

Effects of Hierarchical Mentoring on Freshman Retention in a Biology First-Year Experience Course

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ABSTRACT

Higher education must improve student retention and graduation rates to meet increased demand for STEM degrees in the workforce projected for the next ten years. The high rate of attrition among STEM students entering college compels institutions to implement strategies that improve student retention because more states now employ performance-based funding models with increased pressures to improve student outcomes, such as first- and second-year retention rates. We piloted a two-year hierarchical mentoring model as part of a first-year experience course developed for biology students (BioSkills) to increase retention rates among first-time-in-college (FTIC) students. We describe the mentoring structure we adopted and how the design of BioSkills supports and educates future biology professionals. Our findings show that FTIC students who participated in this program earned significantly higher first-year GPAs and were retained at higher rates than students who did not participate, which documents the impact of BioSkills as a successful first-year intervention. However, we were surprised that the benefit of BioSkills was not replicated among under-represented minority (URM) students. We briefly speculate on explanations for this finding. Lastly, we offer best practice suggestions for future implementation.

Key Words: mentoring; first-year success; retention; first-year GPA; performance funding.

○ Introduction

STEM degree completion has become a national priority and has increased the emphasis placed on metrics such as student retention and success, as measured by first-year GPA and progress toward degree completion. In 2012, the President's Council of Advisors on Science and Technology called for an estimated 34 percent increase in STEM graduates to meet projected economic demands to produce one million more STEM professionals in the next decade (PCAST, 2012). Currently, fewer than 40 percent of U.S. undergraduates earn

a STEM degree. STEM completion is particularly low among under-represented minorities (URM), who earn fewer than 25 percent of STEM degrees awarded nationally (NAS, 2011). Therefore, STEM disciplines need to identify strategies that can improve undergraduate performance outcomes to support and train the next generation of STEM professionals (AAAS, 2010).

The first year is the most important year for long-term retention (see Feldman, 2005, for a review). Students' confidence and self-reported motivation contribute to overall academic self-efficacy, the confidence in one's ability to accomplish academic tasks, which predicts student persistence in the major (MacPhee et al., 2013). The best predictors of student success are academic preparation and motivation (Upcraft et al., 2004), and recent research documents effective strategies to increase persistence and the motivation of STEM students during their first year in college, such as mentoring (Graham et al., 2013). Because mentoring targets students' social identities and

connects new students to role models, it is an effective method for creating a sense of belonging among incoming students (Zaniewski & Reinholz, 2016). Undergraduates who experience mentoring earn higher GPAs, are retained at higher rates, and make more consistent progress toward degree completion than students who are not mentored (Campbell & Campbell, 1997). In particular, mentoring effectively facilitates development of student identity and promotes social integration into the university (Wilson et al., 2012). In addition, mentoring can have significant impacts on URM students majoring in STEM disciplines (Pentyala et al., 2016). Thus, integrating cohort building and mentoring in an undergraduate program is an effective evidence-based strategy that can increase freshman retention and early academic success as measured by first-

year GPA (Whittaker & Montgomery, 2012).

In addition to the need for improved STEM retention, educational outcomes in STEM disciplines now undergo increased scrutiny and

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demands from government offices, which align strategic goals (including learning goals) with budget allocations. At the state level, these pressures increasingly take the form of performance-based funding (PBF), in which budget allocations are determined by institutional performance on state-defined metrics (Dougherty & Reddy, 2013). Currently, 32 states implement some form of PBF for public higher education (Hillman, 2016). Authors of PBF models attempt to increase productivity in higher education by funding institutions based on metrics (e.g., four-year graduation rate of first-time-in-college [FTIC] students). Their goal is to improve student success during enrollment in and after completion of degree programs, rather than rewarding inputs or activity metrics (e.g., number of FTIC students enrolled; Reindl & Reyna, 2011). Moreover, PBF metrics often include measures of retention, GPA, and the production of graduates in STEM disciplines to support national goals to increase the size of the STEM workforce.

