HISTORY AND EVOLUTION OF STEM SUPPLEMENTAL INSTRUCTION AT SAN FRANCISCO STATE UNIVERSITY: A LARGE, URBAN, MINORITY-SERVING INSTITUTION

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ABSTRACT

Supplemental Instructions (SIs) were introduced into the San Francisco State University College of Science & Engineering curriculum in 1999. The goal was to improve student performance and retention and to decrease the time to degree in STEM majors. While for the most part we followed the structure and activities as developed by the International Center for Supplemental Instruction at the University of Missouri, Kansas City, we discovered several variations that significantly improved our outcomes. First and foremost, we created SI courses that require attendance, which results in higher students' performance outcomes compared to drop-in options. Second, at SFSU the SI courses are led by pairs of undergraduate student facilitators (who are all STEM majors) trained in active learning strategies. Each year, more than half of our facilitators return to teach for another year. Thus, each section has a returning "experienced" facilitator who works with a new "novice" facilitator. Third, the SI courses were created with a distinct course prefix and listed as courses that generate revenue and make data access

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available for comparison studies. Results are presented that compare SI impact by gender and with groups underrepresented in STEM disciplines.

Keywords: Supplemental instruction (SI); facilitated study groups (FSG); near-peer instruction; STEM retention; STEM workshops; implementation of SI

INTRODUCTION

Retention of STEM majors is a national concern. Students leaving STEM majors are not leaving because STEM majors are too hard. They are leaving because they are not engaged in the classroom and what they are learning in lower-division STEM courses has little apparent value in the context of their life. To increase engagement and build community in STEM classes, the Supplemental Instruction (SI) program at SFSU was established to support learning in large-lecture science and math classes. Since establishment in 1999, this program has evolved to reflect the changing student needs and demographics, along with increased knowledge of factors affecting student success, particularly success of historically underrepresented (HU) students as defined by the National Science Foundation (Hispanic/Latino, African American, Native American, Pacific Islander).

The suggestion that minority populations leave STEM because they are lacking in motivation and academic preparation has been greatly exaggerated (Schuman, Steeh, Bobo, & Krysan, 1997) and the focus on student deficits has been called into question (Bensimon, 2007; Ford & Grantham, 2003; Trujillo & Tanner, 2014). In fact, some studies find that HU students are both motivated to pursue science careers and academically well prepared (Hurtado et al., 2006; Seymour & Hewitt, 2000). The problems appear to be related to engagement and value, both of which we have tried to address through SI.

SI is an international model for student support that began at the University of Missouri−Kansas City in 1974. As explained in several sources (Arendale, 1994; Martin & Arendale, 1992), SI was conceived as a means of increasing student performance by targeting difficult courses rather than high-risk students. The idea of using SI to support students from HU groups more properly specifically stems from the work done by Uri Treisman while teaching at the University of California, Berkeley (Hsu, Murphy, & Treisman, 2008; Treisman, 1992). Treisman found that HU students were underperforming in their classes compared with their peers despite being a highly motivated and select group. Through his lecturer position at the university, his particular focus was African American students in calculus. While introducing an SI class that was open to everyone, he specifically recruited HU students, and he was able to raise their performance in calculus to a level on par with or better than the average performance among all other groups at the university.

SI classes are cooperative learning environments where students participate in learning activities that complement the course material, focusing on student misconceptions and difficulties, construction of a scaffolded knowledge base, applications involving problem-solving, and articulation of constructs with peers (Gasiewski, Eagan, Garcia, Hurtado, & Chang, 2012; Rath, Peterfreund, Xenos, Bayliss, & Carnal, 2007). The students enrolled in the SI classes benefit by interacting with role models, often senior undergraduate STEM majors, who help them in many ways. This peer support has been used to improve study and problem-solving skills by demonstrating strategies that were effective for them, develop teamwork and oral communications skills, and, for HU students, provide validation that students "like them" can succeed in science majors. All of these benefits contribute to the overall increase in first-year students' success and persistence in their STEM majors (Arendale, 1997; Arendale, 2004; Martin & Arendale, 1992).

San Francisco State University (SFSU) is a large urban Minority-serving Institution. Since 1999, SFSU has offered Science SI, a series of voluntary one-unit courses supplementing the STEM major gatekeeper courses. Facilitators create learning communities that focus on conceptual understanding and mutual support. Instruction is mainly through hands-on, interactive, small-group work, and course size is limited to 20.

HISTORY OF SI DEVELOPMENT AND IMPLEMENTATION PLAN AT SFSU

The initial efforts to address the high failure rates (>40%) of SFSU STEM students in first- and second-year major's courses was to develop "Facilitated Study Groups" (FSG). These FSGs were modeled after those described by Treisman, "Our idea was to construct a hybrid of the regular discussion sections and the 'Math Workshops'" (Treisman, 1992). While these were active efforts to create a mechanism to resolve the same challenges as those addressed by SI programs like the one at U Missouri at Kansas City (UMKC), we were not aware of those efforts or the name used until several years after we started. We developed many of the same approaches as the UMKC SI; however, it turned out to be fortuitous in that in our design we included a very important additional component that has had a significant impact, namely mandatory attendance. Mandatory attendance would otherwise have been overlooked if we had been aware of and adopted the UMKC SI model as they do not have this requirement. That is, we created "FSG workshops" that, unlike the UMKC model, required regular attendance like a formal class. A review article reporting the outcome of 27 peer-reviewed SI research publications (Dawson, van der Meer, Skalicky, & Cowley, 2014) reports that the effectiveness of the SI programs is directly correlated with the number of class meetings attended, with better outcomes from attending more meetings. Over the first six years of offering the SFSU FSG Workshops, we discovered the SI literature and eventually changed the name to SI (Peterfreund, Rath, Xenos, & Bayliss, 2008; Rath, Peterfreund, Xenos, Bayliss, & Carnal, 2007; Rath, Peterfreund, Bayliss, Runquist, & Simonis, 2012).

Interestingly, we found that the SFSU SI participants performed better overall than the participants described in the UMKC SI data provided on their webpage. This observation has been reinforced by Dawson et al. (2014) in their comparison of a number of SI programs that increased attendance leads to increased success (pp. 625–626). We assigned the SFSU SI sections with a new college-wide unique course prefix (SCI) that did not conflict with department designations and had the same course number as the corresponding Biology, Chemistry, Physics, and Mathematics courses they supported. The creation of a course title for each of the one-unit SI sections provided the opportunity to track each student who participated or did not participate in SI, allowing us to compare performance in the respective courses. In one study, we were able to compare the performance of 2,164 SI participants out of 10,259 students enrolled in 137 SI sections from 1999 to 2005 (Peterfreund et al., 2008). The SI groups performed better than the non-SI groups in all but one case (pre-calculus). Also, in most cases, the proportion of SI participants passing the course was substantially higher than that of the non-SI participants. We have included, in the sections “Program Outcomes” and “Stabilization of SI Budget Support”, the results obtained for another SI group of 7,451 that includes data on the performance of HU students as well as the differences in performance by gender.

Implementation Plan

Despite the favorable outcomes for students who participate in SI programs, these programs are often considered expensive, and it has been a challenge to incorporate the program into the institutional structure permanently. When external funding runs out, and SI offerings drop, participation and success rates decrease dramatically (Fullilove & Treisman, 1990).

