# An Exploration of Differences Between Undergraduate Mathematics Students' Knowledge About Graduate School at R1 versus Liberal Arts Institutions

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*Abstract: The Carnegie Classification sorts institutions by their different styles of education. Two prominent types of institutions are high research activity universities (R1) and liberal arts focused colleges (LA). Institutional characteristics may positively (e.g. Eide et al., 1998) or negatively (e.g. Astin, 1997) affect graduate school aspirations. We analyzed responses from a national undergraduate mathematics major sample using chi-squared and Mann-Whitney U tests to identify differences between students' knowledge about graduate school and its application process by these two types of institutions. Using this same sample, we used chi-squared tests to explore the differences between departmental (professors, advisors, and mentors) support by institution type. We interpret these results with the theories of social and cultural capital and offer suggestions for future research investigations.*

*Keywords:* Graduate School Applications, Graduate School, Liberal Arts, R1, Social Capital

## Introduction

Higher education institutions are diversified to accommodate different educational goals. Some universities and colleges focus on research activity, others focus on teaching and mentoring of smaller student bodies, and others prepare students for specific skills-based professions. Studies show that these institutional characteristics affect student outcomes including whether or not students attend graduate school (Adedokun et al., 2012; Astin, 1997; Blaney & Wofford, 2021; Bruthers & Matyas, 2020; Eide et al., 1998; Ethington & Smart, 1986; Faurot et al., 2013; Hanson et al., 2016; Hathaway et al., 2002; Hearn, 1987; Kot, 2014; Mu & Fosnacht, 2019; Ostrove et al., 2011; Willis et al., 2013; Zhang, 2005).

Institutions with a similar focus often have many characteristics in common. The categorical system used in classifying institutions is the Carnegie Classification of Higher Education Institutions or Carnegie Classification for short (Indiana University Center for Postsecondary Research, n.d.). The Carnegie Classification sorts universities into doctoral universities, master's colleges and universities, baccalaureate colleges, baccalaureate/associates colleges, associates colleges, and special focus institutions. Each category contains smaller subcategories and the two main categories we will focus on are doctoral universities with high research activity (R1 institutions) and baccalaureate colleges with a liberal arts focus (LA institutions). In the most recent classification from 2021, the baccalaureate colleges with a liberal arts focus were labelled as baccalaureate colleges with an arts and sciences focus. We maintain the LA (liberal arts) label since most of those institutions still self-identify with that label.

## Literature Review

Devereux (2023) states that an institution's classification ranking has a direct linear relationship with its level of sponsored research and foundation funding with higher rankings associated with larger amounts of funding demonstrating a Matthew effect, in that institutions

with resources are more adept at securing more resources (Devereux, 2023). Thus, non R1 institutions experience limitations or barriers in growing their faculty and administrative resources leading to strain on existing faculty and staff to secure externally sponsored funding (Devereux, 2023). Grunig (1997) discusses similar findings with research and reputation arguing that institutions increase their research levels to supply satisfaction to their customers so that they can receive the resources (funding) needed to continue their mission (education). Thus, the higher the institutions' classification, the more resources they obtain, and thus their customers (students) perceive higher quality service (education).

Before examining the literature on undergraduate institution effects on students' graduate educational goals, it must be noted that Etmanski (2019) suggests that the "cooling out" hypothesis (students opting out of pursuing an advanced degree) does not play out within the Ph.D. program, but instead prior to the entrance into the program. Additionally, Astin (1997) reports that attending an R1 institution negatively affects graduate school aspirations. Thus, it is imperative for all undergraduate, but especially R1, institutions to not adopt cultural characteristics that discourage students from pursuing a Ph.D.

Some studies note that the quality of the undergraduate institution affects graduate school aspirations and attendance. Eide et al. (1998) and Zhang (2005) report that graduates from high quality or elite colleges were more likely to enroll in graduate programs and for that program to be at a R1 institution. These studies viewed attending R1 institutions for a Ph.D. positively since these institutions focus on providing Ph.D. students with necessary and higher quality research experiences due to their additional resources (Devereux, 2023; Grunig, 1997). With regards to undergraduate research experiences, participating in research experiences in general have been shown to have positive effects on graduate education (Adedokun et al., 2012; Bruthers & Matyas, 2020; Hathaway et al., 2002; Willis et al., 2013). Personal connections with professors through interactions or teaching also affects graduate school aspirations. Researchers have shown that good teaching practices (e.g. non-classroom interactions, frequency of interactions, teaching clarity and organization), mentorship by faculty on undergraduate research projects, integration within the social and academic systems of the institution, and supportive departmental climate have positive effects on persistence to graduate school (Ethington & Smart, 1986; Faurot et al., 2013; Hanson et al., 2016; Ostrove et al., 2011). Researchers have also shown that personal relationships with faculty have a strong positive effect on graduate school aspiration (Blaney & Wofford, 2021; Hearn, 1987). Thus, personal relationships with professors impact graduate school aspirations.

