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Abstract

This quantitative study aimed to understand the association between five different types of face-to-face support from institutional agents and the academic progress of international students in STEM master's programs in the U.S. We used one-of-a-kind primary survey data from a National Science Foundation grant that included over 350 master's students across 12 research institutions in the U.S. Drawing from the concepts of social, cultural, and navigational capital, we proposed that support from all five institutional agents of peers, faculty, mentors, advisors, and staff would be important for reaching academic milestones in their master's programs. Based on ordinal logistic regression findings, we found that support from peers and faculty played a positive and statistically significant role in academic progress whereas support from staff played a negative and statistical role. In our final models, we did not find any statistical results for the influence of support from mentors or advisors. In the concluding sections, we draw on existing research and programs to explain our mixed findings and, based on our findings, proposed programs and policies to leverage the positive influence of peers and faculty and to offset the negative and non-findings for our other institutional agents.

Introduction

International graduate students (IGS) are important to U.S. higher education within science, technology, engineering, and mathematics (STEM) programs in three different but overlapping measures. *Numerically*, Open Doors (IIE, 2025) reported that the total enrollment of IGS in the 2023/24 academic year (AY) was 502,291—up 7.6% from the prior year whose enrollment of 467,027 had set the previous all-time high. Interestingly, the increase in IGS in both AY2022/23 and AY2023/24 was mainly due to a surge in master's students. In both academic years, about 64% were at the master's level whereas 30% were at the doctoral level with the remaining 6% in professional and unspecified programs. This compares to master's students comprising 50% and doctoral students at 40% of IGS in AY2020/21, representing a 24-percentage point increase in the gap between master's and doctoral students in just 2 – 3 years.

Programmatically, Anderson (2014) argued that doctoral-granting institutions rely on IGS to maintain their graduate programs because IGS often constitute most students within specific fields that in turn attract top-flight faculty. Student-wise, Regets (2007) found that an extra 10 IGS were associated with an extra 3.0 domestic White and 0.20 underrepresented minority students. Shih (2017) also found no crowding-out of domestic students by IGS using the Integrated Postsecondary Education Data. For every 10 additional IGS there were 8 additional domestic graduate students. NFAP (2021) concurred, arguing the presence of IGS allows U.S. institutions to offer high quality STEM programs and without their presence the number of domestic students pursuing graduate degrees would pale in comparison to the U.S. economy. This report also cited the work of Chellaraj et al. (2008) that found for every 1,000 IGS blocked from graduate programs there was an estimated loss of $210 billion in university-based patents and $1 billion in lost tuition over a 10-year span.

Academically, departments with a larger percentage of IGS also have higher rates of general graduation and graduation among domestic students. Abegaz et al. (2020) found that a 1% increase in IGS enrollment led to a 0.7% - 1.0% increase in graduation rates in California and Illinois. The study also found that for each additional IGS PhD recipient, the number of total graduates increased by about 0.7 and domestic graduates by 0.2. Comparable results were found by Zhou and Okahana (2019) where additional STEM IGS in doctoral programs statistically increased the overall and STEM graduation rates and decreased the time-to-degree. This graduation premium associated with IGS is critical for departments and institutions given that domestic students' graduation rates are 13-percentage points lower than their IGS peers in STEM fields (Council of Graduate Schools, 2008).

Thus, it is imperative to understand the factors that contribute to the academic success of IGS. Xu (2014) argued that few studies have examined the factors that promote academic success in graduate education, and Veliz (2020, p. 150) stated few studies have focused on IGS experiences connecting with and navigating the university community and socializing agents. Further, academic success is important personally to IGS. For example, in interviews with 15 Chinese IGS Gu & Usinger (2021) found that "academic success" was the main priority of all the students, and Hyun (2019) found among 12 IGS that they all had clear academic achievement goals. Moreover, timely support is important to IGS because they feel that it is "extremely important" to succeed in their first semester (Anandavalli et al., 2021).

We aimed to fill these gaps mentioned by Xu and Veliz above by using primary survey data from an AY2015 – 2021 *National Science Foundation g*rant to examine how micro face-to-face academic and non-academic interactions with five supportive institutional agents—peers, mentors, faculty, advisors, staff—influenced the degree progress of IGS in STEM master's programs at 12 predominately White (PWI) R1 and R2 research-based institutions in the Western and Mid-Western U.S. Our focus on these agents was informed by research (see below) showing how they provide the dominant tangible resources, which we conceptualize as "capital" that directly and indirectly impacts the academic success of IGS. Our focus on degree progress was an important outcome variable to study as it is a consistent predictor of graduation (CGS, 2013).

We focused only on master's students and their academic progress for four reasons: compared to doctoral students (a) there is a notable lack of research concerning STEM master's academic success (CGS, 2013); (b) we had more

complete educational information on our master's respondents; and (c) master's students represent the larger percentage and growth of IGS in STEM graduate programs (IIE, 2025). Fourth, a master's degree is often a requirement for research-related jobs and entry into STEM PhD programs as well as improving completion and attrition rates by 5 – 7 percentage points once entering into these PhD programs (CGS, 2013, 2015).

