EDUCATIONAL PROPOSAL

STATEMENT OF THE PROBLEM, SIGNIFICANCE OF THE PROBLEM, AND YOUR PLAN OF PROCEDURE*. Describe identified educational priorities in your department and explicitly detail how your plan fits. State clearly the problems or issues you wish to address and how they relate to any ongoing work. Cite precedent. Carefully outline the importance of your plan and the impact it may have on your undergraduate and/or graduate students. A viable approach should be given, including examples from your own prior experience and/or from the literature. Indicate ways in which the completion of this work has a broader impact. Use Arial 11 point font. Limit to three pages.*

1) Introduction, Background, and Motivation

Grinnell College is a highly selective liberal arts college, which consistently ranks in the top 20 liberal arts institutions nationally according to U.S. News & World Report. The student body consists of approximately 1,650 undergraduate students. One-third of the students graduate with a degree from the Science Division (which includes the natural and physical sciences, psychology, mathematics, and computer science). Many of these students go on to obtain Ph.D.'s in STEM fields. In the most recent NSF InfoBrief Baccalaureate Origins of S&E Doctorate Recipients, Grinnell ranks 7th out of all colleges and universities in the United States for producing science and engineering Ph.D.s and 5th of all Carnegie-classified baccalaureate institutions [25].

Between the early 1990's and 2008, the number of students of color graduating with science majors at Grinnell went up by a factor of 2.5, and the number of female science majors doubled. In the Physics Department, where I hold my appointment, the fraction of female majors has climbed from 18% in the 1990's, which was very near to the national average at that time, to a current 10-year running average of 30%, with notable classes composed of over 50% women. Additionally, the number of domestic students of color amongst physics majors has increased from about one in every five class years to approximately one such student each year.

The increase in participation of underrepresented minorities in the Science Division corresponds with the development of institutional programming to support diversity in the sciences. Twenty years ago, the Science Division at Grinnell developed the Grinnell Science Project[1] (GSP) to encourage members of underrepresented groups (including women in physics and mathematics and first-generation college students) to pursue science degrees. In 2011 GSP received the Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring for its outstanding results in bringing underrepresented students, especially students of color, into majors in the sciences. GSP students arrive early to campus to take part in pre-orientation activities, which include lab experiences, opportunities to meet faculty members, and team-building exercises. GSP also resulted in pedagogical changes across the Science Division curriculum to better encourage a diverse student body. I have been personally involved in the GSP pre-orientation every year since arriving at Grinnell, typically through running research-based workshops for small groups and participating in social events. I plan to be one of the GSP faculty directors in the coming years, likely in the summer of 2018 after I return from my junior sabbatical leave.

Despite the notable successes of GSP, students from underrepresented groups still show lower rates of persistence and success in Science Division classes than their peers. Almost half of the D and F grades assigned in Science Division classes over the last 5 years went to domestic students of color, and 25% went to first generation college students. The reasons for the high failure rate amongst minority groups in science classes are complex and difficult to assess, but anecdotal evidence points to a couple of key factors. The first concerns preparedness related to technical skills. The second concerns mentoring and a sense of "belonging". This proposal aims to address these two key aspects with new programming that will supplement the existing structure of GSP.

2) Spatial Reasoning Skills Development

In the early 1990's Michigan Technological University underwent a pilot program aimed at improving the spatial reasoning skills of students with weak technical backgrounds. Students enrolled in engineering classes were assessed for basic spatial reasoning skills at the beginning of the semester, and students with low scores were invited to take part in a short course on spatial skills. Outcomes from the pilot program showed that female students who enrolled in the course had dramatic increases in spatial reasoning over the course of the semester

[1] GSP: https://www.grinnell.edu/academics/divisions/science/gsp

and an increased likelihood of ultimately graduating with an engineering degree [26]. **To address student preparedness and retention for STEM majors, I will develop and teach a similar spatial skills course for students at Grinnell.**

During the first week of classes in the fall semester, all students taking their first 100-level Science Division class that counts toward one of the division's majors will be given a short spatial skills pre-test of approximately 5-10 minutes in duration. The pre-test questions will be primarily compiled from assessments available through the NSF's Spatial Intelligence and Learning Center (SILC)[2]. Test questions will be chosen to echo the skill-set that is required for students taking Science Division courses at Grinnell, with a heavy emphasis on 3-D visualization including 1-D, 2-D, and verbal representation of 3-D data. Faculty in all Science Division departments will be consulted in preparing the finalized assessment to assure that it is reflective of course content across the division.

