school application process are viewed as barriers by minoritized students for applying. As part of a larger study of undergraduate student knowledge of the graduate school application process, we analyze 515 responses from undergraduate math majors using Mann-Whitney U tests to identify differences in what participants view as a barrier to apply to graduate school by race/ethnicity. We discuss two main results and recommend changes to graduate programs wishing to recruit more minoritized students.

Keywords: Graduate school application, undergraduate mathematics majors, Theory of Racialized Organizations, Minoritized students

On June 29, 2023, the U.S. Supreme Court struck down Affirmative Action on college admissions (Students for Fair Admissions Inc. v. President & Fellows of Harvard College, 2023). This decision has the potential to impact the ability of future minoritized¹ students to enter college both at the undergraduate and graduate levels. This will be especially problematic for the field of mathematics given its lack of racial diversity that becomes more pronounced at higher levels. While 31.9% of the U.S. population identify as Hispanic/Latinx or African American (U.S. Census, 2020), in recent years only 15.9% of mathematics and statistics (mathematics-only data unavailable) bachelor’s degrees were earned by minoritized students (National Center for Science and Engineering Statistics, 2019). Finally, only 7.4% of new mathematics doctoral recipients were minoritized (Golbeck, et al., 2020).

Diversity in graduate admissions has become an important topic of research and conflict in the last decade. Recent higher education research has shed light on what faculty think about the role of diversity in final-round decisions in the graduate admissions process (Posselt, 2016). Often, diversity is discussed as a “goal” for institutions of higher education to achieve. Yet, in their admissions processes, the conditionality of diversity comes secondary to the perceived obligation of “protecting well-established standards of conventional achievement,” such as high program rankings and competitive test scores (Posselt, 2016). However, it is well-documented that gaps in standardized test scores fall along lines of socio-economic identity and are not adequate indicators of intelligence (Posselt, 2016). If diversity is considered a criterion for

¹ Minoritized is an alternative way of referring to people who are often labeled as “Underrepresented Minorities” in STEM. This alternative phrasing makes it clear that it is power imbalances and systematic oppression that cause these groups to be less represented in STEM (Wingrove-Haugland & McLeod, 2021).

graduate admissions only secondary to traditional quantitative measures, then current admission practices are likely to “perpetuate enrollment inequities” (Posselt, 2016).

While this research provides great insight on the admissions process across multiple disciplines it loses context and insight that can be gained through Discipline-Based Education Research. Physics education researchers have conducted multiple studies of the graduate application process (Chari & Potvin, 2019a, 2019b; Potvin, et al., 2017; Scherr, et al., 2017; Young & Caballero, 2019). Physics departments “express a ... demand for greater numbers of students from [minoritized] groups, but simultaneously report a lack of such applicants” (Potvin et al., 2017). This finding mirrors smaller scale research in the field of mathematics which found “low graduate mathematics application rates from historically underrepresented groups” (Gevertz & Wares, 2020). If the U.S. is to increase diversity in STEM graduate programs, we must examine whether minoritized students apply for graduate school at the same rate as their non-minoritized peers and if not, determine how to address the disparity.

Students who want to pursue graduate school in mathematics often face multiple financial barriers. These burdens can include working to support their family (instead of acquiring research experience or studying), rent, transportation, paying off undergraduate debt, GRE costs, and application fees (Cochran et al., 2018). Multiple studies have shown that application fees limit the number of applications from students from low-income backgrounds (Cadena et al., 2023; Cochran et al., 2018; Roberts et al., 2021; Wilson, et al., 2018). Some programs have implemented fee waivers for this reason. However, the effort required to gain fee waivers deters students from applying to graduate school. For example, students may need to complete their application in advance of the normal deadline or achieve a higher GPA (Cadena et al., 2023; Roberts et al., 2021). In some cases, fee waivers require U.S. citizenship, so undocumented or international students may not qualify for waivers. In addition, the application fee may sometimes cost a student an entire month’s salary (Cadena et al., 2023). Thus, financial burdens, and application fees in particular, negatively, and significantly impact low-income students applying to graduate school.