The SI program at SFSU was very successful, and students in the SI courses showed increased students’ performance and progression through subsequent courses in a sequence despite having lower academic indicators compared to non-SI students (Rath et al., 2007). The SI benefits were manifold, especially for HU students who benefitted the most (Rath et al., 2007). From 1999 to 2009, the SI program at SFSU was serving ~500 students/semester with funding from a National Institutes of Health (NIH NIGMS MBRS RISE grant GM059298) grant. Then, due to loss of funding and the fiscal crisis, the program was not offered for one academic year. Unfortunately, during the hiatus, there was a significant loss of workshop materials and knowledge as continuity was broken. In 2010, the program was restarted but served many fewer students. Then in 2014, the program was funded by a new grant, (NIH BUILD grant UL1GM118985-03, 5TL4GM118986-03, 5RL5GM118984-03), to create undergraduate student teaching and mentoring opportunities of peers (as well as professional development around social contextual factors that are particularly relevant for HU students. These changes were taking place while the undergraduate student population was shifting, with significant growth in the number of first-year students, STEM majors, and Hispanic and Asian students.

Program Evolution

In 2009–2010, when the grants that supported SI came to an end, the Student Enrichment Opportunities (SEO) office transferred responsibility for the management and funding of SI to the College of Science and Engineering. Unfortunately, the California State University system suffered very large budget cuts that year, to the extent that the system took the unprecedented step of furloughing all staff and faculty for 10% of their time for the academic year. Due to this crisis, the College put the SI program on hiatus until funding could be found to run the program. The following year, Eric Hsu, Professor of Mathematics and the new director of the Center for Science and Mathematics Education (CSME), took over management of SI and re-launched it. Despite the lack of dedicated funding, each year CSME and the Dean of the College found one-time sources of funding to keep the program running in what was called "caretaker mode."

The SI program was on hiatus for only a year, but it was a surprisingly disruptive break, which damaged institutional processes, curriculum, and culture. Part of this was due to the break coming as the program passed in leadership to the College, which caused disruption and a re-negotiation of basic processes. The disciplinary departments demanded that the college (and thus CSME) take over the responsibility for deciding which classes to offer, acquiring space to house classes, scheduling classes, selecting instructors, hiring instructors, paying instructors, training instructors, supervising instructors, publicizing classes, and coordinating instructors of the main course and SI.

In addition to this disruption, the departments asked that the workshops be taught by graduate instructors, which is the standard model for other labs, and not by successful undergraduates, which was our preferred model. Furthermore, departments dropped the expectation that faculty would work closely and regularly with the SI instructors.

Another effect of the hiatus included literal loss of curriculum materials. Without a unit having responsibility for SI, workshop curricula items (such as worksheets and assignments) were lost due to retirements of SI supervisors and turnover among instructor without orderly handoffs. Thus, SI instructors, mostly graduate students, had to come up with their own materials without the support of the main course instructor.

In the re-start year, the program shrunk dramatically. Instead of offering seats for 20–40% of students in introductory science and math classes, there were only seats for about 10% of students. As a result, our data analysis revealed that SI participants and non-participants had similar performance. This indicated a mild positive effect, as the SI participants had lower SAT I test scores and high school GPAs. However, CSME always intended for this caretaker mode to be temporary until further funds could be found to support something closer to the original model.

In 2014, a team of science education and STEM faculty were granted federal NIH funds (SF BUILD) that were used to revamp the SI program. The following two significant changes were made: (1) undergraduates worked together in dyads to facilitate the SI workshops and (2) the SI facilitator training piloted workshops about the psychosocial factors important to success in STEM courses, including stereotype threat, implicit bias, and growth mindset.

THEORETICAL UNDERPINNINGS OF SI

The current research on why HU students do not achieve academic equity or persist in STEM higher education settings is grounded in three theoretical constructs. The work on stereotype threat and critical-race theory contends that the academic setting is fraught with cues that convey threat, non-inclusion, and even inferiority to HU students (Estrada et al., 2018). While much work has described the threatening environment for HU students, this chapter will focus on theories and strategies that decrease the threat experienced by HU students by affirming their goals and values, validating their experiences, and using near-peer instructors/mentors to personalize the learning environment through social and cognitive congruence.

Communal Goal Affirmation Theory

Communal goal affirmation theory (also called *goal congruency theory*) suggests that HU students and women may not pursue STEM fields because the goals of these fields, along with the environments where the training occurs, are not congruent with their personal goals and values (Diekman, Brown, Johnston, & Clark, 2010; Diekman, Clark, Johnston, Brown, & Steinberg, 2011). Research, examining why HU students persist, has called into question the educational environment's emphasis on individualistic goals that focus on personal gain (Abele & Wojciszke, 2007; Diekman et al., 2010; Stephens, Fryberg, Markus, Johnson, & Covarrubias, 2012). The (Western) culture of science in the United States is also predominantly individualistic and lacks emphasis on communal goals (Diekman et al., 2011). Communal goals, in contrast, are based on interdependence and the benefits of working with and helping others (Diekman et al., 2011). Goal congruency theory suggests that people pursue and persist toward goals that match their values (Sansone, Sachau, & Weir, 1989). When there is congruence, there is increased motivation (Isaac, Sansone, & Smith, 1999) and, interestingly, increased feelings of belonging in academic contexts. When applied to STEM field progression, research indicates that some students perceive and then avoid STEM fields that emphasize agency and personal success as opposed to helping others and having community impact (Abele & Wojciszke, 2007; Diekman et al., 2010; Smith, Cech, Metz, Huntoon, & Moyer, 2014). Smith et al. (2014) conclude their work by stating that it is critical for STEM programs to "foster an environment where communal, as well as individualistic, work goals can be afforded" (p. 425).

Validation Theory

Rendón, Linares, and Munoz (2011) define validation as the "intentional, proactive affirmation of students by in- and out-of-class agents (i.e., faculty, students, and academic affairs staff, family members, and peers) in order to (1) validate students as generators of knowledge and as valued members of the college learning community; and (2) foster personal development and social adjustment" (p. 12). Rendón (Rendón, 1994) found that students who experienced validating educational situations were more likely to persist despite academic and social challenges. Rendón's theory for validation proposes that students are most likely to succeed in college if they are empowered to view themselves as capable learners through academic and interpersonal validation by agents inside and outside the classroom. Thus, validation can be seen as a precondition for academic integration (Tinto, 1997), which predicts higher rates of student retention and persistence (Braxton, 2002).

Affirming students as knowledgeable and valued provides students with a sense of self-worth that helps them succeed (Pérez & Ceja, 2010). Numerous studies have emphasized the importance of support and encouragement (Crisp, Taggart, & Nora, 2014; Nora &Cabrera, 1996) and demonstrated the critical role of affirmation for Latino students. In a longitudinal investigation of 146 Latino STEM majors, strong relationships with the faculty led to better academic performance (Cole & Espinoza, 2008). The study suggests that faculty play an important role in creating an engaging environment for Latino students and that departure from STEM majors is because of a "chilly academic environment." It found that faculty accessibility and efforts to engage students outside of the classroom are positive indicators of the environment of the student's chosen field.

While many qualitative studies use Rendón's (1994) theory of validation as a foundational framework to examine the experiences of non-traditional students, there is only one report of validation theory being used in an empirical study. In a study of community college students, Barnett (2011) tested the validation construct as a type of faculty/staff interaction that predicts students' academic integration and intent to persist in college. To do this, Barnett (2011) operationalized students' perception of faculty validation into four constructs: students being known and valued, caring instruction, appreciation for diversity, and mentoring (examples of items are shown in Table 1). Within a sample of 333 community college students, faculty validation's effect on intent to persist

Table 1. Examples of the Four Constructs of Faculty Validation (Barnett, 2011).