Current PBF models (PBF2.0) tie a portion of continuing base funding to scores on performance metrics. The portion of base funding at stake varies based on state funding formulas (Dougherty & Reddy, 2013). Moreover, modern PBF models also include metrics that monitor student progress toward degree completion, such as course completion rates, retention rates within the university, and GPA (Dougherty et al., 2016). Although PBF articulates goals to create student-centered outcomes for academic success, several unintended outcomes have emerged. When PBF ties funding to metrics such as graduation rates, colleges may use strategies that improve metrics without improving student learning. They might reduce the number of credits required for degree completion or eliminate required remedial courses, which tend to delay graduation (Natow et al., 2014). In addition, PBF may motivate colleges to narrow institutional missions (serving a different population of students), encourage instructors to weaken academic standards to increase course “completion” rates, or diminish access to higher education by refusing to admit students who are less likely to graduate or are expected to take longer to complete a degree (Dougherty & Reddy, 2013). Collectively, PBF entails expectations that institutions will create and implement faculty-led programs to improve student outcomes that fit the missions of various colleges. Moreover, development of student-centered programs shown to be successful can inform state recommendations and funding.

Our study implemented a modified hierarchical mentoring model to examine its benefit on retention and first-year GPA among FTIC students. A hierarchical-mentoring program is a multi-layered approach to traditional peer-mentoring that incorporates mentoring, education, and research. The core component is mentoring, which produces significant impacts on student success (Wilson et al., 2012). The second component is undergraduate research, in which mentors and mentees participate in building educational infrastructure in the STEM disciplines. In our study, junior and senior undergraduates and graduate students served as mentors for incoming freshmen. Our hierarchical-mentoring model adapts strategies used at national summer institutes for faculty development. The National Research Council (NRC, 2003) recommends creating summer institutes for biology faculty to improve undergraduate STEM education. Sponsored by the Howard Hughes Medical Institute and the National Academy of Sciences, summer institutes have been held annually since 2002 at both national and regional levels (Wood & Handelsman, 2004). The goal of the summer institutes is to develop

evidence-based pedagogical innovations that improve student learning and overall success in undergraduate STEM education. We adapted these practices to create a hierarchical mentoring education framework for students. Our research question asked whether students would benefit from a first-year Biology Skills course (BioSkills) that combined training on learning strategies, mentoring, and participation in an engaging first-year learning experience. In this study, we report the success of this mentoring model in improving FTIC retention and first-year GPA. In addition, the results from our study suggest that incorporating mentoring models may improve scores on PBF metrics used to reward progression toward degree completion, such as first-year retention and freshmen academic success (e.g., first-year GPA).

○ Method

Setting and Student Recruitment

The Biology Teaching and Mentoring Program was developed and implemented at a medium size regional institution in Florida. BioSkills was designed as a one-credit-hour seminar that meets for 50 minutes once per week for 16 weeks. Classes meet in a classroom with moveable desks that can accommodate up to 60 students. Although BioSkills is intended for FTIC and is required for all biology majors, there is no requirement for when students take the course. Enrollment included first-year FTIC students, transfer students, and other students enrolled as biology majors. However, only FTIC students participated in this study. The focus of this study was the effect of the mentoring program and BioSkills on FTIC students' first-year success (retention and GPA). The cohorts were selected by identifying all FTIC students registered for the introductory General Biology I in fall of the academic year of study (2014 or 2015). Each cohort of Biology I FTIC students included students who took BioSkills during their first year and students who did not take BioSkills during their first year. This natural manipulation allowed us to design a comparison study within the cohort.

The initial mentoring program recruited three senior-level undergraduate Biology majors and two graduate students from the Biology Master of Science Program (Figure 1), who served as mentors to undergraduate students enrolled in BioSkills. Each mentor worked with a small group (typically 10 students). The BioSkills mentoring groups were arranged based on either laboratory course enrollment or the student's declared major (General Biology, Biomedical, or Marine Biology). Mentors met once weekly with a faculty member for pedagogy and mentoring training, which included mentoring among the senior undergraduates and graduate students (Figure 1). In year 1 (2014), mentors were recruited from high-performing juniors, seniors, and graduate students in the Department of Biology. However, in year 2 (2015), all mentors (9) were senior undergraduates. Over two years, 16 students (3 graduate students and 13 undergraduates) served as mentors.

