An Undergraduate STEM Interdisciplinary Research Program: Factors Predictive Of Students' Plans For Careers In STEM

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Abstract

In a year-long undergraduate research program, life science majors were paired with majors in the other STEM disciplines of computer science, engineering, mathematics and physical sciences, to work on interdisciplinary life science projects. Typical teams had one undergraduate in a life science and one from another STEM discipline, along with faculty and graduate student mentors from each of those disciplines. In a survey at the end of the program, undergraduates indicated their career plans: 74% staying in STEM, 26% moving to non-STEM, with most of the latter in healthcare. In the summer phase, the average and range of the total number of interactions between undergraduates and all of their mentors was about the same for students in both career groups. However, students differed in whether they tended to interact more frequently with mentors in their own discipline, or to interact with closer to equal frequency with mentors in both disciplines. Binary logistic regression analysis showed this differential frequency of interaction with mentors by discipline to be predictive of students' career decisions, with students in the non-STEM career group interacting much more within their own discipline and the students in the STEM career group tending to interact almost as frequently with mentors in both disciplines. Analysis also showed that, compared to students who planned on non-STEM careers, those who planned on STEM careers self-reported lower ease of communication with team members but higher ratings for their program experience. Consistent with national data, the student's area of study was predictive: 56% of the life science and 91% of the other STEM majors planned for STEM careers. However, inconsistent with the predominance of men in the STEM workforce, in our program where there were almost equal numbers of men and women in both the life sciences and other STEM fields, there was no gender difference in career choice: 72% of the men and 76% of the women indicated their intention to pursue careers in STEM.

Introduction

Not all students who earn bachelor's degrees in STEM disciplines proceed to careers in STEM, some choosing to apply their knowledge and skills in other occupations (Carnevale, 2012). Participation in research has been effective in getting undergraduates to consider careers in STEM (Yaffe et al, 2014; Linn et al, 2015; Wilson et al, 2018). As students master research tasks, they gain belief in their competence and abilities (Adedokun et al, 2013), and begin to think of themselves as scientists and engineers (Palmer et al, 2015). However, a self-concept of one's ability to do the work is not a sufficient predictor of career choice (Wang & Degol, 2013). Students also seek work that they find interesting, enjoyable, and aligned with their personal goals, factors strongly associated with career aspirations (Graham et al, 2013).

Discipline and gender also appear to impact career decisions of STEM college graduates. Nationwide, only 35% of graduates in mathematics, physical and life sciences, compared to 64- 77% of graduates in computer science and engineering, work in STEM (Carnevale, 2012). This is partly due to life science graduates moving to healthcare (Austin, 2014), work classified by the U.S. Census Bureau as non-STEM (Landivar 2013), and to the high numbers of well-paying jobs in recent years for computer science and engineering graduates (Torpey, 2018). With respect to gender, 77% of STEM workers are men, while 23% are women (Carnevale, 2012). The under-representation of college women in computer science and engineering majors (NSF, 2017) is exacerbated by their career choices such that only 42% of women graduates, compared to 61% of the men, are in STEM two years after graduation (Carnevale, 2012).

Many factors contribute to gender disparity in students' choice of college major and career path (Leaper & Starr, 2019; Jensen & Deemer, 2019), one being gender differences in personal goals (Diekman et al, 2017). In general, men are thought to place greater emphasis on agency, i.e., individual competence, achievement, status and power, while women are thought to place greater emphasis on community; i.e., working with others and working to help others (Carli et al, 2016). That scientific careers fulfill agentic goals and thus offer a good match for students with agentic goals is widely accepted (Brown et al, 2017; Ramsey, 2017). What is not well recognized is that students think that STEM careers cannot fulfill their communal goals (Brown et al, 2015a). It is this perception, not the lack of agentic goals, that is thought to result in fewer women in the STEM workforce. Such misperception can be changed by engaging math and science students in group learning (Boucher et al, 2017; Fuesting et al, 2017). Consistent with this are reports (Thiry et al, 2011; Gardner et al, 2015) that integrating undergraduate researchers into a community of STEM professionals is effective in recruiting students to STEM careers.

Undergraduate research fulfills agentic goals by providing opportunities for individual achievement. We suggest that students engaged in interdisciplinary research (IDR) may derive additional fulfillment from successfully tackling the challenge of working with a discipline different from their own. We also suggest that IDR can fulfill students' desire for working with others as their learning community expands beyond their own discipline to include peers and mentors with background knowledge and skills different from their own. Then, students will see firsthand how their team ends up with a product that they and mentors from their own discipline could not have achieved by themselves. Thus, one could consider that both agentic and communal goals can be fulfilled by engaging in IDR, but in ways that are different from research done only in a student's own discipline. But IDR is not without risk, and failure could dissuade a student from a STEM career. Failure usually stems from team members trained in different disciplines not having a common language (Bracken & Wainwright, 2006) and mutually accepted practices (Leahey, 2016). However, we suggest that this might not pose as much of a problem for undergraduates who have yet to learn discipline-specific protocols and ways of thinking. Indeed, reports show that participation in IDR results in students persisting in STEM majors (Piper & Krebhiel (2015), and in increasing aspiration for STEM careers (Hammond & Lalor, 2009; White, 2017).