Students with low scores on the assessment will be invited to join a 1-credit spatial skills course that I will teach in the second and third year of the funding period. The first year of the grant will be used to develop the spatial skills assessment and accompanying course material while I am on teaching leave for my junior sabbatical. While the selection of students for the spatial skills course will not specifically target individuals from underrepresented groups, anecdotal evidence implies that the majority of students invited to participate in the skills course will come from this population (including first generation college students). Students invited to join the course will not be required to enroll, but they will be heavily encouraged. Faculty advisers of students who are invited to join the course will be informed and asked to follow up with their advisees. This process will mirror an existing structure on campus where first-year students are encouraged to take reading, writing, and math assessments during the first week of classes and can then choose to enroll in 1-credit skills courses in each of those subjects. The cutoff score for determining who will be invited to join the spatial skills class will be chosen initially to meet a target class size of no more than 20 students. This number can be expanded in later years if it is found to be advantageous, but Grinnell courses do not typically enroll more than 30 students in any given section of a class. If many more than 20 students receive very low scores on the assessment exam, preference for enrollment into the spatial skills course will be given to first-year students who state an intention to major in a STEM field.

The spatial skills course will meet once per week throughout the fall semester and will focus on the types of spatial reasoning skills that are applicable across the sciences – graphical reasoning, 3-D visualization, modeling, and visual representation of data. Some materials will be drawn from the spatial reasoning program at Michigan Tech, but I also anticipate developing new materials that align more closely with first year science courses taught at Grinnell. The class will have a hands-on format with plenty of guided group work, often in the form of activities designed to be completed by several students working together. In teaching the class, I will also make use of "clicker" technology – Grinnell owns several sets of classroom response system clickers. Students will regularly be asked to answer short multiple choice questions with the devices following the "think-pair-share" methodology, where they first answer the questions after thinking on their own (think), and then discuss their answers with their peers (pair) before answering the same question for a second time and discussing the correct answer as a class (share). This process will allow them to build a formative understanding of their learning process and to track their own improvement throughout the semester. I have a large amount of experience incorporating these interactive teaching methods into my own classes at Grinnell – I typically teach 100-level lecture-based classes with daily clicker use, and I have also taught a group-work based "workshop" physics class in five out of my six semesters at Grinnell. Based on these experiences, I will apply the strategies that I have found to be most effective in my other 100-level physics courses. As the semester unfolds, some of the work assigned both within and outside of class time will be directly related to assignments that the students have received in their Science Division classes.

The intended impact of the spatial reasoning course is to provide under-prepared students (who often, but not always, coincide with students from underrepresented groups) with additional training, to bring them to equal footing with their peers. One of the appeals to specifically targeting spatial skills in this preparedness intervention rather than running a more generic skills class focused on quantitative reasoning is that I believe this course will not be seen as remedial to the students who ultimately enroll. Spatial reasoning is generally not explicitly taught

[2] NSF SILC: http://spatiallearning.org/index.php/testsainstruments#TSS-silc

in high school and college STEM classes, and many of the exercises that we will use to improve spatial skills appear similar to games or puzzles.

3) Undergraduate Peer Mentoring Program

Following participation in the GSP pre-orientation, there are typically only a few organized activities for GSP participants. Additionally, some students from the GSP target group fail to participate in the pre-orientation program for two key reasons. Each year a number of students who are part of the GSP target group but were not identified for invitation to the pre-orientation program arrive on campus expressing interest in science majors. Additionally, some students decline invitations to the pre-orientation program due to other overlapping obligations on the same time frame or a lack of understanding of the benefits of the program. **To provide continued support for all students from underrepresented groups attempting to major in the sciences, the second part of my educational program will be to build a peer mentoring program in which incoming first year students are paired with junior- and senior-level science majors.**

Email invitations for the mentoring program will be issued at the beginning of the fall semester to all first-year students belonging to one of the GSP target groups (students of color, women in the quantitative and physical sciences, and 1st generation college students) who are enrolled in a 100- or 200-level Science Division class that counts toward a science major. These students will be invited regardless of whether they participated in the GSP pre-orientation, allowing this program to cast a broader net encompassing existing GSP students as well as those who do not yet have a formal affiliation with GSP. I anticipate approximately 50 student pairings in each academic year, which is in line with the average number of students enrolled in the GSP pre-orientation program in a typical year. Student mentors will be recruited primarily from former GSP students, since the community-building aspects of the GSP program will be reflected in the peer mentoring relationships. Additional mentors will be drawn from a group of interested junior and senior-level majors within the Science Division. Judging from participation levels in other mentoring programs on campus, the pool of potential mentors and mentees will be enthusiastic about this program. In recruiting materials we will be sure to point out the benefits of mentoring such as building a support system and making lasting connections with individuals face similar challenges.