Biology Skills Course Design

The BioSkills course is comprised of four modules. Each module includes approximately four weeks of instruction: (1) skills and information on getting involved on campus and in undergraduate research, (2) learning and studying skills, (3) careers in biology, and (4) a discussion of the importance of persistence and mindset

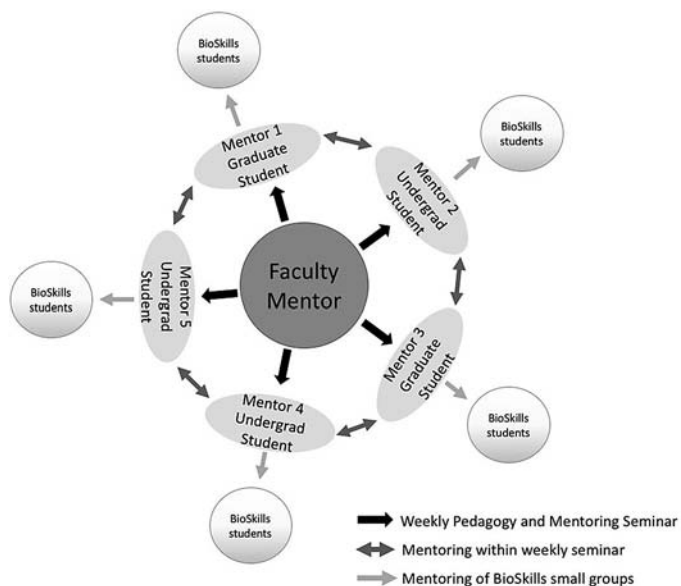


Figure 1. Model of the Biology Teaching and Mentoring Program. One faculty member, three senior undergraduate Biology majors, and two graduate students served as mentors. Mentors participated in weekly pedagogical and mentoring seminars, in which the seniors and graduate students served as mentors to each other. Graduate and undergraduate students then served as mentors to groups of BioSkills students in which they facilitated the BioSkills course activities as described in Table 1.

for academic success. Topics covered and learning outcomes for each module appear in Table 1. During each class period, mentors managed grading and returned homework assignments, facilitated group discussions of the day’s topic, and facilitated “free discussion” time, when mentors asked mentees about how the semester was going. Outside of class, mentors e-mailed their mentees with reminders about course deadlines and described relevant events and campus resources. Mentors sometimes engaged in teaching by presenting a course topic to the entire class. Students completed weekly homework assignments aligned with one or more of the learning outcomes for the module. Homework assignments generally required students to reflect on and apply relevant strategies that could improve their academic and professional success.

Evaluation Method

Because General Biology I is usually the first course students take as biology majors and is taken in the first semester in college, all FTIC students in the fall semester of two academic years who registered for General Biology I participated in the study. For each cohort year (2014 and 2015), we identified students who enrolled in BioSkills in either fall or spring of their freshmen year (BioSkills) and students who did not take BioSkills in their first academic year (No BioSkills). During the two years of this study, 166 students took BioSkills in their first year and 128 students did not take BioSkills in their first year, totaling 294 students who participated in the study. We also examined differences based on gender (78 male students, 216 female students).

Table 1. Biology Skills (BioSkills) course design.

Course Module (4 weeks per module)	Topics	Learning Outcomes (Students will . . .)
Week 1. Getting Involved	Opportunities beyond the classroom Undergraduate Research Advising and curriculum	Find student organizations that fit their interests and goals. Research faculty profiles and draft mock e-mails to inquire about research positions. Self-reflect on degree choices. Identify where and how to get help for completing their degree.
Week 2. Learning and Studying	How people learn/Metacognition Study tips and strategies Testing tips and strategies	Identify their learning style and self-reflect on study habits. Develop note-taking strategies, devise study schedules, and create a list of best practices for future study sessions. Perform an exam autopsy and identify effective practices for studying for and taking exams.
Week 3. Biology Careers	Ethics in Biology Finding careers in Biology CVs, Resumes, and Cover Letters	Identify ethical considerations in biology research. Discuss careers available to students who complete a Biology degree. Write a resume and cover letter for a specific biology-related position.