A different aspect of relationships with professors and departments is the quality of advising the students receive. Mu and Fosnacht (2019) found that students' interactions with advisors were crucial for learning outcomes and that the quality of their peers' interactions with advisors influences students' self-perceived gains, over and above their individual interactions. With regards to centralized advising, students with centralized advising reported a better perception of advising compared to faculty advising and achieved better grade point averages (GPAs) compared to students without any advising (Kennedy-Dudley, 2007; Kot, 2014). It must be noted that these studies have primarily occurred at R1 institutions where faculty members may not have enough time or be offered incentives to invest the necessary amount of time and resources to advise and mentor students well (Faurot et al., 2013; Kot, 2014). Thus, faculty advising at LA institutions might have similar effects since the professors are more likely to be offered the necessary incentives. Therefore, advising affects graduate school aspirations.

In this paper, we address the following research questions:

1. What are the differences between R1 and LA mathematics students' interest in attending graduate school? What are the differences between R1 and LA students with respect to their knowledge about graduate school and applying to graduate school in mathematics?
2. What are the differences between R1 and LA mathematics students with respect to the quality of their relationships with their mathematics departments? Do these relationships have an impact on the answers to the previous question?

## Theoretical Framework

In this paper, we apply the theories of social and cultural capital (Bills, 2000, 2003; Bourdieu, 2018; Coleman, 1988). Coleman (1988) defines social capital by its function, as 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). For this paper, we consider the potential for information abiding in social relations as social capital (Coleman, 1988). Specifically, Coleman (1988) describes "social capital relations that constitute a form of social capital that provides information that facilitates actions" (p. S104). In our case, we view the relationships that undergraduate students have within their departments (peers, advisors, staff, professors, and mentors) as this form of social capital with respect to applying to graduate school in mathematics. Another form of social capital inherent to relations within departments is access to letter writers. Possessing a strong enough social relation with a person (in our case, a mathematics professor) enables the action of asking for a letter of recommendation. In this paper, we focus on student social relationships with their advisors, professors, and mentors.

Bills (2000) defines cultural capital to be "the degree and ease of familiarity that one has with the dominant 'culture' of society" (p. 90).[1] For our purposes, since most graduate schools in mathematics are located at R1 institutions, we argue that R1 students have more cultural capital than LA students regarding graduate school aspirations. Indeed, R1 students are surrounded by graduate students and graduate faculty, and even more so, graduate students at R1 institutions teach undergraduate courses. So, undergraduate students might interact with graduate students as much as the faculty. Therefore, this observation leads to the fact that R1 students have more exposure and so more opportunities to learn about graduate school compared to their LA peers.

## Methods

### Instrument Development

The research team created a survey partly based on another used to investigate undergraduate physics majors' interest in graduate school and how important they believed different aspects of the application process were (Chari & Potvin, 2019).[2] Nineteen survey items were adapted from that instrument. Our survey also provided an opportunity for participants to express their lack of knowledge about different parts of the application process. The final survey had 57 items in four categories: (a) knowledge about different aspects of the application process, (b) barriers for applying, (c) interest in graduate school and what students want in programs they apply to, and

[1] The published manuscript does not contain this quote, but an earlier study cites the unpublished version containing it (Bills, 2000, 2003; Pascarella et al., 2004).

[2] The full survey is available at this link: https://researchrepository.wvu.edu/faculty_publications/3291/

(d) demographic items. Most were Likert scale or multiple choice, but four were open-ended and some multiple-choice items allowed participants to type in text responses.

**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 ($N = 985$). We asked programs to distribute the survey to all undergraduate mathematics majors. Emails were sent Fall 2022 through Spring 2023, via Qualtrics, and follow-up emails were later sent to increase response rate. The survey was also posted on social media, listservs, and in several professional mathematics organizations' newsletters.