The Undergraduate Knowledge of the Mathematics Graduate School Application Process (Knowledge-GAP) project was created to examine undergraduate mathematics majors’ knowledge about the graduate school application process and to facilitate an understanding of perceived barriers to applying to graduate school across different demographic groups. This paper focuses on how minoritized students perceive the application process and seeks to answer the following subset of research questions from the Knowledge-GAP project:

1. *Do perceptions of barriers to applying to graduate school differ by race/ethnicity?*
2. *What factors are most important to minoritized students planning to apply to graduate school?*

Theoretical Background

The Theory of Racialized Organizations (TRO) was developed to help explain “consistency of racialized organizational inequality” (Ray, 2019). This framework calls for researchers interested in racial inequality to critically examine how an organization's policies and institutionalized practices (e.g., admissions procedures) uphold racial disparities (Ray, 2019). It has been applied to many fields and types of organizations since its inception including undergraduate mathematics education (Leyva et al., 2021). In a recent study, Poon et al. (2023) applied the TRO framework “to examine the totality of (undergraduate) admissions as racialized organizations”. They found that even supposedly “race-neutral” admissions policies can increase racial inequality due to the existing racial wealth gap in America (Poon et al., 2023). To explain

this gap, they call upon the concept of racial capitalism (Poon et al., 2023). Melamed (2015) explained racial capitalism by stating: “Racism enshrines the inequalities that capitalism requires . . . by displacing the uneven life chances that are inescapably part of capitalist social relations onto fictions of differing human capacities, historically” along racial lines (p. 77). We extend this framework to graduate admissions to understand differences in perceived barriers to the graduate application process between minoritized and non-minoritized students.

Methods

Instrument Development

The research team created a survey based in part on a survey used to determine undergraduate physics majors’ interest in graduate school and how important they believed different aspects of the application process were (Chari & Potvin, 2019b). Nineteen survey items were adapted from that instrument. A notable difference between that survey and ours 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 look for in programs they apply to, and (d) demographic questions. Most questions were Likert scale or multiple choice, though four were open-ended and some of the multiple-choice items allowed participants to type in a text response. The full survey is available at this link: https://researchrepository.wvu.edu/faculty_publications/3291/.

Data Collection

The research team sent an email with the survey to department chairs and undergraduate program directors at all U.S. undergraduate mathematics programs at colleges and universities with at least 1000 students total ($N = 985$). We requested the survey be sent to all undergraduate mathematics majors. Initial emails were sent Fall 2022 through Spring 2023, via Qualtrics, and follow-up emails were sent to encourage a greater response rate. In addition to direct emails, the survey was also posted 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. Note that students could miss part of a question and still have their response marked as complete. Thus, the N s for different items are not always the same. Statistical tests were run in IBM SPSS.

To address these research questions, we analyzed data collected through two survey items: *To what extent are the following factors a potential barrier to your pursuit of graduate school?* and *How important are the following factors in choosing which schools you apply to?* Both questions were Likert scale items adapted for this study from Chari and Potvin (2019b). The first item had 17 sub-item topics (potential barriers), which students rated on a scale of 1 (not at all a barrier) to 5 (very significant barrier). The second item had 15 sub-item topics (potentially important factors for applying to graduate programs), which students rated on a scale of 1 (not at all important) to 5 (very important).

Results

Participant Demographics

Tables 1 and 2 show annual income for participants while growing up, and racial/ethnic demographics for participants with complete responses. Note that participants were able to select more than one category for racial/ethnic identification.

Table 1. Yearly Income for Participants When They Were Growing Up.

To the best of your knowledge, which category best describes your family's yearly household income while you were growing up?		
<u>Income</u>	<u>N</u>	<u>Percentage</u>
Less than \$60,000	119	22.9%
Between \$60,000 and \$100,000	128	24.7%
More than \$100,000	208	40.1%
Do not know	44	8.5%
Prefer not to say	20	3.9%
Total	519	100%

Table 2. Race/ethnicity of Participants.*

With which racial and ethnic groups do you identify?		
<u>Race/Ethnicity</u>	<u>N</u>	<u>Percentage</u>
American Indian or Alaskan Native	7	1.4%
Asian or Asian American	80	15.5%
Black or African American	21	4.1%
Hispanic, Latine/Latinx, or Spanish Origin	59	11.4%
South Western Asia and North African (Middle Eastern or North African)	8	1.6%
Native Hawaiian or Other Pacific Islander	5	1.0%
White	381	73.8%
Prefer not to say	10	1.9%
Total	516	

Perceptions of Potential Barriers & Important Factors

Participants were separated into two groups based on their response to the survey item asking for their race and ethnicity. Participants who said they belonged to at least one of the following groups were labeled as “minoritized” in the dataset: American Indian or Alaskan Native, Black or African American, Hispanic, Latine/Latinx, or Spanish origin or Native Hawaiian or Other Pacific Islander. While there are issues with combining different identities that have been historically and through modern times excluded in STEM disciplines, this method provides insight into factors potentially excluding these groups from graduate education. In addition, sample sizes in many of the individual groups were too small to run meaningful statistical analyses.