Conceptual Approach: Capital as Resources

There are distinct characteristics, cultures, and requirements of STEM compared to non-STEM fields, such as being lab-based (Malcom & Feder, 2016; Pedraza & Chen, 2022; Rodriguez, Perez, & Schulz, 2022). Importantly, STEM IGS are particularly more likely to report a sense of isolation in their lab and classroom settings (Anandavalli et al., 2021; Dutta, 2015). As such, many argue that diverse forms of social ties and capital, principally cultural and social capital and their offshoots, are critical to participation and success in higher education STEM fields especially for women, underrepresented minorities, and those from low SES backgrounds (Park et al., 2021; Saw, 2020). Further, STEM fields are more likely to require what Archer et al. (2014) termed "science capital." Cooper, Cala, & Brownwell (2021, p.3) stated "[i]t is worth noting that cultural capital is field-specific; that is, if someone has cultural capital in a field, such as the field of science, they have the dispositions to think and act in ways that advance their position or trajectory in science." Likewise, in developing their concept of "scientific research capital," The authors emphasized the role of cultural and social capital. Cultural capital encompassed the knowledge, skills, education, and advantages that help students find and succeed in science research. Social capital was the resources needed to secure and succeed in science research gained through relationships, network associations, and group and peer members. In interviews with 85 undergraduate students at a large research-intensive (i.e., R1) institution in the Southwest U.S. they found that the 43 students participating in undergraduate research experiences mentioned five ways to find a research position: university resources (reported by 84% of students), talking with faculty (68%), talking with advisors (29%), talking with graduate assistants (21%), and talking with peers (21%).

We believe these results among undergraduates would equally—if not more so—apply to IGS. We say this because these forms of capital appear to be more important for traditionally underrepresented students who face more obstacles in a conventional education setting (Saw, 2020; Stanton-Salazar, 2011). According to Stanton-Salazar's network-analytic approach (2011), institutional agents, which are nonfamily individuals, have the capacity and commitment to transmit directly, or negotiate the transmission of, high-valued institutional resources and opportunities, especially to racial and ethnic minorities within educational settings. St. John, Hu, and Fisher (2011) concurred when using the term "academic capital." Specifically, they argued that the social and cultural demands faced by underrepresented students in traditional educational settings requires academic capital as a form of social processes that builds knowledge of educational and career options and support navigation through educational systems and professional organizations.

This social capital, often termed "academic capital" routinely resides within the educational context especially from faculty, administrators, and peers (Palmer & Gasman, 2008). Trammell (2019) refined the concept of academic capital arguing that such capital can be seen as a sub-set within the larger world of social and cultural

capital and defined as the transactional value of relationships, networks, associations, and social knowledge that are geared specifically to the higher education context. Trammell argued that academic capital is important for students who can be overwhelmed with the academy, particularly at larger institutions. Thus, "[a]cademic capital is a framework that takes educators back to the primary importance of relationships, which is what the original theory of social capital was all about." (p.62).

Much like Trammell (2019), we do not present our capital-based approach as a deficit model—that is, IGS lack the requisite capital to succeed in STEM graduate programs and need something to help them succeed. Trammel (2019) argued that students are their own agent with partial control over where they want to spend, invest, and develop such capital. Similarly, like Yosso (2005) writing about Students of Color in schools we assumed that STEM IGS can develop relationships, experiences, and relationships to succeed in PWI and STEM contexts and to build on their *already possessed* "cultural wealth" or capital. Of Yosso's six different types of capital, two were consistent with our focus on institutional agents: (a) Social: networks of people and community resources; and (b) Navigational: maneuvering through social institutions historically not created with Communities of Color in mind. Clearly for Yosso (2005), institutional agents can also play a key role in the further development of different forms of capital. These existing forms of capital may be bolstered by our five institutional agents who provide supportive resources to navigate through institutions that may be hostile to and not created culturally (i.e., PWIs) for IGS.

Empirical Support for the Capital Approach

In this study we focused on interactions with five institutional agents—peers, faculty, mentors, advisors, and staff—knowing they can be direct, different, and immediate sources of important academic and non-academic supportive resources (Veliz, 2020). Our emphasis on these specific institutional agents was informed by research showing how they provide tangible resources (i.e., "capital") benefiting IGS by *directly* impacting academic success but mostly by *indirectly* impacting academic success by minimizing and navigating barriers to success such as isolation, anxiety, language issues, and cultural mismatch (Antony & Schaps, 2021; Lorenzetti et al., 2023; Oyeniyi et al., 2021; Veliz, 2020). The need for varied and immediate resources was highlighted by Anandavalli et al. (2021) who interviewed eight IGS of color. They all reported how important it was to succeed in their first semester but also reported particularly high levels of academic pressure that was exacerbated by little knowledge of institutional resources.

Han et al. (2015) stated that international students need these support agents to overcome cultural, language, and institutional issues—issues that are usually not faced by the general population or even domestic underrepresented minorities in STEM. Once at their institutions, Khanal and Gaulee (2019) found that a lack of knowledge of academic conventions and culture and feeling unwelcomed were commonly mentioned as barriers to success. In a wide-ranging review of the models and literature on the socialization of IGS, Veliz (2020) concluded that IGS, especially those in STEM, face unique challenges and that they fare better when peers, mentors, and other institutional agents are involved to help IGS navigate and feel welcomed in U.S. institutional and educational cultures.