To our knowledge, the question as to whether the extent to which STEM undergraduates interact directly with peers and mentors both within their own discipline and across to one other discipline, is relevant to students' career decisions, has not been addressed. Here, we describe a program at a mid-sized public research university in which small research teams comprised of undergraduate students and mentors from two different STEM disciplines worked on questions in the life sciences that required collaboration with colleagues in mathematics, physical sciences, computer science, or engineering. In addition to working with faculty and graduate student mentors in their own discipline, undergraduates, to different extents, worked directly with the undergraduate student in the collaborating discipline along with that student's faculty and graduate student mentors. We compared the odds of students choosing to pursue careers in STEM or non-STEM with respect to the frequency of their interactions with peers and mentors in the two disciplines, along with other measures of the students' IDR experience from the perspective of the students and their faculty mentors.

Methods

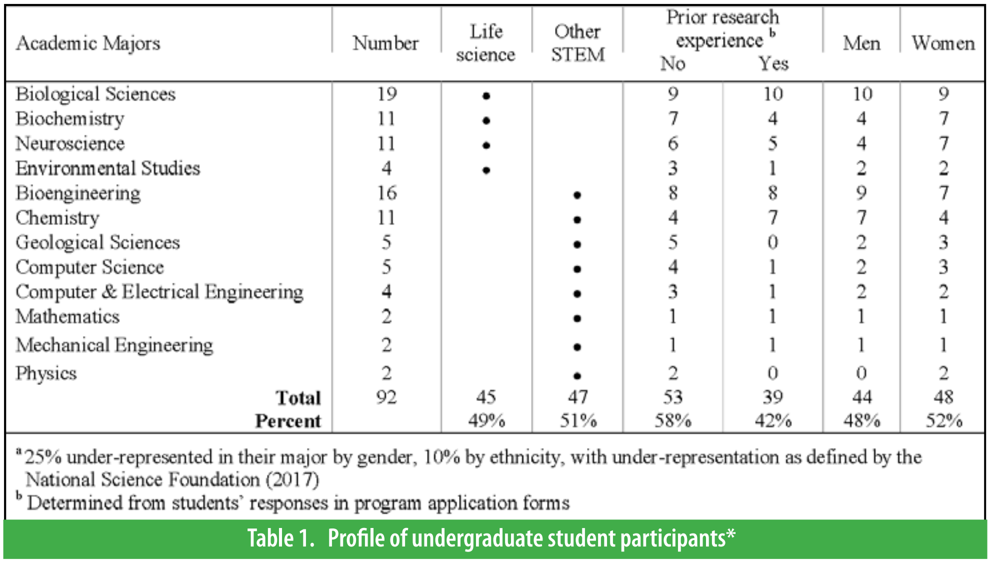
Program

Participating faculty members, ranging in experience from assistant professors to tenured faculty, affiliated with 11 of the 12 STEM departments on our campus teamed up to design projects relating to questions in a life science that required expertise from mathematics or a physical science, computer science or engineering discipline. Collaborations were facilitated by arranging one-on-one or small-group meetings with faculty who wanted to participate in the program. The projects required that the work be suitable for undergraduates working full time with stipend support in the summer and part-time through the following academic year. Most projects involved creation of new procedures, devices, or software. Others required computational analysis of large datasets relating to questions in the life sciences. A few projects were federally funded; most were pilot studies. Collaborating faculty members wrote one-page project descriptions that specified the role of each undergraduate. These project descriptions also identified one or two graduate students, appointed by the faculty mentors, who would assist in mentoring. Undergraduates were asked to indicate up to three projects of interest to them; then project placements were based on feedback from the faculty after they had interviewed three or more applicants. This assessment covers the three years beyond the pilot year during which 41 teams were formed. Twenty-two teams consisted of two undergraduates, one from a life science and one from another STEM discipline, along with their respective faculty and graduate student mentors; 13 teams had three undergraduates; 6 teams had only one graduate student mentor. Over half of the faculty and a third of the graduate students mentored for more than one year. Formal participation of undergraduates in the program was limited to one year, although many continued involvement in their projects until graduation.

Undergraduate participants were about evenly divided between life science and other STEM majors (Table 1), and between juniors and seniors with a few sophomores. GPAs were in the top 50% for their major. Biochemistry and bioengineering majors were classified as life science and other STEM respectively, based on the overlap in their curricula with other life science and engineering majors. On the possibility that prior research experience might be an advantage in conducting IDR, we asked students whether they had research experience in high school and/or college prior to the program. Forty-two percent self-identified as having had research experience.