Known and Valued	Caring Instruction
• I feel accepted as a capable student by my instructors • My instructors show that they believe in my ability to do the class work	• It seems my instructors really care about whether I am learning • My instructors seem to genuinely care how I am doing
Appreciation for Diversity	Mentoring
• People of color are encouraged to contribute to the class discussion • Women are encouraged to contribute to the class discussion	• I have had at least one instructor in this college who helped me to believe in myself • At least one instructor has talked with me about my personal goals at this college

was indirect, mediated through students' sense of academic integration. The strongest predictor of a sense of academic integration was caring instruction, though the other three constructs were also significant predictors.

Social Development Theory

Vygotsky recognized that learning takes place through interactions and communications with the social environment including peers, teachers, and other experts (1962). According to Vygotsky (1980), learning is optimized if a distance between what is already known and understood and what must still be learned is just enough to stimulate active inquiry by the student, a distance called the "zone of proximal development." Near-peers that function as "more knowledgeable others" (Vygotsky, 1980) may sense this zone of proximal development much more easily than content experts, who may not always understand the cognitive problems student experience when processing new information (Topping, 2005). The cognitive congruence between peer and near-peer can help students construct knowledge.

Near-peers also differ from formal teachers because they cannot use the same rewards/punishments to motivate students. Instead, they offer interpersonal rewards such as friendship and role modeling. The social congruence between a student (peer) and more knowledgeable other (near-peer) can result in a trusting relationship that might facilitate self-disclosure of ignorance and cognitive errors, enabling subsequent diagnosis and correction (Topping, 2005). Near-peers are more interested in the daily lives, study experiences, and personalities of those being taught than regular teachers (Moust & Schmidt, 1995). Role models build confidence (Lockspeiser, O'Sullivan, Teherani, & Muller, 2008) and also can help reveal the unwritten rules to survive/persist ("hidden curriculum") in a STEM major.

Summary

The research on communal goal affirmation, validation theory, and social development theory describe how the social context through peers, near-peers, and instructors can better affirm students, connect to their values, and develop a more validating, supportive, and personal learning environment. Further research is needed to better understand the nuances of how HU and majority students are alike and differ with regard to these relationships. These theories provide strong evidence that interventions that provide affirmation and validation cues along with social, cognitive, and goal congruence can connect students to their academic community, which relates to greater persistence and more equitable outcomes.

INSTITUTIONAL CONTEXT

San Francisco State University Context

Founded in 1899 as a teacher's college, SFSU is a comprehensive public university that awards baccalaureate and master's degrees. With a total enrollment of

29,465 in Fall 2014, SFSU is the sixth largest of the 23 campuses in the California State University (CSU) system and the seventh largest of all public master's granting colleges and universities in the nation. SFSU and the other CSU campuses continue to provide the most affordable university education in California and frequently represent the *only* affordable option for economically disadvantaged students. A total of 47% of SFSU undergraduates receive Federal Pell Grants, and 78% of all SFSU students worked part- or full-time to help meet the cost of their education.

SFSU is one of the nation's most ethnically and culturally diverse campuses. Of those declaring their ethnicity in Fall 2014, students of color comprised 68.2% of the undergraduates and 42.7% of the graduate students. The combined undergraduate and graduate student population are as follows: 5.4% African American, 0.3% Native American, 27.3% Hispanic, 32.3% Asian/Pacific Islander, 28.3% White, and 6.5% "two or more races." In total, 10,235 of these are from the four federally designated underrepresented ethnic minority (URM) groups. Approximately 57% of SFSU undergraduate students are female.

SFSU, like the state of California and the nation at large, has witnessed significant growth in the Latino population. In Fall 2014, SFSU reached 25% enrollment of Latino undergraduates to become designated a Hispanic-serving Institution (HSI). In Fall 2016, Latino students accounted for 34.5% of the undergraduate population. This university and HSIs like it are challenged to support and graduate a population that is largely low-income and first-generation college-going (Table 2).

SFSU has also seen incredible growth in the number of science, technology engineering, and math (STEM) majors. While the campus has not grown significantly in the number of total undergraduates, there has been growth in the number of first-time first-year students. Many of these students matriculate with the intention of pursuing a STEM major, with significant growth coming from the Hispanic/Latino students (Fig. 1). With this changing STEM student profile, the SI program at SFSU plays an even more important role in providing support for students, particularly HU students, to successfully excel in and complete a STEM major.

Table 2. SFSU Undergraduate (UG) Enrollments in STEM.

SFSU Undergraduate Enrollments in STEM	F 2013	F 2014	F 2015
Total UG enrollment SFSU	25,176	25,055	25,776
Total UG enrollment SFSU, Hispanic/Latino*	6,144	6,244	7,563
Percentage Hispanic/Latino UG enrollment, Pell eligible*	57.4%	58.1%	60.3%
Total UG enrollment, SFSU Hispanic/Latino STEM*	1,166	1,204	1,457
Percentage Hispanic/Latino in STEM UG enrollment – Pell eligible*	58.5%	60.2%	62.9%

Notes: All figures exclude non-matriculated (transitory) students and 2nd BAs; *Hispanic headcounts are US Citizens or Permanent Residents only.

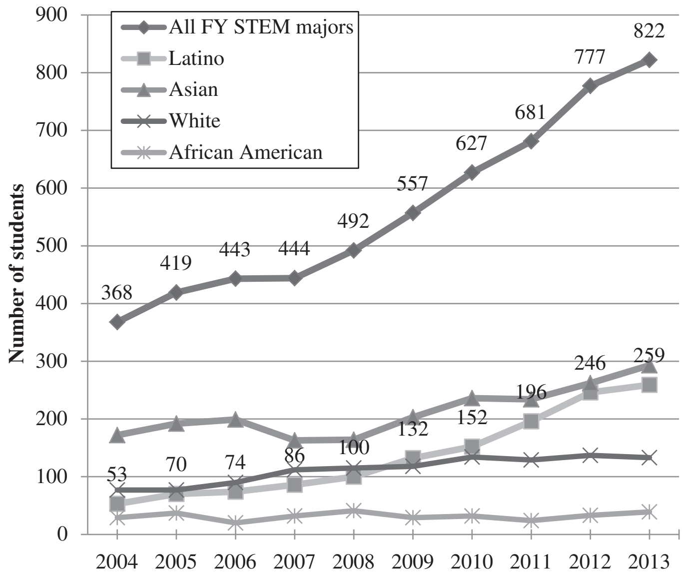

Fig. 1. Growth in the Number of First-year STEM Majors at SFSU from 2004 to 2013. The Numbers for Each Year are the Number of Students, all FY STEM Majors (Top Numbers) and Latino FY STEM (Lower Numbers).

PROGRAM GOALS, STRUCTURE AND COMPONENTS, AND IMPLEMENTATION, ADAPTATION DUE TO INSTITUTIONAL CONTEXT

Program Goals

The goal of the SI program is to support student success, particularly for HU students, in STEM courses that may be thought of as "high risk" (Martin & Arendale, 1993). At SFSU, these high-risk courses are characterized by large classes in which each student has little opportunity to interact with the professor, voluntary or unrecorded class attendance, and infrequent examinations that focus on higher-order cognitive skills that are practiced with limited feedback. The changing undergraduate STEM student profile at SFSU, along with the development of knowledge about social–contextual factors important to learning, brought about a rethinking of how we should teach and serve our SI students. Beginning in 2014, we changed the SI instruction model from lecturers and Graduate Teaching Assistants focusing on content and cooperative group work (1999–2009), to undergraduate leaders who work in pairs to facilitate the SI section. These undergraduates go through extensive SI leader training (30 plus hours) that now focuses on social contextual factors that affect performance that lead to inequities (such as stereotype threat and implicit bias) and provide teaching and learning strategies to overcome them (affirming communal goals, growth mindset, "giving back").