Extant research on IGS in U.S. institutions supports these arguments and conclusions. For example, a study among 188 IGS at a large R1 university found greater levels of support by their mentors and advisors were associated with a sense of belonging and fitting in within their departments. Encouragement from these agents also positively affected IGS' academic self-concept and self-confidence (Curtin et al., 2013). The link between positive support and encouragement and academic self-confidence represents a vital connection and resource as Lykebn-Segosebe (2017) interviewed in-depth seven East Asian IGS at a private R1 doctoral university and found that the initial stressor in graduate school was a lack of "academic confidence." Main components of this lack of confidence were acculturative stress and poor interactions with professors.

Likewise, academically, Hyun (2019, p. 59) interviewed 12 IGS who mentioned the need for supporters "who could understand them as who really they are" and their circumstances and difficulties with being an IGS. The study further found that making academic and personal relationships and interactions with peers and faculty—especially those who were academically oriented—were keys in overcoming academic challenges. These agents can play an important academic role as interviews with 15 Chinese IGS at a midsized public university found that academic success was the main priority for all students prior to departure to the U.S. But once here, they reported that the academic culture of the U.S. was more independent than they had realized (Gu & Usinger, 2021).

Further research supports our approach. In a study of five IGS in a mid-size Canadian university, Moores and Popaduik (2011) analyzed 134 critical incidents and concluded that the narratives revealed that simple interactions and discussions with peers made the IGS feel like they were in a supportive family-like environment that valued them personally. Support from faculty, staff, and other institutional agents was about genuine academic and personal support ("caring") as well as practical and administrative aid, all of which helped IGS transition cross-culturally and academically. In support of Yosso (2005), this study's IGS participants reported that their transitions were aided when they had a "cultural guide." These guides may also be a resource for better mental health. A longitudinal study of 54 Chinese and Indian IGS found that greater interactions with host peers significantly decreased levels of acculturative-related self-reported depression (i.e., CES-D scale) over time (Ma, 2021).

For the three interviewed IGS in Moglen (2017), the specific source of stress was language difficulties that resulted in isolation and academic uncomfortableness. The partial remedies were social interactions and connectedness in safe environments where English was spoken. These safe language environments created by institutional agents are necessary to IGS as Zhou et al. (2011) found in a case study on 10 IGS. The participants reported that interactions with faculty, peers, and other staff greatly helped their academic adjustments and motivation to succeed, yet language was a barrier to some of the IGS. Moon et al. (2020) also found that language difficulties created the greatest academic challenges among six Chinese and South Korean IGS. The need for supportive institutional agents was highlighted in this study as the participants reported that they were disappointed with institutional resources geared toward helping IGS. Rodriguez et al. (2019) also found that a lack of institutional resources and knowledge of these resources led to difficulties in academic and general adjustments among seven IGS from a large public research university. These resources from institutional agents and sources, especially academically oriented, are important to IGS as a literature review by Shane et al. (2020) found that a lack of such

resources was one of the main issues hindering the academic success of IGS.

Continuing with the research themes above, Nguyen (2013) interviewed six faculty advisors for IGS, and all reported the need for them to personalize the faculty-IGS relationship and be committed to their student's academic success. In a qualitative study on 27 East Asian IGS by Park et al. (2018), social relationships with peers and faculty advisors provided a vital resource: the acquisition of disciplinary skills that allowed the IGS to academically succeed in their STEM programs. A more recent study (Myers et al., 2023) found that peer and faculty interactions were especially important to help STEM IGS transition interculturally into PWIs perhaps explaining those findings of Ma (2021) who found that greater interactions with host peers decreased stress and depressive symptoms among East Asian IGS at an R1 institution. Lastly, the theme of peer support again emerged in a qualitative study of 13 Canadian IGS who reported that peer relationships provided a safe space and sense of belonging as well as being a source of knowledge to navigate unfamiliar norms, purpose, motivation, and coping (Lorenzetti et al., 2023).

Thus, based on our model and the literature, we expect that those that report more Peer Interaction Support, Faculty Interpersonal Support, Advisor Support, Mentor Cultural Support, and Staff/Other Faculty Support, individually, will have made greater advances in Academic Progress.

Methods

Participants

This survey-based quantitative study was part of a larger mixed-methods National Science Foundation funded project under their Alliances for Graduate Education and the Professoriate program's Transformation track. Our study was designed jointly with a distinct (i.e., different subjects) qualitative component to understand the socialization experiences of graduate students in STEM with a particular interest in underrepresented minorities and IGS. The Social Science Research Group (SSRG) designed and administered the Graduate Student Experience survey and followed the Tailored Design Method (Dillman et al., 2009) for rigor and reliability in all aspects of data collection and analyses. Institutional Review Board "Exempt" approval was granted in accordance with the Code of Federal Regulations, Part 46, section 101.