Table 1. Continued

Course Module (4 weeks per module)	Topics	Learning Outcomes (Students will . . .)
Week 4. Persistence and Mindset	Chapter 2, "What Makes an Expert?" from <i>What the Best College Students Do</i> (Bain, 2012) <i>Understanding Mindset</i> (Dweck, 2006)	Self-reflect on their own questions in college. Discuss how a student's mindset can help or hinder their academic success.

Research Design for Statistical Analysis

The analyses reported here are based on a $2 \times 2 \times 2$ analysis of variance (ANOVA) design in which the three factors were cohort year (year of matriculation, 2014 or 2015), enrollment in BioSkills (enrolled, not enrolled during first year), and gender (male, female). Preliminary analyses treated enrollment in BioSkills as a three-level factor that reflected the term enrolled (fall, spring, not enrolled). However, these analyses did not produce significant trends based on term enrolled; therefore, all reported analyses treat BioSkills enrollment as a yes/no variable. Separate analyses were conducted for each of the two dependent measures: first-year GPA and first-to-second year retention. Additional measures included data obtained from student records (unweighted high school GPA, SAT score, and ACT score). Because participants could not be randomly assigned (students self-selected to enroll in BioSkills), we analyzed student record measures as dependent measures to address questions about the equivalence of groups based on academic preparation. In addition, student record measures were included as covariates in a series of ANOVAs for the two main dependent variables as an additional check on the impact of academic preparation on the findings. We do not report the analyses with covariates because they yielded the same conclusions as the simple ANOVAs.

Results

Because students self-select to enroll in BioSkills in their first year, we conducted three $2 \times 2 \times 2$ ANOVAs to compare incoming unweighted high school GPA, SAT superscore, and ACT score for groups created by cohort (year of enrollment), enrollment in BioSkills in their first academic year, and gender. We found no significant differences among groups for SAT or ACT scores (based on cohort, enrollment in BioSkills, or gender) and no significant interactions between factors. However, we did find a significant difference in high school GPA based on enrollment in BioSkills (students who took BioSkills had higher high school GPAs) and gender (female students had higher high school GPAs). No other comparisons or interactions among factors for the high school GPA measure were statistically reliable.

To assess the impact of the BioSkills course and the hierarchical mentoring program on FTIC student success, we computed a $2 \times 2 \times 2$ ANOVA on the first-year cumulative GPA. Students who took BioSkills in their first year earned significantly higher first-year cumulative GPAs than students who did not take BioSkills. This difference produced a significant main effect of BioSkills enrollment on students' first-year GPA [$F(1,286) = 12.353$, $MSE = 0.905$, $p < 0.01$; Figure 2A]. No other main effects or interactions were statistically