During the pilot year, only 25% of the undergraduates who applied to the program were women. By conducting small-group program information sessions, and by reaching out to faculty as well as to campus organizations that support women in STEM, we increased the number of women applicants. As a result, in the next three years of the program covered in this analysis, our program had almost equal representation by gender in the life sciences and the other STEM fields. This was so, even though, on our campus, female students are under-represented in the STEM majors outside of the life sciences.

At the start of the program each year, we conducted parallel training workshops to help graduate student mentors and undergraduate students anticipate and deal with problems especially those relating to communication across disciplines, mentoring, and responsible conduct specific to IDR (Stamp et al., 2015). The workshop emphasized the importance of setting expectations early, determining when mentors can begin to let mentees work independently, and the need for regular communication to monitor research progress.



Academic Majors	Number	Life science	Other STEM	Prior research experience [b] No	Prior research experience [b] Yes	Men	Women
Biological Sciences	19	•		9	10	10	9
Biochemistry	11	•		7	4	4	7
Neuroscience	11	•		6	5	4	7
Environmental Studies	4	•		3	1	2	2
Bioengineering	16		•	8	8	9	7
Chemistry	11		•	4	7	7	4
Geological Sciences	5		•	5	0	2	3
Computer Science	5		•	4	1	2	3
Computer & Electrical Engineering	4		•	3	1	2	2
Mathematics	2		•	1	1	1	1
Mechanical Engineering	2		•	1	1	1	1
Physics	2		•	2	0	0	2
Total	92	45	47	53	39	44	48
Percent		49%	51%	58%	42%	48%	52%

[a] 25% under-represented in their major by gender, 10% by ethnicity, with under-representation as defined by the National Science Foundation (2017)

[b] Determined from students' responses in program application forms

Table 1. Profile of undergraduate student participants*

Effective and constructive communication among team members has been shown to be crucial to success in IDR (Brown et al, 2015b). Thus, we engaged the undergraduate students in cross-disciplinary communication regularly throughout the program. In the training workshop, as suggested by Repko (2008), the undergraduates presented systems maps of their projects from the point of view of their respective disciplines, detailing what they knew and what they aimed to find out in their research. The undergraduates on each team were asked to deliver a joint oral presentation of their project during the first three weekly meetings of the summer, a progress report in the form of a poster at the end of the summer session, a 20-minute oral presentation scheduled during monthly meetings of the academic year, and a final research poster presentation at the end of the academic year. The audience for the oral presentations consisted of all the undergraduate program participants as well as the faculty and graduate research mentors of the presenters. Poster presentations were open to everyone on campus. The presentations also had the benefit of showing undergraduates examples, beyond their own projects, of collaboration between the life sciences and other STEM disciplines. Promoting cross-disciplinary interaction was further augmented by several faculty mentors who had their undergraduate mentees work together in both of their laboratories at the beginning of the program.

A number of meetings were devoted to career discussions. Having learned in the pilot year of female undergraduate students' perceptions about the lack of work-life balance in STEM careers, each year, we invited female faculty mentors and their spouses to talk about how they combined career and families with young children. As a result of these panel sessions, the students, especially the women, shifted to thinking that balancing work with having and taking care of children would not be any more difficult in STEM than in another profession (mostly in healthcare) that they were also considering (Tan-Wilson & Stamp, 2015).

Survey data

In a survey conducted at the end of the program year, with respect to the first question, undergraduates were asked to state their career goal. These were later categorized as STEM or non-STEM, as defined by the U.S. Census Bureau (Landivar, 2013). Thus, intention to apply to medical, dental and other health professional school was categorized as non-STEM. However, even though the census bureau considers all K-12 teachers including science teachers as being employed in the education sector, not in STEM jobs, we classified the career goals of the two students who were going into secondary school science teaching as STEM.

Although joint presentations by undergraduate partners ensured a minimum of cross-disciplinary interaction between undergraduates, further interaction between undergraduate partners and the extent of interaction between undergraduates and mentors who were in or outside the students' disciplines were left up to each team to determine. A project could proceed with undergraduates working only with mentors in their own discipline, cross-disciplinary communication occurring largely at the mentor level. Or, undergraduates could, in addition to working with mentors in their own discipline, interact directly with faculty and/or graduate student mentors in the discipline different from their own. Thus, undergraduates differed in where they stood in the spectrum from having an experience that was closer to being mostly in their own discipline or closer to interacting as frequently with mentors in their own as well as in the collaborating discipline. To determine this, in a survey administered at the end of the summer session, the undergraduates were asked to indicate the frequency of their interaction with each member of their team. We needed to do so at the end of the summer instead of at the end of the program year because, during the academic year, undergraduates, as well as faculty and graduate mentors, had varying course loads and thus, varying time for research. In the summer, all students received a stipend so that they could conduct research on a full-time basis; and mentors were not teaching in the classroom. The choices were "at least – once a day, twice a week, once a week, once a month, or once in the summer".