The SSRG sent the survey to a census of graduate students (n =13,180) in STEM programs at the 12 research universities. The 12 participating institutions were PWI, located in the Western and Mid-Western regions of the U.S., and met three criteria: (1) demonstrated success with the recruitment and retention of diverse students, (2) classified as research doctoral institutions where six were Very High Research Activity (R1) and six were Higher Research Activity (R2) activity, and (3) had graduate instructional programs and classified Carnegie as STEM Dominant (STEM/D) comprehensive programs without medical and veterinary school (CP), and comprehensive programs with medical and veterinary schools (CP/Med/Vet).

There were 4,012 respondents to the survey resulting in a response rate of 30%. Of these 4,012 students, there were 1,085 IGS representing 27% of the final sample. Of these 1,085 we examined only master's students who

comprised 33% (n = 358) of our IGS sample. IGS status was determined by survey responses to a citizenship status question indicating "Citizen of another country, residing in the U.S. with a student visa or other nonresident visa."

Study Variables

The original survey was validated by SSRG in 2015 based on the entire sample of 4,012 domestic and international students. All items used to create original indices were drawn from existing well-validated instruments used on non-IS students. For our sub-sample of IGS, it was possible that the items that comprised each index clustered to create sub-indices. To test this, we conducted exploratory factor analyses and found that each analysis revealed that our outcome and predictor indices all displayed a simple structure, exceeded the eigenvalue-one criterion, and loaded on a single factor. For each measure, we created a composite additive index by summing the individual items and reported the corresponding Cronbach's alpha and eigenvalues.

Academic Progress

Academic Progress was addressed with the following question: *"Which of the following academic milestones have you completed towards your Master's degree? Check all that apply."* There were five ordinal options: (a) thesis committee chosen; (b) thesis proposal successfully completed; (c) thesis completed and approved by committee; (d) thesis defended successfully and approved by committee; and (e) thesis submitted to the graduate school. We then coded each student on an ordinal scale of 1 – 5 based on their highest milestone reported. Given the different amount of time students have been enrolled in the program, in all regression models we controlled for two variables: (a) what year they were in the program (1 = first-year student to 6 = 6^{th} year or greater), and (b) how many, if any, total semesters they have taken off from pursuing their current master's degree. "Stopouts" tend to slow-down academic progress among STEM master's students (CGS, 2013).

Influential Agents and Capital

Five predictor multi-item indices tapped interactions with influential agents and the potential support capital they provided. Below we summarize each independent variable. The full schedule of questions for each index is in Table 1.

Peer Interaction Support ($\alpha = 0.85$; eigenvalue 3.71) was a 7-item index to measure the extent to which students engaged with and found support from their peers in social, personal, and intellectual interactions using all seven measures from the validated Peer-Group Interactions Scale (Pascarella & Terenzini, 1980). *Faculty Interpersonal Support* ($\alpha = 0.91$; eigenvalue: 3.96) index combined six items from two Faculty Scales developed and validated by Pascarella and Terenzini (1980) that measured diverse types of support from faculty outside the classroom involving issues of careers and personal growth. The 5-item *Mentor's Cultural Support* ($\alpha = 0.90$; eigenvalue 3.35) index tapped psycho-sociocultural aspects of the mentoring relationship based on research on the role of culture for persistence in science and engineering (Guillory & Wolverton, 2008; Museus & Quaye, 2009) and

items from the Career WISE survey (Prime et al., 2015). *Advisor Support* (α = 0.88; eigenvalue 2.98) index also used items from the Career WISE survey and combined five questions about the extent to which the student's major advisor was available, timely, constructive, and interested. Lastly, we used a 7-item *Staff/Other Faculty Support* (α = 0.85; eigenvalue 2.75) index developed and tested by SSRG as a proxy for navigational capital that asked the student to evaluate seven statements about the extent to which university staff and others (e.g., financial aid, library, tutoring, faculty) were available and willing to help.

Table 1. Wording and Coding for Items Comprising the Predictor Indices: International Graduate Master's Students in U.S. STEM Programs, 2015 – 2017 (n = 358)

Staff/Other Faculty Support 1=Strongly Disagree to 7=Strongly Agree. All items coded/recoded so higher scores represent greater support. (α = 0.85)	1. The library staff is willing to help me find materials/books. 2. University staff have been warm and friendly. 3. Faculty have not been available to discuss my academic concerns. 4. Faculty have been available for help outside of class. 5. Faculty have been available to help me make course choices. 6. Financial aid staff have been willing to help me with my financial concerns. 7. There are tutoring services available for me on campus.
Peer Interaction Support 1=Strongly Disagree to 5=Strongly Agree. All items coded/recoded so higher scores represent greater support. (α = 0.85)	1. Since coming to this university, I have developed close personal relationships with other students. 2. The student friendships I have developed at this university have been personally satisfying. 3. My interpersonal relationships with other students have had a positive influence on my personal growth, attitudes, and values. 4. My interpersonal relationships with other students have had a positive influence on my intellectual growth and interests in ideas. 5. It has been difficult for me to meet and make friends with other students. 6. Students would be willing to listen to me and help if I had personal problems. 7. I am more likely to attend a cultural event (for example, a concert, lecture, or art show) now than I was before coming to this university.
Faculty Non-Academic Support 1=Strongly Disagree to 5=Strongly Agree. All items coded/recoded so higher scores represent greater support. (α = 0.91)	1. My non-classroom interactions with faculty have had a positive influence on my personal growth, values, and attitudes. 2. My non-classroom interactions with faculty have had a positive influence on my career goals and aspirations. 3. Since coming to this university, I have developed a close personal relationship with at least one faculty member. 4. I am satisfied with the opportunities to meet/interact informally with faculty.