Mentor pairings will be assigned in consultation with our Science Learning Center staff along with other Science Division faculty. Whenever possible, pairings will be made between students from the same underrepresented group and Science Division department (i.e. a female physics major mentoring a first-year female physics student). Mentor-mentee pairs will be required to meet monthly throughout the academic year, and will be encouraged to meet more frequently as they wish. All mentoring pairs will be asked to sign a contract that stipulates requirements such as frequency of meetings and tenets of respect and confidentiality. Groups of mentored students will additionally be paired with a faculty member from the Science Division for small group meetings that will occur several times throughout the semester. In all cases the faculty mentor will *not* be the same individual who is currently teaching one of the mentee's classes. Initial meetings between mentored students and their peer and faculty mentors will be required to occur within the first three weeks of the semester. The goal is for students to build a relationship with a faculty and student mentor before any major graded work is returned in any of their Science Division classes, which can alter the dynamic of relationships between students and their superiors.

4) Education Plan Timeline

Year 1: Prepare materials for spatial reasoning assessment and course, prepare contracts and expectations for mentoring program, and recruit faculty and student mentors.

Year 2: Pilot the spatial reasoning course and peer mentoring program at Grinnell College.

Year 3: Make adjustments to both programs based on outcomes from the previous year. Share assessment data from both programs with faculty and administrators at Grinnell to support institutionalizing the most successful elements of these programs.

ASSESSMENT PLAN. *Define expected outcomes of your educational plan. How will your evaluation design provide information to improve your project as it develops and progresses? How will you determine whether your stated project objectives are being met according to the proposed timeline?*

Students enrolled in the spatial skills course will have their final grades tracked and compared with students who did not enroll in the class. We will specifically look at the final grade distribution as a function of gender and underrepresented minority status. At the end of the semester we will re-test all students enrolled in the spatial skills course to determine the level of improvement on the initial spatial skills assessment. In cases where the professor agrees to work with us, we will also re-test full sections of 100-level science students to compare the level of improvement of students enrolled in the spatial reasoning class to those who were not invited to join the class and to those who chose not to take the class. Feedback from this assessment process will allow us to determine whether the students enrolled in the intervention class are improving as desired, and updates will be made to the curriculum of the course if these goals are not being met.

To determine the long-term benefits of the mentoring program, participants will be tracked by Grinnell's Office of Institutional Research to compare rates of science major declaration against the group of students who chose not to participate in the program. Participants will also be evaluated for various metrics of academic success over the course of their college career (cumulative GPA, Science Division GPA, and level of participation in Science Division activities such as on-campus research, departmental employment, weekly research seminars, and social events). If any gains are found for students participating in the program, we will examine how long-lived these advantages are after the one-year formal mentoring relationship ends. In the short-term, to evaluate mentoring program from year to year in its initial stages, we will develop an exit survey for all students participating in the program as a mentor or a mentee. The survey will ask students about the quality of their mentoring relationships and their likelihood of encouraging other students to participate in the program in the future. For the mentored students, we will ask about their perceptions of STEM majors at Grinnell and how those perceptions have changed and evolved over the course of their first year of college. The outcome of these surveys will allow us to alter the guidelines of the program if the mentoring relationships are not seen as uniformly positive.

Identify departmental or institutional colleagues who might play a role in this educational endeavor (as mentors, collaborators, etc.) as appropriate and describe the role they will play.

Mark Schneider (professor of physics and former associate dean of the college) – Dr. Schneider was one of the original GSP leaders, and he has been involved for many years with programming to promote inclusivity in the physics department. He also has considerable experience with institutional initiatives to increase diversity across the college as a recent associate dean. Dr. Schneider will mentor me as I develop my educational programs. He will also be directly involved in the mentoring program as a faculty mentor and by providing organizational support for the program.

Minna Mahlab (director of the Science Learning Center) – As director of Grinnell's Science Learning Center, Ms. Mahab is heavily involved each year in organizing the GSP pre-orientation. She also personally knows many of the students who will be invited to mentor first-year students, and each year she forges personal relationships with most of the students who will be the target beneficiaries of the mentoring program. Ms. Mahlab will provide assistance in assigning the mentor pairings. She will additionally provide feedback at all stages of my educational program as someone who has been heavily involved with diversity initiatives within the Science Division.

LETTER OF SUPPORT. *Include a letter of support from your Departmental Chair, Dean or Provost that endorses your educational proposal and indicates why you are the appropriate faculty member to undertake this project. Please insert the letter following the ACADEMIC LEADERSHIP STATEMENT.*

LIST OF REFERENCES

[25] Mark K. Fiegener and Steven L. Proudfoot. InfoBrief: Baccalaureate Origins of S&E Doctorate Recipients, NSF 13-323, April 2013

[26] S. A. Sorby & B. J. Baartmans, "The Development and Assessment of a Course for Enhancing the 3-D Spatial Visualization Skills of First Year Engineering Students", *Journal of Engineering Education*, 89, 301, 2000