Data analysis

We assigned proportional interaction frequency scores (IF):45 for a reported frequency of at least once a day, five days a week, for 9 weeks in the summer, 18 (twice a week), 9 (once a week), 2 (once a month), 1 (once in the summer), and 0 (no interaction). With respect to the interaction frequency between undergraduates (IF-UG) in teams with three undergraduates, our main interest was in cross-disciplinary interaction; therefore, only the frequency of interaction with the undergraduate outside of the student's discipline was considered. For students who had two partners outside their discipline, the scores were averaged. We refer to the interaction frequency of the undergraduate with the faculty and graduate student mentor in the same discipline as IF-FMs and IF-GMs, respectively; and the interaction frequency of the undergraduate with the faculty and graduate student mentor in the other discipline as IF-FMo and IF-GMo, respectively.

All undergraduates had faculty mentors in each discipline represented in their project; however, in teams that had only one graduate student mentor, some undergraduates lacked either a graduate student mentor in their own or in the collaborating discipline. In those cases, faculty mentors assumed more mentoring responsibilities. Therefore, in our analysis to determine whether undergraduates worked primarily with mentors in their own discipline, or tended to work with mentors in both disciplines, we looked at sums of the interaction frequencies with faculty and graduate student mentors: (IF-FMo + IF-GMo) for mentors in the collaborating discipline and (IF-FMs + IF-GMs) for mentors in the student's own discipline. We refer to the difference ((IF-FMo + IF-GMo) – (IF-FMs + IF-GMs)) as the mentor-discipline interaction score. If undergraduates interacted with about equal frequency with mentors in both disciplines, the mentor-discipline interaction score would be close to 0. If undergraduates interacted less frequently with mentors outside their discipline, their scores would be negative. Similarly, to compare undergraduates' frequency of interaction with faculty vs graduate student mentors, we define a mentor-level interaction score as ((IF-FMs + IF-FMo) – (IF-GMs + IF-GMo)). An all-mentor interaction score, defined as (IF-FMs + IF-FMo + IF-GMs + IF-GMo) served as an estimate of undergraduates' frequency of interaction with all mentors.

To further characterize interactions of the undergraduates with team members, we included additional questions in the same end-of-program survey where undergraduates stated their career goal. Because communication across disciplines is often cited as a problem in IDR (Brown et al, 2015), we asked students to "Rate from 1 to 5 the ease of communication that you had with team members, with 1 being "Had difficulty communicating" and 5 being "I communicated very well with my team members. Explain sources of difficulty." And, "On a scale of 1 to 5 with 5 being the best, how would you rate your overall experience in the research program?"

Only responses of the 81 students (88% of the undergraduate participants) who returned both summer and end-of-program surveys, and stated their career goal, were included in this analysis. This group had similar proportions of disciplinary area, gender, and prior research experience, as the entire group.

At the end of the summer phase, we asked faculty mentors (response rate of 100%) to assess their principal mentee, usually the undergraduate in their discipline as a researcher in IDR. Ratings were from 1 to 5, with 5 being the best.

Binary logistic regression analysis was used to develop an empirical model of students' career plans – STEM or non-STEM – with the goal of identifying response variables that are statistically significant predictors of career choice, variables that can be subjected to validation in future studies (De Wolf et al, 2003). Toward this end, we looked at: the frequency of undergraduates' interaction with peers across disciplines; their all-mentor, mentor-level, and mentor-discipline interaction scores; undergraduate students' self-reported ease of communication with their team and ratings of their program experience; faculty mentors' assessment of their mentees' work in IDR; as well as students' disciplinary area, gender, and whether they had done research prior to the program. The logistic regression analysis was based on the relationship between the odds ratio of a student choosing a STEM over a non-STEM career and predictor variables as expressed in the equation

$$\ln\left(p/(1-p)\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n$$

where p is the probability of a student choosing a career in STEM and X the variables. The analysis was conducted using JMP software (SAS). The whole model test (α of 0.05) evaluates the model in comparison to a null, intercept-only model where coefficients of all variables equaled zero. A lack of fit test evaluates the model relative to a saturated model with theoretically perfect fit to all unique sets of responses. A confusion matrix (classification table) predicting the career choice of each individual student was generated and compared to their actual choices.

Results

Career decisions of students

Toward the end of their year-long program, 60 undergraduates (74%) indicated their intention to pursue careers in STEM fields, more than half of them planning on graduate studies. The other 21 students (26%) indicated their intention to pursue careers in non-STEM fields, most of them in medicine or other professions in healthcare.