	5. Faculty members I have had contact with are willing to spend time out of class to discuss issues of interest and importance to students. 6. The faculty I have had contact with are. Interested in helping students grow in more than just academic areas.
Mentor Cultural Support 1=Strongly Disagree to 5=Strongly Agree. All items coded/recoded so higher scores represent greater support. (α = 0.90)	1. Is interested (engaged) in my culture. 2. Is interested in me beyond my academic role. 3. Is tolerant about any cultural differences between us. 4. Appreciates cultural diversity. 5. Is friendly toward my family.
Advisor Support 1=Strongly Disagree to 5=Strongly Agree. All items coded/recoded so higher scores represent greater support. (α = 0.88)	1. Is regularly available for advising. 2. Meets with me to discuss research. 3. Is interested in my goals and projects. 4. Provides constructive criticism on my project/research. 5. Returns my work in a timely manner.

Control Variables

Given the lack of quantitative research on our study variables, we used a select set of controls that have been shown to influence the academic and personal lives of IGS (e.g., Curtin et al., 2013; Wang, 2009; Veliz, 2020). Gender was self-reported by the respondents with a binary question offered in the survey (0 = male and 1 = female). Age was captured with a variable where 1 = 18-21 years old to 6 = over 40 years old. We used six race/ethnicity categories from the survey. Even though Asian/Pacific Islander was the largest category, we choose White/Caucasian as the reference category given that our 12 institutions were PWIs. Additional control variables included (a) first STEM student in family (0 = no; 1 = yes); (b) whether married (0 = no; 1 = yes); (c) number of dependents (0 to 2 or more); and (d) parent's highest education level (1 = high school diploma/GED to 8 = doctorate degree).

We included two variables to tap the larger academic environments among the IGS. We coded whether the student was enrolled in an R1: Doctoral Universities – Highest Research Activity vs. an R2: Doctoral Universities – Higher Research Activity (0 = no; 1 = yes). We collapsed the nine measured STEM fields into Biglan's (1973) four disciplinary "Hard" categories: (1) Pure Life (e.g., Biology, Physiology), (2) Pure Nonlife (e.g., Mathematics, Chemistry), (3) Applied Life (e.g., Agriculture, Medicine), and (4) Applied Nonlife (e.g., all Engineering fields, Computer Science). The Biglan classification captures differences in socialization and culture in disparate STEM fields, especially labs (Rodriguez et al., 2022).

Statistical Adjustments and Analyses

Of the original 1,085 IGS in the sample, we omitted 68 due to incomplete surveys and an additional 19 students who did not report their age, race, and/or sex. The rates of missing values on individual items were extremely low for survey data, ranging from 0.0% to 3.3%. Even so, we wanted to produce the most unbiased regression estimates by using multiple imputation methods to generate values for any missing data by generating five imputed datasets as suggested by StataCorp (2021). The final analytical sample was 358 IGS in master's STEM programs.

Ordered logistic regression techniques were used to estimate the relationships between our predictor and outcome variables because our academic progress outcome had a natural ordering of progress (low to high progress) but the distances between each adjacent academic milestone were not mathematically known. To generate robust errors, we used the data set's *Institution* variable in the *clustvar* statement in the STATA *ologit* command to identify that institutional affiliation was where respondents clustered.

Results

Descriptives of Study Variables

Table 2 displays all the study and control variables. STEM IGS reported moderate progress in their master's program as a mean of 1.97 indicated that the average student was at the "thesis proposal successfully completed" milestone. For interactive support and capital resources, the averages were moderate-to-high across the board compared to their respective maximums: Staff/Other Faculty Support (M=38.26), Peer Interaction Support (M=25.75), Faculty Interpersonal Support (M=22.61), Mentor Cultural Support (M=18.39), and Advisor Support (M=18.39).

The standard deviations for these variables—especially Academic Progress—showed a fair amount of variability from student-to-student confirming prior research that students differ widely in their access to influential agents (Zhou et al., 2011). For the academic main control variables, the average student had been in the program for over two years (2.38), and stopouts were relatively rare with a mean of 0.76 indicating the average student had less than one stopout experience. This lack of stopout perhaps explains the close association between year in program and academic milestone achieved.

Regression Estimates

Table 2 contains the ordered logistic regression estimates for the associations between our five measures of interpersonal capital and academic progress in terms of program milestones achieved. We presented the odds ratios (i.e., the exponentiated values of the parameter estimates (e^{β}) because they are substantively more accessible than logistic coefficients or log odds. For capital variables, odds ratios estimate the multiplicative effects of a one-unit change on the odds of moving onto the next academic milestone category (e.g., moving from "thesis committee chosen" to "thesis proposal successfully completed"). For any dichotomous variable, odds ratios estimate the multiplicative effects of being in one category compared to the other or reference category on the

odds of moving onto the next academic milestone category. Odds ratios of 1.0 indicate no influence of capital on academic progress, ratios less than 1.0 represent a multiplicative decrease on academic progress, and ratios greater than 1.0 represent a multiplicative increase on academic progress. Odds ratios can also be interpreted in terms of percentage change in the odds through a simple transformation: $(e^{\beta} - 1) \times 100$.