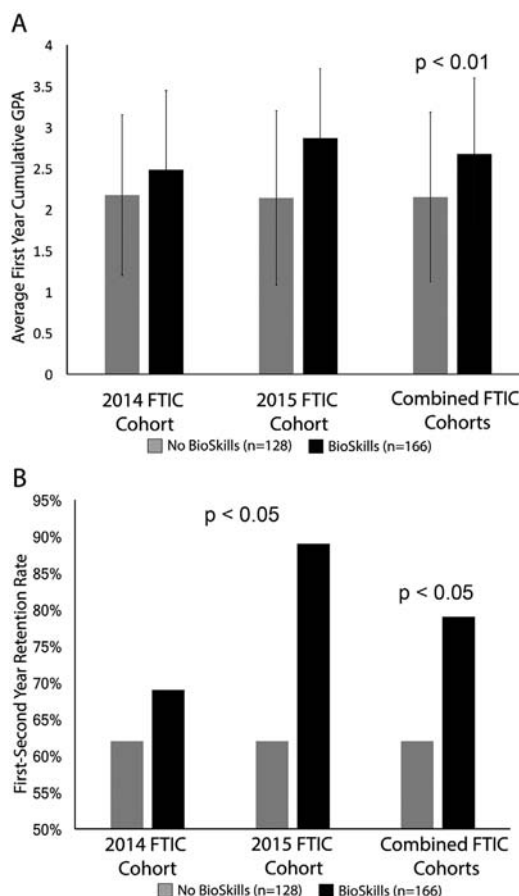


Figure 2. (A) Average first year cumulative GPA comparison between FTIC students who enrolled in BioSkills in their first year and FTIC students that did not enroll in BioSkills within their first year. No interaction found between cohorts (using a $2 \times 2 \times 2$ ANOVA). Error bars indicate standard deviation. **(B)** First to second year retention rate for FTIC BioSkills students in their first year compared to those FTIC students that did not take BioSkills in their first year (No BioSkills). Interaction was found between the 2014 and 2015 cohorts based on the $2 \times 2 \times 2$ ANOVA.

reliable. Although data for the 2015 cohort showed a larger increase in GPA compared to the 2014 cohort, suggesting that improvements implemented in 2015 may have increased the impact of BioSkills on GPA, this trend toward an interaction was not statistically reliable. To account for potential differences attributable to entering high school GPA, we also conducted an ANCOVA (analysis of covariance),

which replicated the ANOVA model and included high school GPA as a covariate. However, including high school GPA as a covariate did not alter any of the statistical findings reported for the ANOVA.

We were also interested in whether students who took BioSkills in their first year were retained at higher rates than students who did not. A second $2 \times 2 \times 2$ ANOVA examined first-to-second year retention as a function of cohort year, gender, and enrollment in BioSkills (Figure 2B). Significantly more students who enrolled in BioSkills were retained (79%) compared to students who did not enroll in BioSkills (62%), producing a significant main effect of BioSkills enrollment [$F(1,286) = 4.731, MSE = 0.193, p = 0.03$]. In addition, students who took BioSkills in 2014 had a 69 percent first-year retention rate, whereas that rate jumped to 89 percent for the 2015 cohort. In contrast, students who did not take BioSkills were retained at a flat rate (62%) in both cohorts. This pattern was confirmed by a significant interaction between cohort year and BioSkills enrollment [$F(1,286) = 5.344, MSE = 0.193, p = 0.022$]. No other main effects or interactions were statistically reliable. As with the analysis of first-year GPA, we conducted a second analysis of the retention data that included high school GPA as a covariate. This analysis produced the same pattern of findings reported above.

Because mentoring programs can produce significant benefits for URM students majoring in STEM disciplines, we explored the effect of enrollment in BioSkills on URM vs. non-URM first-year cumulative GPA from the combined cohorts (Figure 3). Surprisingly, although non-URM students who took BioSkills earned significantly higher undergraduate GPAs in their first year [$F(1,290) = 6.393, MSE = 0.930, p = 0.012$], the benefit of BioSkills was not replicated for URM students. URM students who did and did not enroll in BioSkills in their first year earned similar first year GPAs. A follow-up analysis examined differences in GPA based on the term of enrollment in BioSkills (fall, spring, no enrollment). However, the semester in which these students enrolled in BioSkills was unrelated to their first-year GPA.

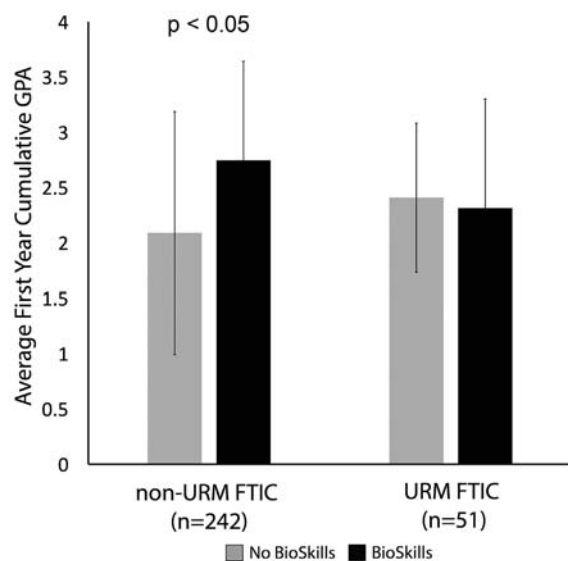


Figure 3. The effect of BioSkills on average first year cumulative GPA comparison between URM and non-URM FTIC students from the 2014 and 2015 cohorts combined. Error bars indicate standard deviation.