Frequency of interactions of undergraduates with team members during the summer

Undergraduates in the two career groups reported similar range of interaction frequency with their undergraduate partner in the collaborating discipline (IF-UG), with an overall mean frequency of about three times a week (Fig. 1A). The two career groups were similar with respect to the range of the all-mentor interaction score, the sum of interaction frequencies with all the mentors on their team averaging about seven times a week (Fig. 1B). They also had similar ranges of mentor-level interaction scores, interacting with faculty an average of two to three times a week and with graduate students an average of about four times a week (Figs. 1C-E).

Where the undergraduates in the two career groups differed was in the frequency of their interaction with mentors in the two disciplines. In general, as expected, most of the students interacted more frequently with mentors in their own discipline. However, comparing the two career groups, on average, the STEM career group reported higher frequency of interaction with mentors in their own discipline (IF-FMS + IF-GMS) (fig. 1G). Thus, the mentor-discipline interaction scores, ((IF-FMo + IF-GMo) – (IF-FMs + IF-GMs)) for more of the un-

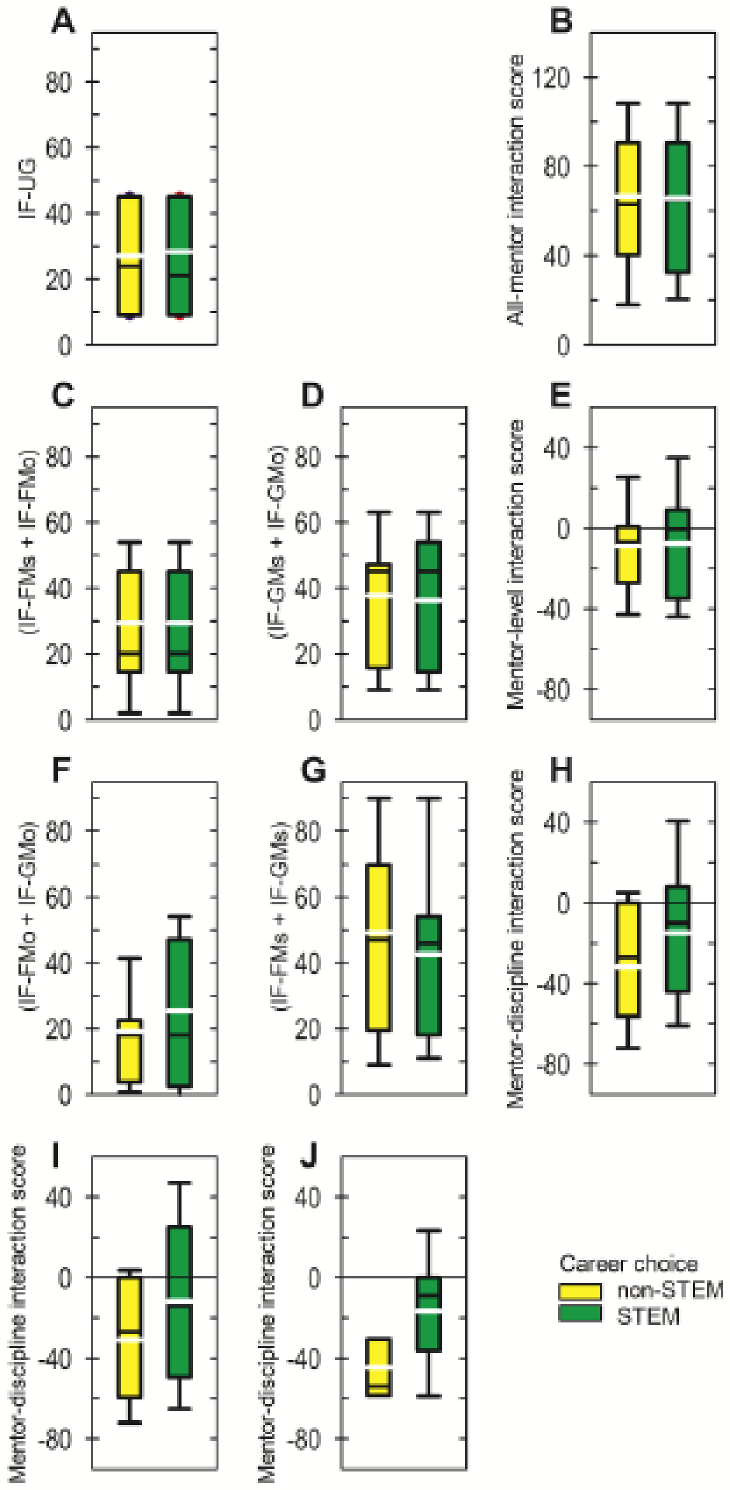


Fig. 1. Interaction frequency scores (IF) of undergraduates in STEM and non-STEM career groups with team members. Undergraduate partner (UG), faculty and graduate student mentors in UG's discipline (FMs and GMs), in other discipline (FMo and GMo). A, Interaction frequency with undergraduate partner in collaborating discipline (IF-UG); B, All-mentor interaction score; C, Sum of IF with faculty mentors in both disciplines; D, Sum of IF with graduate student mentors in both disciplines; E. Mentor-level interaction score with negative score meaning more frequent interaction with a graduate student compared to a faculty mentor; F, Sum of IF with mentors in the discipline different from the UG student's discipline; G, Sum of IF with mentors in the UG student's own discipline; H. Mentor-discipline interaction score; I, Mentor-discipline interaction scores for life science students who chose non-STEM and STEM careers; J. Same as I, for students with academic majors in STEM fields outside of the life sciences. Black and white lines inside the box represent the median and mean, respectively; whiskers and edges represent the 5th, 25th, 75th and 95th percentiles.

dergraduates in the STEM career group were closer to 0, indicating that they worked with faculty and/or graduate student mentors in the collaborating discipline almost as frequently as with mentors in their own discipline (Fig. 1H). In contrast, more of the undergraduates in the STEM career group had more negative scores, indicating that they worked much more frequently with mentors in their own discipline. This differential pattern between students in the two career groups was observed, whether students' academic majors were in the life sciences or other STEM fields (Fig. 1 I-J).

Variables predictive of STEM career choice

Binary logistic regression analysis was carried out to identify response variables that predicted students' choice of STEM or non-STEM careers (Table 2). Test of the model against one where all coefficients were set to 0 showed a good fit ($P < .0001$). Test against a saturated model ($df=75$) for lack of fit returned a p of .93, further indication that the model showed a good fit to the data. The parameters that were significant were students' mentor-discipline interaction score, the disciplinary area of their academic major, students' self-reported ease of communication with the team and ratings of their research program experience (Table 2).