Table 2. Descriptive Statistics for Study Variables: International Graduate Master's Students in U.S. STEM Programs, 2015 – 2017 (n = 358)

Variable	Coding	M or %	SD
Outcome			
Academic Progress	1 – 5	1.97	1.30
Focal Predictor Indices			
Staff/Other Faculty Support (α = 0.85)	7 – 49	38.26	7.81
Peer Interaction Support (α = 0.85)	7 – 35	25.75	5.11
Faculty Non-Academic Support (α = 0.91)	6 – 30	22.61	4.86
Mentor Cultural Support (α = 0.90)	5 – 25	18.39	4.69
Advisor Support (α = 0.88)	5 – 25	19.80	4.43
Controls			
Year in School	1 – 6	2.38	1.70
Stopout	0 – 4	0.76	1.44
Female	0 = no; 1 = yes	38%	---
Age	1 – 6	2.74	0.83
Asian/Pacific Islander	0 = no; 1 = yes	67.9%	---
Black/African American	0 = no; 1 = yes	8.7%	---
Hispanic/Latino	0 = no; 1 = yes	6.9%	---
White/Caucasian (reference)	0 = no; 1 = yes	9.7%	---
Other	0 = no; 1 = yes	6.8%	---
First STEM Student in Family	0 = no; 1 = yes	65%	---
Married	0 = no; 1 = yes	17%	---
Number of Dependents	0 – 2	0.40	0.77
Parents' Highest Education Level	1 – 8	4.49	2.19
R1 Institution	0 = no; 1 = yes	75%	---
Pure Life	0 = no; 1 = yes	19%	---
Pure Nonlife	0 = no; 1 = yes	24%	---
Applied Life	0 = no; 1 = yes	7.0%	---
Applied Nonlife (reference)	0 = no; 1 = yes	50%	---

We estimated seven regression models: Models 1 – 5 estimated the bivariate relationships between each measure of capital and academic progress. These models did not statistically adjust for the competing influence of the other four capital variables not in the model or the control variables. The last two models served two purposes: Model

6 required each measure of capital to compete with each other to influence academic progress, and Model 7 was the saturated model to determine if any results in Model 6 were altered in the presence of the controls. Briefly, in Models 1 – 5, all measures except for Advisor Support were statistically associated with academic progress (Mentor Cultural Support marginally at $p < .10$) while controlling for year in the program and any stopouts.

Table 3. Odds Ratios for Regressing Academic Progress on Capital Support from Institutional Agents: International Graduate Master's Students in U.S. STEM Programs, 2015 – 2017 (n = 358)

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Focal Predictor Indices							
Staff/Other Faculty Support	0.84***	---	---	---	---	0.90***	0.89***
Peer Interaction Support	---	1.16**	---	---	---	1.14**	1.14**
Faculty Non-Academic Support	---	---	1.18***	---	---	1.16***	1.13***
Mentor Cultural Support	---	---	---	1.09†	---	1.02	1.03
Advisor Support	---	---	---	---	1.00	0.88	0.91
Year in Program	1.93***	1.95***	1.97***	1.97***	1.99***	1.93***	1.91***
Stopout	0.66***	0.67***	0.67***	0.68***	0.66***	0.65***	0.69***
Controls							
Female	---	---	---	---	---	---	0.86
Age	---	---	---	---	---	---	0.66***
White/Caucasian (reference)	---	---	---	---	---	---	---
Asian/Pacific Islander	---	---	---	---	---	---	0.81
Black/African American	---	---	---	---	---	---	0.98
Hispanic/Latino	---	---	---	---	---	---	0.55**
Other	---	---	---	---	---	---	0.89
First STEM Student in Family	---	---	---	---	---	---	0.72***
Married	---	---	---	---	---	---	1.22*
Number of Dependents	---	---	---	---	---	---	0.89
Parents' Highest Education Level	---	---	---	---	---	---	1.41***
R1 Institution	---	---	---	---	---	---	0.85
Applied Nonlife (reference)	---	---	---	---	---	---	---
Pure Life	---	---	---	---	---	---	0.56*
Pure Nonlife	---	---	---	---	---	---	1.15
Applied Life	---	---	---	---	---	---	1.38
Log Likelihood	-2896.7	2900.1	-2850.8	-2696.5	-2781.0	-2636.1	-2052.5
LR Chi-Square	62.65***	62.51***	66.27***	61.36***	63.61***	81.43***	74.24***

† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$ (2-tailed tests).

Both higher levels of Peer Interaction Support and Faculty Interpersonal Support were associated with the achievement of higher levels of academic progress. The Peer Interaction odds ratio (1.16; $p < .01$) indicated that a one-unit increase in reported support increased the odds of reaching the next academic milestone (e.g., moving from "thesis committee chosen" to "thesis proposal successfully completed") by 1.16 times or 16%. Similarly, each unit increase in Faculty Interpersonal Support (1.18; $p < .001$) increased the odds of reaching the next milestone by 1.18 times or 18%. But for Staff/Other Faculty Support, (0.84; $p < .001$), each unit increase in reported support *decreased* the odds of reaching the next academic milestone by 0.84 times or 16%. Across these five models, Year in Program was statistically linked to further academic progress while Stopouts were negatively linked.