We report here only on a subset of the sub-item topics for both items, seven for the first item and five for the second item. A one-way analysis of variance (ANOVA) was not employed because for 8 of the 12 sub-item topics, the Homogeneity of Variance assumption was

violated. Thus, for ease of comparison and consistency, Mann-Whitney U tests were performed using the minoritized/non-minoritized variables for all sub-item topics. Table 3 contains Mann-Whitney U test results for the minoritized/non-minoritized groups for the 515 participants who responded to the selected sub-item topics from the first survey item.

Table 3. Mann-Whitney U test results for selected items for the question, “To what extent are the following factors a potential barrier to your pursuit of graduate school?” using the minoritized/non-minoritized variable.

<u>Item</u>	<u>Group</u>	<u>N</u>	<u>Mean</u>	<u>Mean Rank</u>	<u>U</u>	<u>Z</u>	<u>p</u>	<u>r</u>
Graduate application fees	Minoritized	85	3.08	313.68	13542	-3.88	<.001	0.17
	Not	430	2.47	246.99				
Paying for the General GRE Test (\$220)	Minoritized	85	3.40	317.02	13003.5	-4.22	<.001	0.19
	Not	427	2.69	244.45				
Paying for the GRE Mathematics Subject Test (\$150)	Minoritized	85	3.38	320.90	12843.5	-4.41	<.001	0.19
	Not	429	2.62	244.94				
Sending GRE scores to programs (\$30 per program)	Minoritized	85	3.16	311.82	13530.5	-3.83	<.001	0.17
	Not	428	2.50	246.11				
Availability of scholarships/funds or my ability to pay tuition	Minoritized	84	4.19	320.87	12653	-4.47	<.001	0.20
	Not	429	3.55	244.49				
Parenting or family responsibilities	Minoritized	84	2.35	316.92	12901	-4.60	<.001	0.20
	Not	428	1.68	244.64				
A lack of mathematicians/scientists that look like me	Minoritized	83	2.82	322.11	12358	-4.74	<.001	0.21
	Not	429	1.93	243.81				

The output of a Mann-Whitney U test is a Z value on a normal distribution. The Z values in Table 3 indicate that the minoritized group has greater means than the non-minoritized group. These results show there is a statistically significant difference (all p 's < .05) between the minoritized/non-minoritized groups in the responses for all seven sub-item topics. In all cases the minoritized participants were more likely to view each sub-item topic as a potential barrier to their pursuit of graduate school than their peers. All of these results had a small effect size (all r 's between 0.1 and 0.3).

For the second survey item, “How important are the following factors in choosing which schools you apply to?”, it should be noted that not all participants saw this item. Prior to this, participants were asked to state their interest in graduate school in mathematics. Only participants who responded with anything other than “Not interested in graduate school in mathematics” saw this item. Table 4 contains Mann-Whitney U test results for the

minoritized/non-minoritized groups for the 435 participants who responded to the selected sub-item topics from the second survey item.

Table 4. Mann-Whitney U test results for selected options for the question, “How important are the following factors in choosing which schools you apply to?” using the minoritized/non-minoritized variable.

<u>Item</u>	<u>Group</u>	<u>N</u>	<u>Mean</u>	<u>Mean</u> <u>Rank</u>	<u>U</u>	<u>Z</u>	<u>p</u>	<u>r</u>
Availability/Amount of assistantships or scholarships	Minoritized	74	4.61	259.74	10194	-3.51	<.001	0.17
	Not	360	4.20	208.82				
Cost of living	Minoritized	74	4.54	278.77	8860	-4.84	<.001	0.23
	Not	361	3.92	205.54				
No GRE General Test requirement or no minimum score requirement	Minoritized	74	3.09	257.91	10329.5	-3.12	.002	0.15
	Not	360	2.52	209.19				
Having peers who are the same race/ethnicity as myself	Minoritized	73	2.52	278.45	8654	-5.52	<.001	0.27
	Not	360	1.51	204.54				
Having a thesis advisor of the same race/ethnicity as myself	Minoritized	73	2.19	274.76	8850.5	-5.62	<.001	0.27
	Not	359	1.34	204.65				

**Note the total N for these tables are strictly less than the previous tables since participants not interested in graduate school did not get this question.*

The Z values in Table 4 indicate that the minoritized group has greater means than the non-minoritized group. These results show there is a statistically significant difference (all p 's < .05) between the minoritized/non-minoritized groups in the responses for all five sub-item topics. In all cases the minoritized participants were more likely to view each sub-item topic as an important factor in choosing which school to apply to than their peers. All of these results had a small effect size (all r 's between 0.1 and 0.3).