The analysis showed higher mentor-discipline interaction scores to be a significant predictor ($p = .015$) of the career choice of the students in our program, with a unit odds ratio of $e^{0.0259}$ per unit change in regressor through the entire range from -90 to +90. To visualize how this translates to career decisions, we compare two hypothetical situations. Student A interacts four times a week in the summer with a mentor in his/her own discipline and three times a week with a mentor in the collaborating discipline, translating to a mentor-discipline interaction score of -9. Student B interacts six times a week in the summer with a mentor in his/her own discipline and once a week with a mentor in the collaborating discipline, translating to a score of -45. This amounts to a difference of 36 units out of the maximum difference of 180 units between students who interacted only with a mentor in their own and students who interacted only with mentors in the collaborating, discipline. Thus, all other factors being equal, the odds for Student A choosing a STEM over a non-STEM career was $e^{0.0259x36}$ or 2.5 times higher than that for Student B.

The disciplinary area of the students' academic major was also a predictor of career choice ($p = .0008$). Specifically, 56% of students in the life sciences (LS) and 91% of students in other STEM (OS) areas planned on STEM careers (Table 2, Fig. 2A). The higher percentage of OS students choosing STEM careers may be a reflection of ample job opportunities in STEM for students trained in computer science and engineering (Torpey, 2018). However, we note that even among the OS students, those who chose careers in STEM also reported interacting more equally with mentors in their own as well as in the collaborating discipline (Fig. 1J).

Ease of communication with the team reported by students in the STEM and non-STEM career groups revealed different patterns especially with respect to those reporting the scores of 4 and 5 ($p = .0042$) (Table 2, Fig. 2B). About half of the non-STEM career group gave themselves the highest score of 5, while about one-third gave themselves a score of 4. In contrast, only one-third of the students in the STEM career group gave themselves the highest score of 5, the same number as those who gave themselves scores of 4. Difficulties mentioned and the percentage citing them were: difficulty with an individual team member (13%), difficulty in scheduling meeting times (26%), and disciplinary differences (60%). The students who cited disciplinary differences also described how they coped with the situation by learning enough of the other discipline to carry out their research. Some wrote about learning on their own, while others got help from their undergraduate partner or a mentor. Interestingly, 82% of the students who cited disciplinary differences were in the STEM career group.

Students' program experience rating was predictive of STEM career choice ($p = .0051$) (Table 2, Fig. 2C). The odds of choosing a STEM over a non-STEM career were higher among students who assigned the highest score of 5.

Individual student's career choices were predicted based on the equation generated by the model, and the prediction compared to students' actual choices (Table 3). The classification table shows a true positive rate (sensitivity) of 0.93 and a true negative rate (specificity) of 0.62, i.e. the model was 93% correct in predicting which students planned on STEM careers and 62% correct in predicting which students did not plan on STEM careers. The overall accuracy of the model was 85%.