**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 our research questions, we analyzed responses to six survey items. Four were multiple choice items. The first asked participants about their interest in graduate school in mathematics. Possible responses included not interested, interested in earning a masters degree only, interested in earning a masters then a doctorate, interested in attending a post baccalaureate program before a doctorate, interested in earning a doctorate without a masters or a post baccalaureate first, and not sure. The second asked participants to rate their familiarity with the following concepts about the GRE Mathematics Subject Test; response choices included never heard of the item or if they have heard of the item before. The list of sub-items included the subject tests are only available three times a year, the subject test is not available to take from home and you must travel to a testing center to take it, and the Mathematics Subject GRE costs $150 to take. The third asked participants if their advisor (the person who helped the participant sign up for their courses) was faculty in mathematics, faculty in another discipline, staff (not faculty), or other. Then, the fourth asked if their advisor would support them in applying to graduate school. Possible responses were Yes (but I have not asked), Yes (they either suggested it and/or are actively supporting me), No (I have not asked), and No (I have asked). Another item was binary asking if students had a mathematical mentor (someone who had not necessarily been formally assigned to the participant by their institution but gives them advice on how to advance their career in mathematics). The last two were Likert scale items: *To what extent are the following factors a potential barrier to your pursuit of graduate school?* and *To what extent do you…* (followed by a set of phrases). The first item was adapted from Chari and Potvin (2019) and had 17 sub-item topics rated on a scale of 1 (not at all a barrier) to 5 (very significant barrier). The second item had 11 sub-item topics rated on a scale of 1 (not at all) to 5 (very much so). Chi-squared tests of association were employed to analyze the multiple-choice items. For the Likert scale items, a one-way analysis of variance (ANOVA) was not employed because for three out of the four sub-items, the Homogeneity of Variance assumption was violated. Thus, for ease of comparison and consistency, Mann-Whitney U tests were performed using the R1/LA variables for all sub-items.

## Results

Before we present our main results, a few small reports are in order. First, a chi-squared test of association found that there was no significant difference between R1 and LA participants in wanting to attend graduate school. Second, for all the $\chi^2$ tests of associations applied to questions regarding knowledge of graduate school, only two questions were statistically significant and they covered knowledge about the GRE Mathematics Subject Test, specifically whether participants knew: (1) Subject Tests are only available three times a year in September, October, and April [$\chi^2(1, 211) = 4.279$ ($p = 0.039$, $V = .14$)]; (2) The subject test is not available to take from home and you must travel to a testing center to take it [$\chi^2$ $(1, 211) = 4.244$ ($p = 0.039$, $V = .14$)]. For those questions, only participants who recorded that they knew about the GRE Mathematics Subject Test saw them. Thus, there was not a significant difference between the populations with knowing about the GRE Mathematics Subject Test, but there was a significant difference in specific knowledge about the test.

*Table 1. Descriptive statistics for the question, "Who is your undergraduate advisor?" using the R1/LA variable.*

| Group | Type | Faculty in Mathematics | Faculty in Another Discipline | Staff (not faculty) |
|---|---|---|---|---|
| R1 | Observed | 115 | 31 | 70 |
| | Expected | 139.1 | 32.0 | 50.3 |
| LA | Observed | 98 | 18 | 7 |
| | Expected | 73.9 | 17.0 | 26.7 |

*Table 2. Descriptive statistics for the question, "Do you think your undergraduate advisor would support you in applying to graduate school in mathematics?" using the R1/LA variable.*

| Group | Type | Yes (not asked) | Yes (suggested or actively supporting) | No (not asked/asked) |
|---|---|---|---|---|
| R1 | Observed | 144 | 39 | 41 |
| | Expected | 138.7 | 57.9 | 27.4 |
| LA | Observed | 74 | 52 | 2 |
| | Expected | 79.3 | 33.1 | 15.6 |

*Table 3. Descriptive statistics for the question, "Do you have someone you consider a mathematical mentor?" using the R1/LA variable.*

| Group | Type | Yes | No |
|---|---|---|---|
| R1 | Observed | 119 | 123 |
| | Expected | 137.6 | 104.4 |
| LA | Observed | 92 | 37 |
| | Expected | 73.4 | 55.6 |

When analyzing between the populations about departmental support, we found that LA participants were more likely than R1 participants to have an advisor that is a faculty member in mathematics [$\chi^2$ $(2, 339) = 38.384$ ($p < 0.001$, $V = .31$)] (Table 1), feel supported in applying to graduate school by their advisor [$\chi^2$ $(4, 372) = 45.248$ ($p < 0.001$, $V = .35$)] (Table 2), and have a

math mentor [$\chi^2$ (1, 371) = 16.823 ($p < 0.001$, $V = .21$)] (Table 3). All these results were statistically significant differences ($p < 0.05$). The first two have a medium effect size ($r$ between 0.3 and 0.5) and the third one has a small effect size ($r$ between 0.1 and 0.3).

Note that only 2 (< 2%) out of 128 LA participants reported not feeling supported by their undergraduate advisor in applying to graduate school compared to 41 (18%) out of 224 R1 participants. This perceived lower lack of support, mentorship, and connection in mathematics was also reflected in Tables 4 and 5, related to Mann-Whitney U results on four Likert scale items.