Structure and Components

At SFSU, the SI program exists in the form of one-unit supplemental courses that primarily support large-lecture science courses. These courses meet for 75 minutes once per week to go over concepts and do problems in groups based on material covered in the lecture course. Students who enroll in the supplemental course commit to attending workshops each week for the entire term, and their grade in the supplemental course is based solely on attendance and participation.

At SFSU, the SI courses are led by pairs of undergraduate student facilitators (who are all STEM majors) trained in active learning strategies. When selected, the facilitators make a one-year commitment to the program. This year-long commitment gives facilitators time to develop into strong leaders and also builds a tight-knit, supportive community of facilitators. Each year, more than half of our facilitators return to teach for another year. Thus, each section has a returning "experienced" facilitator who works with a new "novice" facilitator. The experienced facilitator mentors the novice facilitator in how to structure and run the SI classroom and after the first term, the two facilitators have become equals. Notably, these partnerships have decreased the amount of time that facilitators spend with program staff discussing classroom issues and barriers, thus allowing more time for professional development during staff meetings.

The partnerships are also very valuable for the SI students. They get to see two different perspectives on how to view the same question, which shows students that diversity in experience is valuable to the scientific enterprise. Frequently, the two facilitators are not from the same major, and they can tell their students how a concept will be applied in different contexts. For most students, this is the only time they will see two different instructors approaching the same content and sharing their own understanding. Students also benefit from having two near-peer role models who share their own experiences for how to successfully navigate the institution. These two role models also share more similar career goals to the students, compared to instructors who are disciplinary experts and add even greater value to the SI student.

Like other SI programs, the SI program at SFSU relies on a program coordinator, faculty to lead each disciplinary group (Biology, Chemistry, Computer Science, Math, Physics), and the cooperation of instructors to ensure that what is taught in the SI section matches the lecture. The apprenticeship model where experienced facilitators work to train novice facilitators in the classroom, along with more than half of our facilitators returning to facilitate for a second or third year, has resulted in an efficient transfer of materials and knowledge-base for how to successfully run an SI section.

Implementation and Adaptation to Institutional Context

At SFSU, the SI program has been exclusively administered through the College of Science and Engineering (CoSE). The SI program is not drop-in. Students self-select to enroll in a one-unit course that is supplemental to the lecture course. Each course is listed under the SCI prefix, with the course number frequently matching the lecture course number. For example, the SCI 115 course supports the CHEM 115: General Chemistry 1 course. Enrollment of students into the SCI courses allows the program and institution to follow students as they progress through their major.

PROGRAM OUTCOMES

In addition to the extensive data analysis provided for the SFSU SI program in three peer-reviewed publications (Peterfreund et al.; 2008; Rath et al., 2007; Rath et al., 2012) and a review by Dawson et al. 2014, we present additional unpublished data in this chapter that addresses issues of the impact of SI by gender and comparison of HU versus majority students' performance. The data presented and discussed were derived from the participants in the courses listed in Table 3. All of the SI sections have a course number, attendance is required, and the SI sections are graded, allowing the use of institutional data for analysis (which involves grades by semester and SI status for the supported STEM courses between Fall 1999 and Spring 2005). A participant was excluded if they did not complete (receive a grade) in the SI section or course. A total of 7,451 students were enrolled in the courses, and 18% (1,345) participated in SI. The courses and SI analyzed include Biology I, Chemistry I, Genetics, Organic Chemistry I, and Calculus I. Physics I was not included in this report.

In an attempt to understand the relative preparation of each group (SI and non-SI), we compared the SAT scores and high school GPA for each group to control for any obvious bias that might occur when students self-select to participate in the SI sections. As is apparent in Table 4, there was a significant difference in the SAT I Math and Verbal scores ($p < 0.005$ % value), indicating a statistically significant difference favoring the non-SI group enrolled in Biology I. There is no significant difference between the groups relative to high school GPA. A comparison of SAT I Math scores correlated with the course grade is presented in Table 4. As you can see for the students receiving an "A" or "B" grade, the SI students had numerically lower but not significantly different SAT I Math scores; however, a comparison of SI and non-SI students receiving a "C" grade reveals a significantly ($p < 0.005$) lower SAT Math score for the SI participants. The pattern of SI participants having significantly lower SAT

Table 3. SI Supported Courses.

Course	Semesters SI	# SI	# Non-SI
Introduction to Biology I	13	394	990
Genetics	11	195	568
General Chemistry I	10	278	1,511
Organic Chemistry I	11	209	626
General Physics I	12	113	1,216
Calculus I	6	156	1,195
		1,345	6,106

Table 4. Biology I: Student Background.

		SI		Non-SI
SAT I Math		**492**		**518**
SAT I Verbal		**471**		**498**
High school GPA		3.20		3.17
Grade in Class	SI SAT Math		Non-SI SAT Math	Difference
A	570 ($n = 22$)		581 ($n = 46$)	−11
B	527 ($n = 39$)		536 ($n = 72$)	−9
C	447 ($n = 67$)		510 ($n = 123$)	−**63**

Note: Bold = $p < 0.005$.

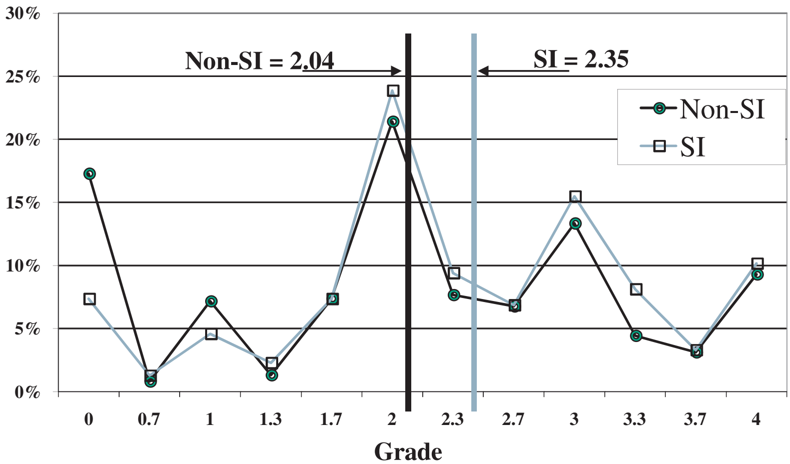

Fig. 2. Intro Biology – Course Grades. *Note*: SI: "C−" or better – 85%; non-SI: "C−" or better – 73%.

scores in comparison with non-SI participants occurs repeatedly and, in our opinion, reflects the benefit of using SI rather than a remedial approach to the successful launching of entry-level STEM majors. That is, it appears the SI experience is compensating for deficiencies that would otherwise limit a passing performance, which is critical to avoiding repeating the course and/or dropping out or changing the major to a non-STEM discipline.