	Chi square	DF	P^{a}
Whole model test ^{b} (against null model)	38.86	8	<.0001*
Lack of fit test ^{c} (against saturated model)	51.08	67	.93
Parameters	Estimates ^{d}	Standard error	P
Intercept	-0.600	1.829	.743
Mentor-discipline interaction score	0.0259	0.011	.0148*
Disciplinary area [LS]	-1.345 ^{e}	0.402	.0008*
Ease of communication with team [5-4]	-1.862 ^{f}	0.917	.0042*
Rating of program experience [5-4]	2.571 ^{g}	0.919	.0051*

[a] asterisks denote statistical significance

[b] $n = 81$; α of 0.05; $R^2(U)$ of 0.42; AUC (area under ROC curve of 0.9)

[c] DF=75 for saturated model, 8 for fitted model; high P value indicates a good fit

[d] Estimates of regression coefficients

[e] Negative coefficient and [LS] notation indicates that a major in the life sciences is predictive of a non-STEM career choice

[f] Negative coefficient and [5-4] notation indicates that the student self-rated level of 5 rather than 4 for ease of communication with the team was predictive of non-STEM career choice

[g] Positive coefficient and [5-4] notation indicates that the program experience rating of the highest level of 5 rather than the next level of 4 was predictive of STEM career choice

Table 2. Test of binary logistic regression model based on odds ratio of students choosing careers in STEM over non-STEM

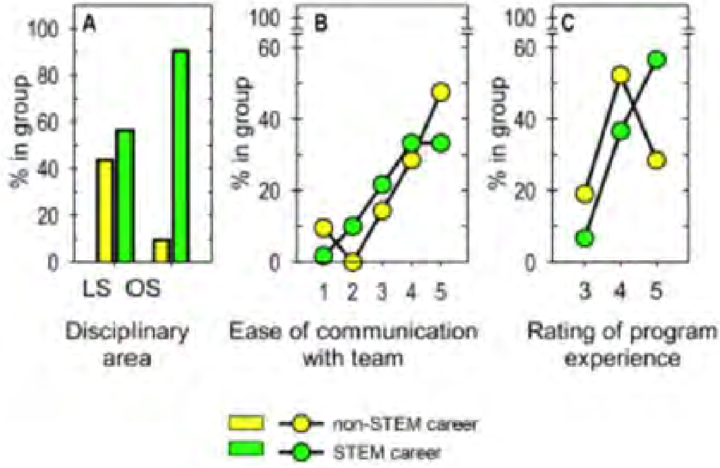


Fig. 2. Other predictors of students' choice of STEM or non-STEM career. A, Disciplinary area: % of life science (LS) and other STEM (OS) majors with STEM or non-STEM career plans; B, Student self- reported ease of communication with team, with 5 being the best; C, Rating of program experience, with 5 being the best (No student gave ratings of 1 or 2.)

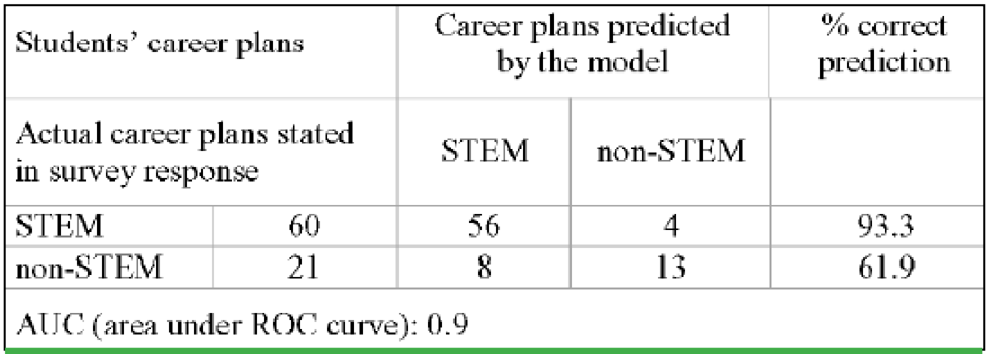
Variables not correlated to STEM career choice

Other variables tested – mentors' assessment of mentees as researchers in IDR, research experience prior to the program, and student's gender did not show correlation to career choice by contingency table analysis (α of 0.05). Mentors' ratings of their mentees as researchers in IDR showed 40% receiving the highest score of 5, 50% with the score of 4, and 10% with scores from 1 to 3, with no advantage for having research experience prior to the program ($P = .244$). Students' decisions to pursue STEM or non-STEM careers were not correlated to their mentor's evaluation of their ability to carry out IDR ($P = .575$), nor to the student having had prior research experience ($P = .864$). Of the 9 students who were from ethnic groups under-represented in STEM, 4 of the 5 who were life science majors opted for STEM careers, one was undecided. Of majors in other STEM fields, 3 opted for STEM careers, one did not turn in a survey.