*Table 4. 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 R1/LA variable.*

| Item | Group | *N* | Mean | Mean Rank | *U* | *Z* | *p* | *r* |
|---|---|---|---|---|---|---|---|---|
| Obtaining letters of recommendation | R1 | 242 | 2.77 | 208.79 | 10335 | -5.61 | <.001 | 0.29 |
| | LA | 130 | 2.01 | 145.00 | | | | |

Table 4 contains Mann-Whitney U test results for R1/LA groups for the 372 participants who responded to the selected sub-item. The output of a Mann-Whitney U test is a $Z$ value on a normal distribution. The $Z$ value in Table 4 indicated that the mean of the R1 group was higher than the LA group. The result shows that there was a significant difference ($p < 0.05$) between the R1/LA groups. The R1 participants were more likely to view obtaining letters of recommendation as a barrier to their pursuit of graduate school compared to the LA participants. This result has a small effect size ($r$ between 0.1 and 0.3).

*Table 5. Mann-Whitney U test results for selected items for the question, "To what extent do you…" using the R1/LA variable.*

| Item | Group | *N* | Mean | Mean Rank | *U* | *Z* | *p* | *r* |
|---|---|---|---|---|---|---|---|---|
| Have mentors who encourage you to study mathematics | R1 | 243 | 3.42 | 168.41 | 11278 | -4.63 | <.001 | 0.24 |
| | LA | 129 | 4.14 | 220.57 | | | | |
| Relate to your classmates in mathematics classes | R1 | 243 | 2.88 | 174.65 | 12794.5 | -2.99 | 0.003 | 0.16 |
| | LA | 129 | 3.29 | 208.82 | | | | |
| Feel like you belong in mathematics classes | R1 | 243 | 3.42 | 176.27 | 13187 | -2.60 | 0.009 | 0.13 |
| | LA | 129 | 3.78 | 205.78 | | | | |

Table 5 contains Mann-Whitney U test results for R1/LA groups for 372 participants who responded to the selected sub-items. The $Z$ value in Table 5 indicated that the means for the LA group was higher than the means of the R1 group. The results show that there were significant differences ($p < .05$) between the R1/LA groups. The LA participants were more likely to have mentors who encourage them to study mathematics, relate to their classmates in mathematics classes, and feel like they belonged in mathematics classes compared to their R1 peers. These results had small effect sizes ($r$'s between 0.1 and 0.3).

## Discussion

Results from this exploratory study revealed that there was no statistically significant difference between our R1 and LA participants about knowledge of graduate school and the graduate application process except for specific knowledge about the GRE Mathematics Subject Test. We find these results encouraging, suggesting that in general, relationships at both institutions provide students with similar information. This is important given all the additional opportunities and resources available to R1 institutions and students (Devereux, 2023; Faurot et al., 2013; Grunig 1997; Hathaway et al., 2002). We conclude that LA students are receiving the same resources from their institutions or outside of their institutions, e.g. research experiences (Adedokun et al., 2012; Bruthers & Matyas, 2020; Faurot et al., 2013; Hathaway et al., 2002; Willis et al., 2013). Further research needs to be done to figure out which relationships are giving these students their social capital. Further, we found no statistically significant differences in aspirations to attend graduate school between these two groups.

We believe the supportiveness of the LA departments is providing their students with their capital (see results from Tables 1 through 5). In congruence with the literature, it seems that their personal relationships with their professors, advisors, and mentors are leading them to want to aspire to graduate school (Blaney & Wofford, 2021; Hanson et al., 2016; Hearn, 1987; Mu & Fosnacht, 2019). In further congruence, it appears that the supportiveness of their departments is also contributing to them wanting to aspire to graduate school (Ostrove et al., 2011). However, we note that, based on Table 1, 32.4% of the R1 participants had an advisor who was staff and only about half (53.2%) of our R1 participants had an advisor who was mathematics faculty. Based on the literature, these results are not surprising (Kennedy-Dudley, 2007; Kot, 2014), but they show that a sizeable portion of our R1 participants perceive that they are missing out on a crucial component of support from their mathematics community compared to the LA participants. We see this lack of support in Table 2 where 18% of R1 participants either assumed their advisor would not support them or that their advisor refused to support them in applying to graduate school. This leads us to conclude that our R1 participants are not forming personal connections with their professors, advisors, and mentors, or, at least in the case of mentors, they do not have one (see Tables 3 - 5). Further research must be done to investigate why this phenomenon occurs. However, these students still acquire the same knowledge as the LA students but without utilizing the social capital within relationships with their professors, advisors, and mentors. Instead, we argued that they acquire it through their cultural capital. We also hypothesize that they wield social capital but through their relationships with their peers and within math clubs. Further research must be done to confirm this argument. In conclusion, the LA participants acquire through their social capital the same advantages that the R1 participants acquire through their social and cultural capital, but further research must be conducted to decipher where R1 participants are acquiring their knowledge.

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