Model 6 considers the competing associations between capital and academic progress with little change from Model 5. Both Peer Interaction and Faculty Interpersonal Support continued to be associated with greater odds of reaching the next academic milestone by 14% and 16%, respectively whereas Staff/Other Faculty Support also continued its influence on reaching the next academic milestone albeit negatively at 10%. The minor change between Models 5 and 6 is that the marginally significant result ($p < .10$) for Mentor Cultural Support became non-significant when competing against the other measures of support.

The final Model 7 included all of the control variables in the regression equation with no substantial or statistical changes from Model 6. One possible reason for this is that only a few of the control variables emerged as significant predictors of academic progress above and beyond the strong influence of Year in Program and Stopouts. Interestingly, two common measures of capital were statistically significant: (1) students who were the first STEM students in their family reported a decrease in their odds of reaching the next milestone by 28%; and (2) students coming from parents with higher educational levels were more likely to advance to the next academic milestone—each unit increase in parents' highest educational level increased the odds by 41%. Across all seven models, Chi-Square tests were statistically significant at $p < .001$, which indicated a very low likelihood of making a Type I error and that the models with the predictor variables fit the data structure better and better predicts variation in the outcome variable compared to a null model (i.e., no predictors).

Discussion and Conclusion

We apply a capital-based approach to examine how interactions with influential academic and institutional agents were potential influencers on academic progress among IGS in STEM master's programs. To the best of our knowledge, this study represents a first-of-its-kind in terms of the scope of the sample, capital variables, and techniques, and contributes to existing research in three ways. First, it fills a quantitative gap highlighted by CGS (2013) on the academic progress among IGS in STEM master's programs. Second, our research contributes to the large body of qualitative, single institution, and small sample research (e.g., Dutta, 2015; Kaya, 2020). These contributions were possible by our one-of-a-kind data from 12 research-based institutions, over 350 STEM IGS, and rigorous statistical techniques (logit, validated multi-item indices, multiple imputation, robust standard errors). Third, we focus on understudied topics—cultural and social issues. A review of research in STEM journals from 2000—2018 found that only 9.8% of published articles addressed "culture, social, and gender" issues (Li et

al., 2020). We view our measures of interaction to fall under the broad rubric of "social" including a cultural measure involving mentors.

Of course, there exist limitations of the current study. First, the data are cross-sectional so we could not determine causality between our predictors and outcome variable. It is possible that as these students reach higher academic milestones they interact with, say, faculty and peers more often due to academic needs or an easing of cultural differences. Second, while our five measures of interactions with influential agents were validated and multi-itemed, every item did not *directly* measure the exchange of capital resources. For example, one of the seven items comprising the Peer Interaction Support index was worded "Since coming to this university I have developed close personal relationships with other students." A "close personal relationship" is certainly a requirement and precursor for the acquisition of social, cultural, and navigational capital, but it is not a guarantee. However, many items in our indices could be seen as directly measuring capital. For example, one item on the Staff/Other Faculty index was worded "[t]he library staff is willing to help me find materials/books. Third, the data lacked information of the prior educational experiences of the IGS in our sample, especially information about their undergraduate academics and experiences as well as English language proficiency. Thus, we were unable to control for the types and levels of capital that they brought with them into their STEM graduate program.

Our ordered logistic regression findings were mostly consistent across the seven models. The final model with all of the predictors and control variables is the most stringent test of our assumption: that interactions with these five agents are a potential source of important capital resources that may positively aid IGS in their pursuit of STEM Master's degrees. Our results did not fully align with our expectations. Support from peers and faculty did promote advanced academic milestones. However, the findings for Staff/Other Faculty contradicted our expectations, while the non-roles of mentors and advisors provided no evidence either way.

Peers and faculty have long been shown to be an important support network for IGS, and our results confirm these important roles that these agents assume (Veliz, 2020). The scope of the results also needs to be contextualized. In Model 7, the odds ratio for Peer Interaction Support was 1.14 ($p < .05$) suggesting that each unit increase in such interaction is associated with a 14% increase in the odds of achieving the next academic milestone. While 14% does not seem like much, the index for Peer Interaction Support ranges from 7 to 35 suggesting that a few units increase in Peer Interaction can have a profound influence on academic milestones. Indeed, just a 5-unit increase (about one-standard deviation; SD = 5.11) would result in a 70% (5 x 14%) increase in the odds of reaching the next academic milestone. The story is similar for Faculty Interpersonal Support whose range is 6 to 30, where just a few units increase would have a weighty multiplier effect on the 1.13 odds ratio ($p < .001$) found in Model 7. Indeed, a similar one-standard deviation increase of about 5 (SD = 4.86) would result in a 65% (5 x 13%) increase in the odds of reaching the next academic milestone.