These Mann-Whitney U test results show that minoritized participants are more concerned about the cost of different aspects of the graduate school application process compared to their peers. They are also more concerned about being able to afford to attend graduate school. Finally, they are more concerned about having peers and advisors with the same race/ethnicity in the graduate programs to which they apply.

Annual Income

To examine the relationship between family income and minoritized status, participant responses to the item “To the best of your knowledge, which category best describes your family's yearly household income while you were growing up?” were analyzed. A Chi-squared test of association determined that there was an association between ethnicity status and income category $\chi^2(4, N = 512) = 46.44, p = <.001, V = .30$. This result had a medium effect size. Minoritized participants were more likely to come from lower income families than their peers: half of the minoritized participants were from families that made less than \$60,000 dollars a year while only 17.6% of non-minoritized participants were from families that made less than \$60,000 dollars a year.

Discussion

These test results show two main threads in which minoritized participants demonstrate different concerns from their peers: finances and a lack of racial diversity in graduate education. The financial concerns are most obvious in results for 7 of the 12 sub-item topics showing that minoritized participants were directly concerned about funding or finances. Results from another two sub-item topics, familial responsibilities and favoring programs with less stringent GRE requirements, may also be caused (at least in part) by financial concerns. We also found that significantly more minoritized participants reported that they were from low-income households than their peers. The Theory of Racialized Organization and racial capitalism explain how the apparently uniform cost of the application process serves as a contextual barrier and thus a gatekeeper, preventing minoritized students from entering mathematics programs at the graduate level. The results from the last three sub-item topics that do not fit under the topic of finances demonstrate minoritized participants' well-grounded concerns that they will be the only person who looks like them in their department. We know from the demographics of mathematics graduate programs that many mathematics departments are likely to have few, if any, minoritized students (Golbeck, et al., 2019). This can have multiple repercussions for the few minoritized students at these programs. The Theory of Racialized Organizations calls into question why programs have so few minoritized students and the impact that could have on students who are applying. Did these programs previously admit minoritized students who either left of their own volition or were forced out? Is the work of minoritized students, both inside and outside of the classroom, systematically undervalued at these programs? The lack of diversity in these programs negatively impacts minoritized students' decisions to apply.

Based on these results we recommend that programs hoping to recruit and support minoritized students seek ways to minimize the cost of applying to, and staying in, the program. For example, consider removing the GRE General and Subject test requirements (for additional reasons to exclude the GRE from admission requirements, see McEldowney et al., 2024, Miller et al., 2019, and Posselt, 2016). Consider allowing unofficial transcripts in the application and only require official transcripts for admitted students. Advocate for the financial well-being of current graduate students. Try to obtain more funding for graduate students either internally or externally. If faculty are eligible for university childcare programs or childcare subsidies, advocate for graduate students to be eligible for those programs.

In terms of research implications, there is still more data to be analyzed from the Knowledge-GAP survey. A clear next step for the project is to test for differences in knowledge of application fees by race or ethnicity. We also need to examine differences in perceptions of the graduate school application process by other demographic information like gender, income, etc. the Knowledge-GAP is only the first step in studying mathematics graduate student application and admissions processes. More work is necessary to fully understand which factors impact students, especially minoritized students, choice of graduate schools and what obstacles they face. We also look forward to seeing future qualitative research can be done in this area.