Discussion

First-year student success is increasingly important to meet national demands to increase the STEM workforce and to meet expectations for PBF metrics. We investigated the impact of a modified hierarchical mentoring program implemented in a new first-year experience course called BioSkills on the first-year retention and GPA of FTIC students. We report that students who took BioSkills during their first academic year earned significantly higher first-year GPAs and were retained at a significantly higher rate than students who did not enroll in BioSkills (even after adjusting for differences in high school GPAs). The largest proportion of students who fail to progress in higher education leave college between their first and second year (Upcraft et al., 2004). The literature indicates that student persistence is influenced by institution type and availability of first-year programs (Perzadian & Credé, 2016). Our findings document the impact of a strategy (implementing a first-year experience course, including mentoring) that improved the success of first-year biology students at a medium-sized regional university.

Our study replicates existing research, which shows that when students achieve higher first-year GPAs, they are retained at higher rates (Windham et al., 2014; Gershenfeld et al., 2016). Students who took BioSkills earned higher first-year GPAs and were retained at higher rates than students who did not. The first-year retention measure revealed a significant interaction between the cohort year and enrollment in BioSkills. That is, the benefit for retention observed for students who enrolled in BioSkills in 2015 was significantly larger than the benefit for retention observed for students who enrolled in BioSkills in 2014. However, the GPA data only replicated a significant main effect of BioSkills enrollment. Thus, although BioSkills improved retention and GPA in both cohorts, the significantly larger benefit for retention rates observed for students in the 2015 cohort (suggesting a more effective implementation of the BioSkills course for the 2015 cohort) was not observed for the GPA measure, which produced similar benefits for first-year GPA for both cohorts. GPA and retention rates are not perfectly correlated measures, which could account for this small difference in outcomes. Because both retention and GPA were significantly improved for students enrolled in BioSkills, our findings suggest that the supportive conditions created by our intervention appear to have encouraged students to persist and earn higher GPAs in their first year.

Although we did not set out to examine impact on students from URM, and the number of URM students in our sample was relatively small, we note an interesting differential effect of the mentoring program and BioSkills on URM students and non-URM students. Although URM students account for 20 percent of our total student population, our findings suggest that academic gains observed for students in BioSkills primarily benefited non-URM students. Graham et al. (2013) detail the effects of several mentoring programs that produce improved URM student persistence and success. Although our program did not specifically target URM students, we were surprised that we did not observe a benefit for the URM students in our cohorts. Upon reflection, we can identify two reasons why our program was not successful in improving outcomes for URM students. First, our mentors were not diverse. Of the 16 mentors selected, only one mentor was a member of an URM group. Research indicates that students who had mentors with similar ethnic and racial

backgrounds reported more positive attitudes in college (e.g., Frierson et al., 1994). However, other reports suggest that matching mentoring by race and/or ethnicity does not always produce more successful outcomes (Rhodes et al., 2002; Blake-Beard et al., 2011). A second explanation might be that our program failed to establish a community or cohort feeling amongst the students and mentors for URM students. Community building has been shown to improve academic achievement, especially for URM students (Amelink et al., 2013). Future iterations of the BioSkills course will attempt to correct these deficits.

In conclusion, we report that implementation of a first-year experience course using mentors is an effective best practice to improve FTIC student success and retention. We recommend that programs attend to the diversity and makeup of the student population and recruit diverse mentors. To create a stronger sense of community and build supportive cohorts, the course or program should be longer than 50 minutes or should meet multiple times each week. A mentoring program should be implemented in the context of broader curriculum or institutional initiatives, such as living-learning communities or bridge programs, which further support a sense of community. This project did not attempt to separate the effects of the BioSkills course content from mentoring, so the contributions of each component to student success on the outcomes remains unclear. This question will be the subject of future research.

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