The distribution of Biology I course grades is presented in Fig. 2. While at first glance it may not seem like much of an effect, the decrease in the number of "F" grades from 18% for non-SI to 8% for SI is apparent. In comparing the performance by gender (Fig. 3), we see a decrease for males in "F" grades from 20% to 4% while also seeing an increase in "B + " grades from 4% to 12% and "A" grades from 7% to 11%. This sort of granularity is not as apparent in

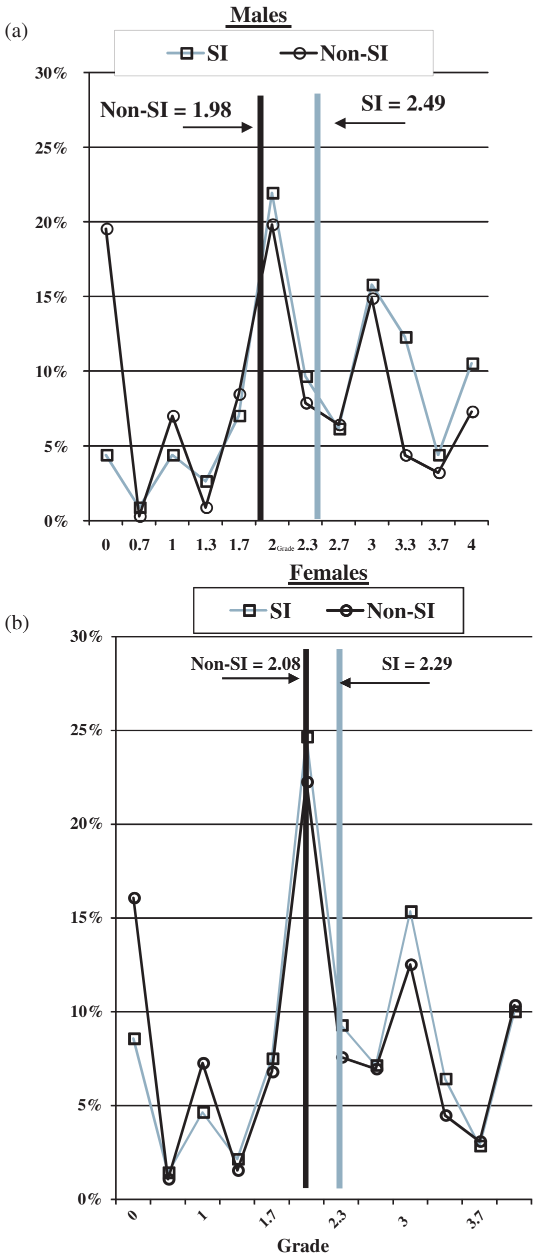

Fig. 3. Biology I: Gender Differences: (a) Males and (b) Females. *Note*: SI – 29% Males, non-SI – 35% Males; SI – 71% Females, non-SI – 65% Females.

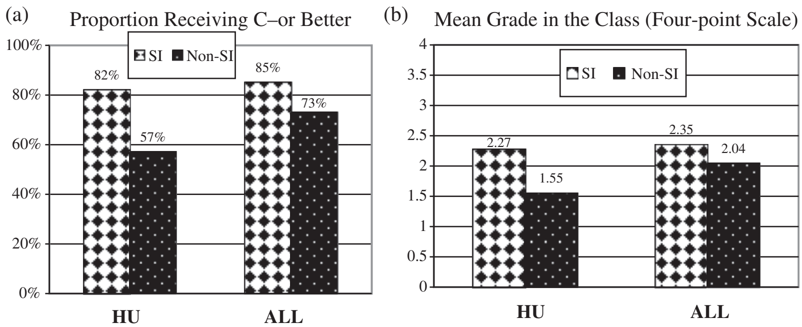

Fig. 4. Biology I: Historically Underrepresented (a) Proportion Receiving "C−" or Better and (b) Mean Grade in the Class (Four-point Scale).

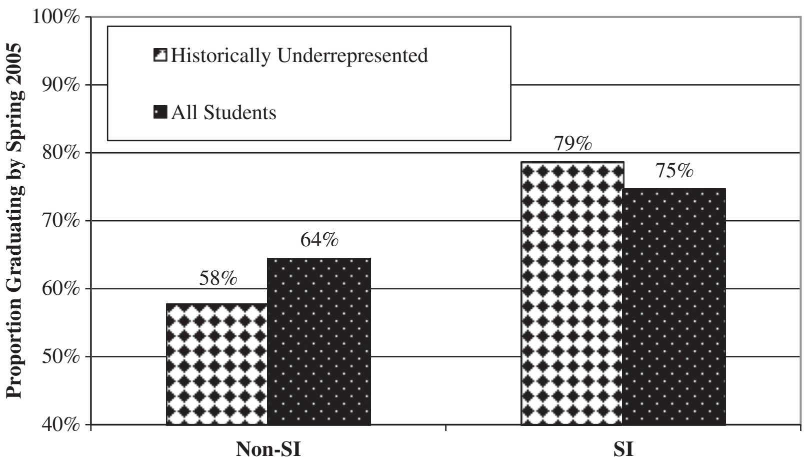

Fig. 5. Graduation Pattern Intro Bio SI Status: HU and All Students based on Students Enrolled Fall 99−Spring 01.

Fig. 1, perhaps because 71% of the SI participants were female. For females, while not as dramatic, the "F" grades drop from 16% to 8%.

As is summarized in Fig. 4, the proportion of students receiving a "C−" grade (minimal grade required to advance) is significantly higher ($p < 0.005$) for both the HU and majority students participating in SI. This is also true for the mean grade in the class. In addition to SI impacting the immediate performance in a class, it also has a cumulative impact on time to and rate of graduation for the participants as seen in Fig. 5. As you can see, 58% ($N = 52$) of the non-SI HU students graduated as compared to 79% ($N = 28$) of the SI HU participants in the same timeframe. In comparison of all non-SI with all SI participants (included the HU students), we see an increase in graduation from 64% ($N =$

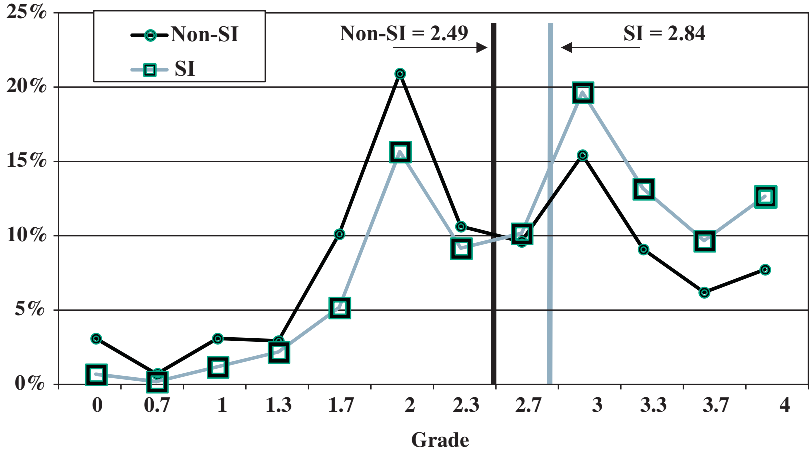

Fig. 6. Genetics: Course Grades. *Note*: SI: "C−" or better − 96%; non-SI: "C−" or better − 91%.

312) to 79% ($N = 126$). Enrolling in SI for Biology I has a dramatic impact on passing the course and graduating sooner (Figs. 4 and 5).