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References

- Cadena, M. A., Amaya, C., Duan, D., Rico, C. A., García-Bayona, L., Blanco, A. T., Agreda, Y. S., Villegas Rodríguez, G. J., Ceja, A., Martinez, V. G., Goldman, O. V., & Fernandez, R. W. (2023). Insights and strategies for improving equity in graduate school admissions. *Cell*, 186(17), 3529-3547.
- Chari, D., & Potvin, G. (2019a). Admissions practices in terminal master's degree-granting physics departments: A comparative analysis. *Physical Review Physics Education Research*, 15(1), 010104.
- Chari, D., & Potvin, G. (2019b). Understanding the importance of graduate admissions criteria according to prospective graduate students. *Physical Review Physics Education Research*, 15(2), 023101.
- Cochran, G. L., Hodapp, T., & Brown, E. E. (2018). Identifying barriers to ethnic/racial minority students' participation in graduate physics. In *Physics Education Research Conference*.
- Estrada, M., Burnett, M., Campbell, A. G., Campbell, P. B., Denetclaw, W. F., Gutiérrez, C. G., Hurtado, S., John, G. H., Matsui, J., McGee, R., Okpodu, C. M., Robinson, T. J., Summers, M. F., Werner-Washburne, M., and Zavala, M. E. (2016). Improving underrepresented Minority student persistence in STEM. *CBE-Life Sciences Education*, 15(3), es5.
- Gevertz, J. L., & Wares, J. R. (2020). Fostering Diversity in Top-Rated Pure Mathematics Graduate Programs. *Notices of the American Mathematical Society*, 67(2).
- Golbeck, A. L., Barr, T. H., & Rose, C. A. (2019). Fall 2017 Departmental Profile Report. *Notices of the American Mathematical Society*, 66(10) 1721-1730.
- Golbeck, A. L., Barr, T. H., & Rose, C. A. (2020). Report on the 2017-2018 New Doctoral Recipients. *Notices of the AMS*, 67(8) 1200-1213.
- Harris P. E. and Winger A. (2020). *Asked and answered: Dialogues on advocating for students of color in mathematics*. Independently published.
- Leyva, L. A., McNeill, R. T., Marshall, B. L., & Guzmán, O. A. (2021). "It seems like they purposefully try to make as many kids drop": An analysis of logics and mechanisms of racial-gendered inequality in introductory mathematics instruction. *The Journal of Higher Education*, 92(5), 784-814.
- McEldowney, T., Townsend, E., Maldonado, D., Michaluk, L., & Deshler, J. (Accepted). Undergraduate Gender Differences in Knowledge of the GRE and Perception of the GRE as a Barrier to Applying to Graduate Mathematics Programs. *Proceedings of the 26th Annual Conference on Research in Undergraduate Mathematics Education*
- Melamed, J. (2015). Racial capitalism. *Critical Ethnic Studies*, 1(1), 76–85.
<https://www.jstor.org/stable/10.5749/jcritethnstud.1.1.0076>
- Miller, C. W., Zwickl, B. M., Posselt, J. R., Silvestrini, R. T., & Hodapp, T. (2019). Typical physics Ph. D. admissions criteria limit access to underrepresented groups but fail to predict doctoral completion. *Science Advances*, 5(1), eaat7550.
<https://doi.org/10.1126/sciadv.aat7550>
- National Center for Science and Engineering Statistics. (2019). *Women, Minorities, and Persons with Disabilities in Science and Engineering: 2019*. Special Report NSF 19-304. Alexandria, VA. Available at <https://www.nsf.gov/statistics/wmpd>
- Poon, O., Lee, D. H., Galvez, E., Song Engler, J., Sérrano, B., Raza, A., Hurtado, J. M., & Chun, N. K. (2023). A Möbius Model of Racialized Organizations: Durability of Racial Inequalities in Admissions. *The Journal of Higher Education*, 1-26.

- Posselt, J. R. (2016). *Inside graduate admissions: Merit, diversity, and faculty gatekeeping*. Harvard University Press.
- Potvin, G., Chari, D., & Hodapp, T. (2017). Investigating approaches to diversity in a national survey of physics doctoral degree programs: The graduate admissions landscape. *Physical Review Physics Education Research*, 13(2), 020142.
- Ray, V. (2019). A theory of racialized organizations. *American Sociological Review*, 84(1), 26-53.
- Roberts, S. F., Pyfrom, E., Hoffman, J. A., Pai, C., Reagan, E. K., & Light, A. E. (2021). Review of racially equitable admissions practices in STEM doctoral programs. *Education Sciences*, 11(6), 270.
- Scherr, R. E., Plisch, M., Gray, K. E., Potvin, G., & Hodapp, T. (2017). Fixed and growth mindsets in physics graduate admissions. *Physical Review Physics Education Research*, 13(2), 020133.
- Students for Fair Admissions Inc. v. President & Fellows of Harvard College, 600 U.S. ____ (2023) <https://supreme.justia.com/cases/federal/us/600/20-1199/>
- U.S. Census Bureau QuickFacts: United States. (2020). Retrieved September 29, 2020, from <https://www.census.gov/quickfacts/fact/table/US/PST045219>
- Wilson, M. A., DePass, A. L., & Bean, A. J. (2018). Institutional interventions that remove barriers to recruit and retain diverse biomedical PhD students. *CBE—Life Sciences Education*, 17(2), ar27.
- Wingrove-Haugland, E., & McLeod, J. (2021). Not “Minority” but “Minoritized”. *Teaching Ethics*, 21(1).
- Young, N. T., & Caballero, M. D. (2019). Using machine learning to understand physics graduate school admissions. *arXiv preprint arXiv:1907.01570*.