Mentors' ratings of male and female undergraduate mentees as interdisciplinary researchers did not show significant difference ($P = .443$). And, in our program, contrary to the well-documented bias toward men in the national STEM workforce, there was no gender bias in students' career decisions: 76% of the women and 72% of the men declared their intention to pursue careers in STEM ($p = .642$).

Free-form comments from students reflect agentic and communal goals

In the survey, we invited the undergraduates to add one or more comments about the program. There were a few main themes to the comments: they were glad to have the research experience (42%) and the opportunity for career advice and advancement (16%). Notably, 39% of the students wrote about the challenge of learning another discipline: "IDR was a great experience as it pushed me out of my comfort zone to learn things not in my specialty", "IDR allows me to pick up/be exposed to different skills and different mindsets towards tackling problems". Statements such as these illustrate how the IDR experience fulfills agentic goals that traditional monodisci-



Students' career plans		Career plans predicted by the model		% correct prediction
Actual career plans stated in survey response		STEM	non-STEM	
STEM	60	56	4	93.3
non-STEM	21	8	13	61.9
AUC (area under ROC curve): 0.9				

Table 3. Classification table testing predictive accuracy of the model

plinary research does not. That their IDR experience also helped fulfill communal goals is evident in the fact that 54% of the students cited the relationships forged either with their undergraduate partner, a specific mentor, or the experience of working as part of an interdisciplinary team. "I liked working as part of a team where different people brought different things to the table. Plus, we got some good results."

Discussion

The program requirement of four joint presentations by life science and other STEM undergraduates set a minimum level of engagement of the students with a researcher in the collaborating discipline. Some teams went farther with more interaction between undergraduate partners and between undergraduates and mentors in the discipline different from their own. Thus, we had a range of students' engagement with team members in their own and in the collaborating discipline that allowed us to test whether and how odds of choosing a career in STEM changed depending on the balance of student's interactions within and across disciplines. Indeed, logistic regression analysis found the student's mentor-discipline interaction score to be a significant predictor of a student opting for a STEM career. The odds of students, who indicated interactions with mentors in the collaborating discipline to be almost as frequent as interactions with mentors in their own discipline, choosing STEM careers were higher than those of students who interacted much more frequently with mentors in their own discipline. Establishing the relevance of balancing within- and across-discipline team interactions to students' decision of whether or not to pursue careers in STEM can be an important addition to the ways by which STEM students in future IDR programs could be encouraged to continue in STEM after graduation. Thus, although we are cognizant of the fact that our mentor-discipline interaction score is only an approximation of the entire IDR mentor-mentee experience of the undergraduate students in our program, we believe that the results of this study warrant a future larger-scale study carried out at multiple institutions, and with more students under-represented by ethnicity, to determine whether working with mentors in their own as well as in the collaborating discipline is relevant to students' decision to pursue STEM careers. If so, faculty mentors could then design projects, form teams, and set expectations so that undergraduates must interact not only with peers as we did in our program, but also with mentors of both disciplines. For programs like the one we describe here, accomplishing this can be as simple as making sure that all teams include a graduate student from both disciplines, by scheduling more frequent team meetings, and assigning the undergraduates at the beginning of the program to work with one another and with graduate mentors in the laboratories of both disciplines.

One might ask, if the experience of working with mentors in both disciplines is predictive of choosing a career in STEM, why didn't the analysis find the frequency of interaction of students with their undergraduate partners in the collaborating discipline to be a predictor of career choice? We suggest that this is due in part to the fact that partners report the same frequency of interaction with each other. By design, a student in the life sciences was the partner of a student from another STEM field; and as results show, about half of the students in the life sciences decided on a non-STEM career whereas almost all of the students in the other STEM fields chose STEM careers. Thus, for almost half of the teams, the frequency of interaction with their undergraduate partner would be the same for both the student in the STEM and the non-STEM career groups. This should not downgrade the importance of the cross-disciplinary interactions between undergraduate partners. As one student wrote, "In order to understand the project, my partner and I sat down for many hours and traded information and illustrations." This was further enhanced for those who spent more time together in the laboratory or field, or in preparation for their reports at team meetings, such that over 40% of the undergraduates reported interacting with their partner at least once a day in the summer, the maximum frequency option listed in the survey. Then, as the students prepared for the various presentations, it was a common occurrence for the partners to visit their mentors' offices together, each undergraduate facilitating the cross-disciplinary interaction of their partner with their mentors. Thus, we suggest that, although an undergraduate could conceivably be included in an IDR project with only mentors in both disciplines to learn from, a team configuration of two undergraduates representing the collaborating disciplines, along with their mentors, can be a more effective arrangement.

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