We have also included two upper-division courses (Genetics and Organic Chemistry) to determine how SI might impact student performance. As one might expect after successfully navigating two years of undergraduate science and math courses, we do not see much difference among the participant's backgrounds; however, we do see a positive impact of SI on grades. As you can see for Genetics in Fig. 6, there is a clear shift to higher grades by the SI participants. For the SI participants, the "B" grades are 20% compared to 15% for the non-SI, "B+" grades at 14% compared to 9%, "A−" grades 10% compared to 6%, and "A" grades 13% compared to 8%.

A review of the grades for Genetics broken out by gender again reveals a different picture for males in comparison with females. As was the case for Biology I, the enrollment of females in SI was higher than males (69% in SI and 65% in the non-SI). In a review of Fig. 7a for males, we see an overall shift to higher grades for males that is quite dramatic for the "B+" from 6% for non-SI to 13% SI, "A−" from 8% to 12% and "A" from 4% to 18%. For the female SI participants (Fig. 7b), there is also a positive shift to higher grades but less dramatic with an increase from 16% "B" for non-SI to 24% for SI. Both the mean grade in the class ($p < 0.005$) and the proportion of SI recipients receiving a "C−" grade ($p < 0.005$) were significant (Fig. 8).

The two most challenging first-year courses for entering STEM majors are chemistry and calculus. As you can see in Table 5, the students enrolling in Chemistry I SI have significantly lower SAT I Math and Verbal scores and similar high school GPAs. That said, the Chemistry I students who enrolled in SI did significantly better ($p < 0.005$) than the non-SI participants. As you can see in Fig. 9, there is a clear shift to higher grade performance by SI participants. SI

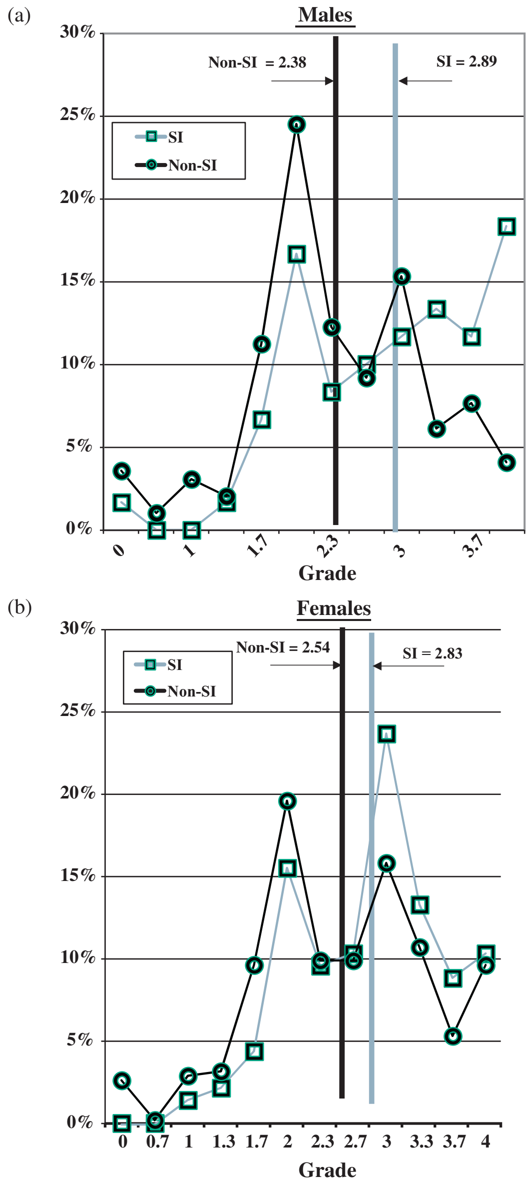

Fig. 7. Genetics: Gender Differences: (a) Males and (b) Females. *Note*: SI – 31% Males, non-SI – 35% Males; SI – 69% Females, non-SI – 65% Females.

had 14% "B" grades as opposed to 10% non-SI, 11% "B+" compared to 9% and 11% "A–" compared to 6% for non-SI. The comparison of male and female participants demonstrates the pattern we have seen with Biology I and Genetics with a more dramatic change for males at the higher grade levels (13% "B"

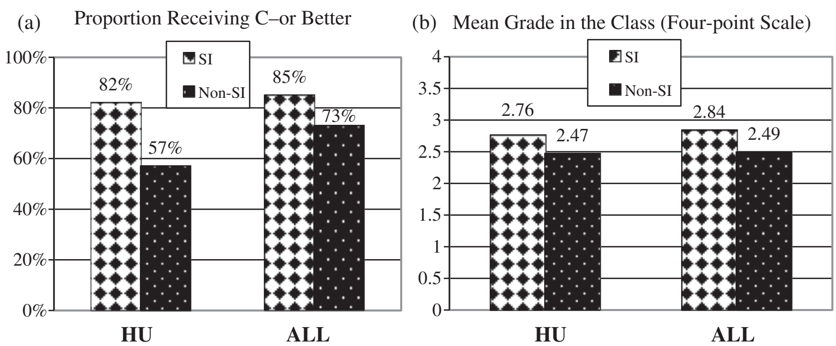

Fig. 8. Genetics: Historically Underrepresented (a) Proportion Receiving C- or Better and (b) Mean Grade in the Class (Four-point Scale).

Table 5. Chemistry I, SAT I and High School Grades.

	SI	Non-SI
SAT I Math	**488**	**523**
SAT I Verbal	**472**	**490**
High school GPA	3.14	3.19

Note: Bold = $p < 0.005$.

grade for SI and 9% for non-SI, 14% "A−" for SI and 7% for non-SI, 5% "A" for SI and 5% for non-SI); but, the female participants show a strong, consistent overall shift of the entire curve to higher grades (Fig. 10). Both the mean grade in the class and the proportion of SI recipients receiving a "C−" grade were significant ($p < 0.05$; Fig. 11).

Organic Chemistry I, like Genetics, is a challenging upper-division course we included in the SI program to determine whether SI would have a differential impact. As you can see in Figs. 12 and 13, SI does have a significant ($p < 0.005$) effect. The threefold drop in "F" grades from 9% for non-SI to 3% for SI participants with a concomitant increase in "A−" grades for participants from non-SI 7% to SI 14% and "A" grades for non-SI of 8% to 13% for SI is dramatic. Both the mean grade in the class ($p < 0.005$) and the proportion of SI recipients receiving a "C−" grade were significant ($p < 0.05$) (Fig. 13).

Calculus has been one of the more difficult courses to support SI because of the number of different instructors (and approaches) involved. While the following results do demonstrate a moderate overall impact on grades, what has not been readily apparent before is the impact SI has had on many individuals with low SAT I Math scores. As you can see in Table 6, the SI participants have significantly ($p < 0.005$) lower SAT I Math scores and according to our Math faculty would not likely pass Calculus I with a 482 SAT I Math score. This score alone would not qualify a student for calculus; rather, it would call for remedial

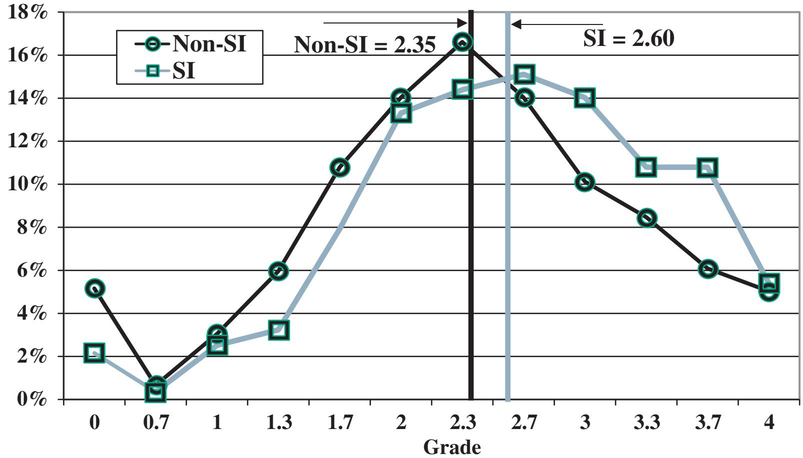

Fig. 9. Chemistry I: Course Grades. *Note*: SI: "C−" or better − 92%; non-SI: "C−" or better − 85%.