We were surprised that mentors and advisors did not play a significant role in advancing academic milestones given the direction of past research (Curtin, 2013; Park et al., 2018). Yet, in this current study is similar to prior research in that we largely reinforce that peers and faculty are the most important agents in the academic, social, and cultural lives of IGS (Moore & Popadiuk, 2011; Rivas et al., 2019). Perhaps this is why the coefficient for

Mentor Cultural Support went from marginally significant ($p < .10$) to non-significant between Models 5 and 6 when this variable had to compete with the influence of peers and faculty.

Our results translate into policy and research implications. First, our non-findings for advisors and mentors may suggest that the STEM IGS in our study did not seek the support of these agents as much as they did of faculty and peers. Research finds that the advisee-advisor relationship among IGS may be difficult as IGS report that advisors have a lack of openness, time, feedback, guidance, and communication whereas advisors report that IGS lack research skills, English proficiency, and independence (Adrian-Taylor et al., 2007; Nguyen, 2013). As a result, IGS are often reluctant to ask for assistance, report language barriers, and cite heightened levels of conflict/disrespect with advisors, and, thus, turn towards peers and macro-institutional resources for such help (Adrian-Taylor et al., 2007; Moon et al., 2020; Nguyen, 2013; Rice et al., 2016; Sustarsic & Zhang, 2022). This is unfortunate given the dominant role of advisors and mentors have in the academic lives of IGS, especially those in the initial stages of their STEM graduate programs (Zhou & Okahana, 2019). These obstacles must be rectified because Park et al. (2018) found that STEM IGS report that advisors are the second most important source, behind peers, for academic success largely through facilitating the acquisition of disciplinary skills. Positive relationships also reduce academic stress among IGS whereas IGS who felt disrespected by their advisors are more likely to be academically stressed (Rice et al., 2016). One possible program, as reported as the second-best conflict prevention measure by IGS, is to have initial and ongoing cultural and diversity training for faculty members (Adrian-Taylor et al., 2007).

Second, the dominant role of peers begs a question: which peers? We join others (Veliz, 2020) in advocating the need for formal programs of peer mentoring and support of IGS students. Lorenzetti et al. (2023) also finds that IGS support formal institutional programs to develop peer relationships, but also the need for informal functions (e.g., weekly get togethers), the inclusion of mentors, and more guidance on how to navigate these roles. These programs need to include a specific component: the involvement of domestic graduate students. Without these interactions, IGS may feel racialized and ethnicized on PWIs (Suspitsyna, 2013) as Gu and Usinger (2021) and Dutta (2015) found overwhelmingly that IGS reported the importance of interactions with American students (and faculty) to bolster their sense of well-being and adaptation. Further, recent qualitative research from Pumacchahua and Rogers (2022) in interviews with Latinx and Black STEM Ph.D. students at PWIs in the U.S. find overwhelmingly that they attribute their social and navigational capital for their academic success and ability to navigate racial slights and hostility and especially microaggressions (73%). For advice in navigating the PWI, 67% of the STEM doctoral students mention the need to find a support system with one student noting: “Find support groups within other graduate student groups. I felt like I definitely maintained my sanity during all the other obstacles I was going through because of them.” (p. 10).

Third, the findings for Staff/Other Faculty Support caught us off guard. One possibility is that IGS who are reluctant to ask for assistance from advisors—as we discuss above—or other institutional agents may be more likely to seek out university resources instead of intra-departmental resources and people. This explanation is consistent with prior research that finds that IGS use this strategy (i.e., use of institutional resources) to help with academic adjustments (Zhou et al., 2011) especially when they have less access, knowledge, and motivation to

seek micro-level support agents (Sustarsic & Zhang, 2022). As such, these support programs and offices need resources that are well-funded, staffed, and *inviting*. Yet, it does not appear that all institutions have these qualities. Indeed, Moon et al. (2020) found IGS to be disappointed with resources geared to IGS, and Tas (2013) found that international students were significantly more likely to report dissatisfaction with orientation, university services, and bureaucracy/authority. One important resource is counseling to overcome isolation and academic pressure among IGS although Anandavelli et al. (2021) found that few IGS knew about or accessed university-based counseling. Consistent with our capital perspective and findings, we echo Trammell's (2019; p.62) suggestion about the development of academic capital vis-à-vis institutional programs: "a dramatic reframing of new-student orientation away from simply how to get help and more toward developing relationships that will matter—when you develop your academic capital you know where to get help; encouraging living and learning communities (LLCs) where faculty, staff, and students interact together, creating and banking academic capital."

Overall, our policy suggestions align with the National Academies of Sciences, Engineering, and Medicine (NAS) (2018) report suggesting several changes to STEM graduate education to best serve students from diverse backgrounds. Most changes center on the creation of supportive atmospheres in STEM to best help those who may have difficulties navigating the institutional structures. To achieve this result, NAS (2018) recommended these actions: (a) faculty mentoring and interactions with students in multiple settings; (b) academic and career advising; (c) be more inclusive and equitable, in terms of both representation and institutional climate; and (d) provide research interactions with peers and others. They conclude by arguing that "this report also calls for a shift from the current system that focuses primarily on the needs of institutions of higher education and those of the research enterprise itself to one which is student centered, placing greater emphasis and focus on graduate students as individuals with diverse needs and challenges." (p. 128).

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