placement in Algebra. One way to consider the impact of SI is to consider how much ground was made up *during* the SI and course participation. A review of Table 7 provides some insights into this point. When we showed Table 7 to our Math department chair (on the faculty for 40 years), he told us it was hard to believe that 12 students with an average SAT I Math score of 470 could even pass let alone achieve a "B" grade. At this point, after being uninterested in SI, he became a believer and took active measures to support the SI program. He was also specifically looking at the 62-point difference from the non-SI students receiving a "B" grade, and he was amazed that the SI students could make up for the difference during the course.

Calculus I: Student Background

The overall performance in Calculus I shows a slight improvement in grades for SI participants with a higher pass rate (Fig. 14). The performance of HU SI participants was significantly higher ($p < 0.05$). There was no significant difference in the mean grade between SI and non-SI (Fig. 15).

In summary, we have found a number of significant outcomes and several unexpected insights relative to the participation and performance of HU students as well as gender differences. Relative to participation in SI, we see:

- Higher course performance (passing and progressing).
- SI takers tend to come to SFSU with weaker academic indicators.
- Takers show higher rates of taking subsequent courses in the major.
- Women are more represented; however, men demonstrate more dramatic improvement.

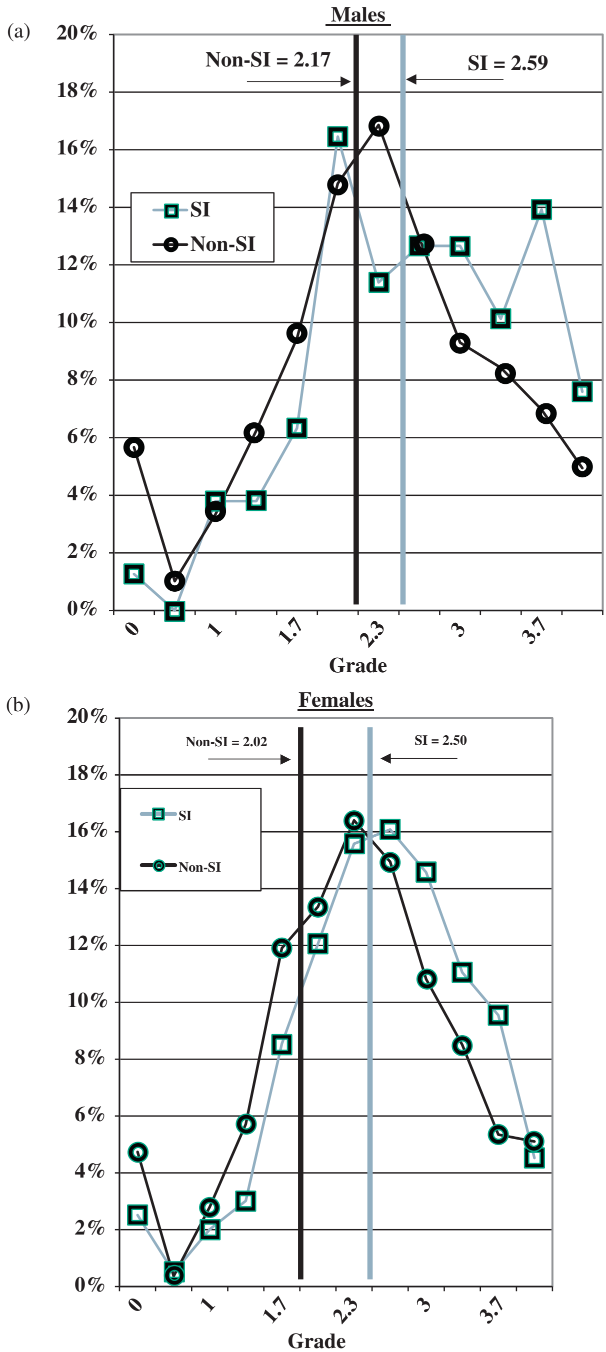

Fig. 10. Chemistry Gender Differences: (a) Males and (b) Females. *Note*: SI – 28% Males, non-SI – 46% Males; SI – 71% Females, non-SI – 54% Females.

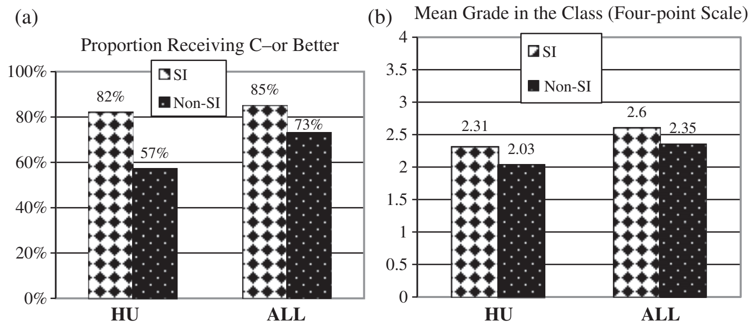

Fig. 11. Chemistry I: Historically Underrepresented (a) Proportion Receiving "C−" or Better and (b) Mean Grade in the Class (Four-point Scale).

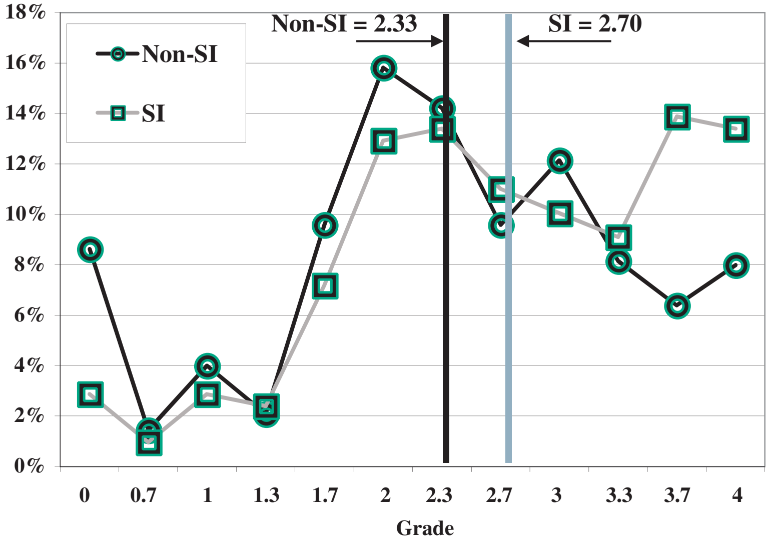

Fig. 12. Organic Chemistry I: Course Grades.

- Performance levels for HU students taking SI to reach and often surpass non-SI takers.
- HU students participate in SI more frequently than majority students.
- SI has a significant impact on upper-division courses resulting in higher grades.

The SI efforts described for these 7,451 participants cost an average of US $115 per SI participant. We calculated that the SI intervention prevented at least 170 students from D/F grades (assuming the failure rate of non-SI students) and also played a role in these students staying in the major as well as college. The

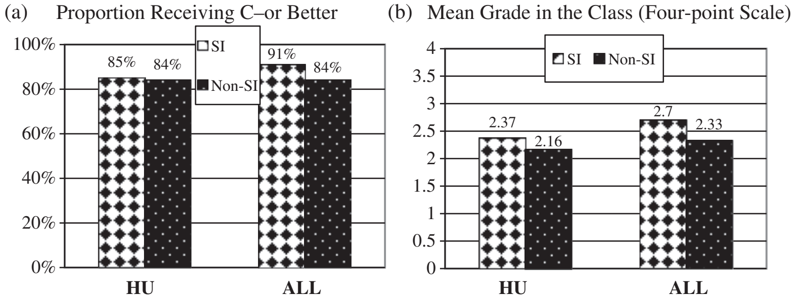

Fig. 13. Organic Chemistry I: Historically Underrepresented (a) Proportion Receiving "C−" or Better and (b) Mean Grade in the Class (Four-point Scale).

Table 6. SAT I and High School GPA.

	SI	Non-SI
SAT I Math	**482**	**526**
SAT I Verbal	466	480
High school GPA	3.14	3.20

Note: Bold = $p < 0.005$.

Table 7. SAT I Math Score Versus Course Grade.

Grade in Class	SI SAT Math	Non-SI SAT Math	Difference
A	519 ($n = 12$)	564 ($n = 118$)	−45
B	470 ($n = 12$)	532 ($n = 84$)	**−62**
C	459 ($n = 11$)	508 ($n = 125$)	−49

Note: Bold = $p < 0.005$.

savings in lost tuition and the cost of more recruitment to replace these students more than justify the costs.

STABILIZATION OF SI BUDGET SUPPORT

Since 2010, SI had been funded by finding one-time money sources each year. Finally, in 2018, an important change in university accounting allowed the institutionalization of the program into the regular college budget. Up until 2018, SFSU colleges had been (under)funded with a fixed sum and then given augmentation money to cover the late addition of the most needed classes. Notably, the budget did not scale with students served. The new policy was to fund colleges in proportion to the number of units taken by students.

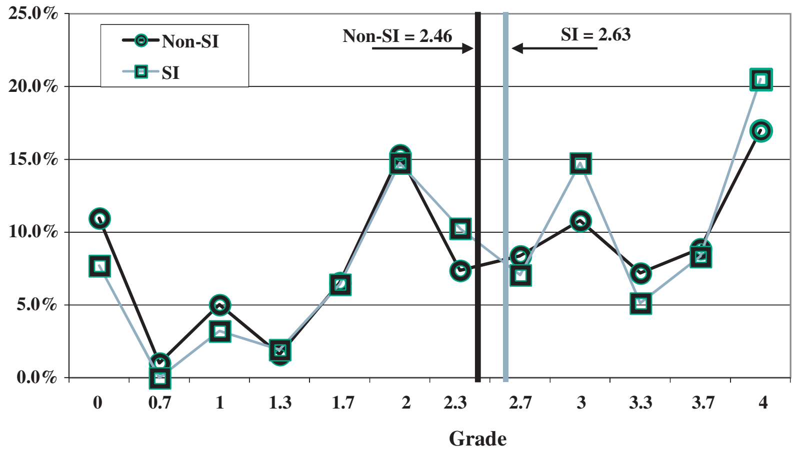

Fig. 14. Calculus I: Course Grades. *Note*: SI: "C−" or better – 87%; non-SI: "C−" or better – 81%.

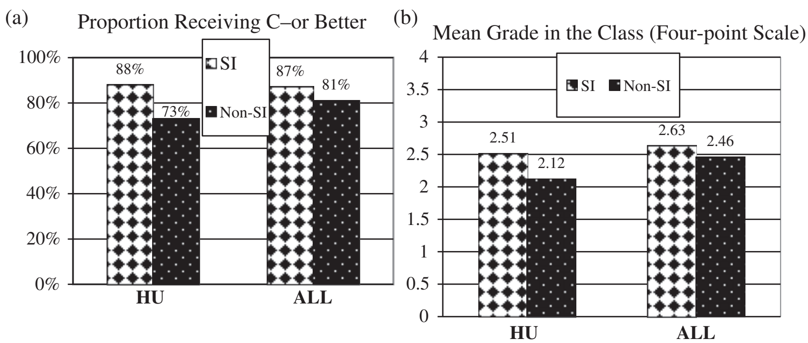

Fig. 15. Calculus I: Historically Underrepresented (a) Proportion Receiving "C−" or Better and (b) Mean Grade in the Class (Four-point Scale).

This was a sensible change and very beneficial for SI. SI had been set up as a proper course, with formal units and instructors of record. It had been run at high financial efficiency during the persistent underfunding. Thus, it turned out that the new formula, where funding was proportional to units taken, gave the College of Science and Engineering more than enough money to pay the student facilitators and instructors of record.

In fact, the formula gave sufficient funds to give the facilitators a small raise, to pay for the program director, and also give support for each department to provide release time for a department-level SI coordinator, who manages the relationships between the SI staff and the instructors of record for the parent courses. Beginning in Fall 2018, SI became a regular part of the college budget.

LESSONS LEARNED AND RECOMMENDATIONS

Undergraduates Are Fantastic SI Facilitators, Particularly When They Work in Pairs

Undergraduate SI facilitators bring a much-needed perspective to the lower-division science courses. As near-peer facilitators in the SI program, they facilitate the workshop and foster a collaborative learning environment where students engage in group work, peer teaching, and problem-solving (Arendale, 2004). They are also able to help students master content while developing and integrating learning and study strategies. While they are not content experts, they can provide personal relevance of content (for instance, they can highlight content that may be important in future classes) and personal connection that lecturers and graduate students are unable to provide.

Recommendations

- *Broadcast success widely across the institution*. A program like SI is seen by many administrators as supplemental and not a necessity and therefore not a funding priority. SI has gained traction at SFSU because of the recent CSU system-wide emphasis on improving graduation rates, which has put the spotlight on campus programs that improve student success. The current SI model is very effective and has remarkably consistent and positive data behind it as provided by the peer-reviewed publication of the SFSU SI program and results (Peterfreund et al., 2008; Rath et al., 2007; and Rath et al., 2012). Sharing these data has led the administration to view SI as a higher funding priority and a model to be spread to other subject areas.
- *Students make great ambassadors for the program*. Just having students and the facilitators sharing their inspiring personal experiences can be very effective, if you can get them in front of key decision-makers. Administrators appreciate having students telling their stories and putting a face and narrative to the numbers.
- *Work together* with institutional research, science education faculty, and evaluation specialists to evaluate the impact of the program. Every program benefits from formative assessment, and campus institutional research is usually the only unit that can get fine-grained student performance data. Science education faculty can help shape the data analysis queries and interpret the results. Furthermore, they can provide perspectives and instruments to be applied at the student level to get qualitative information about the workshops.
- *Program continuity is very important*. The SFSU program was only officially on hiatus for a year, but that gap and change in leadership caused a huge disruption in resources, culture, and practice as discussed above.
- *Formalize SI as much as possible.* In our case, we made the workshops proper courses in the catalog with proper instructors of record and proper units for students enrolled. This helped put the work into a format that the university bureaucracy could understand, which helped with salary, credit toward

tenure, and student incentives. It also allowed SI to quickly take advantage of improvements in the budget process to institutionalize it as part of the college budget.

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