Enhancing Learning Power through First-Year Experiences for Students Majoring in STEM Disciplines

Robert Koch[1], John Kucsera[2], Kathryn Bartle Angus[1], Kimberly Norman[1], Erica Bowers[1], Pradeep Nair[1], Hye Sun Moon[1], Afshin Karimi[1], and Susamma Barua[1]

1 California State University, Fullerton 2 Arroyo Research Services, Asheville, NC

Abstract

Academic programs targeted for first-time students can help their persistence in STEM majors. Our project, ASCEND STEM, included three first-year experiences (FYEs) designed to offer students the skills that would help them successfully traverse potential barriers to academic success. In the FYEs, we sought to strengthen the learning power, improve the academic achievements, and increase the postsecondary success of first-time, full-time freshmen majoring in a STEM discipline. Two models of FYE were offered in three settings—two scenarios were for engineering majors and the third for science and mathematics majors. Both models tested whether the offering of literacy skill building in the context of discipline knowledge acquisition strengthened learning power (as measured by the Effective Lifelong Learning Inventory) and asked whether this could affect academic success and persistence within the STEM major. We found that either model one, integrating literacy skill building and discipline-based concepts into a single course (the approach used in science and math), or model two, pairing a literacy skill building course with either a discipline-based course or a special group support program (the approach used in engineering), improved learning power. Increases in learning power were a valid predictor of improved grades and persistence in engineering where a high-quality control group was available.

Introduction

At California State University, Fullerton (CSUF)—a large, four-year, Hispanic-serving institution in southern California—25% of first-time, full-time students entering as science, technology, engineering, and mathematics (STEM) majors left their department or college within their first year (data from 2012). Of the 75% who continue in STEM their second year (2013), 20% of these students failed to earn 24 or more credits—the minimum needed to establish a five-year graduation trajectory. Not surprising, fewer than half of the students who failed to earn 24 or more credits completed their degrees within five years.

These campus statistics are not uncommon. The 6-yr degree-completion rate of undergraduate STEM majors at U.S. colleges and universities is less than 40% (President's Council of Advisors on Science and Technology [PCAST], 2012). Graduation and persistence rates among women, underrepresented minorities (URM), and first-generation college students are even more troubling. These students leave STEM majors at significantly higher rates than their counterparts. This outcome correlates with several factors (discussed below) that indicate a low level of preparedness. So it is not surprising that these students enter university with less confidence and are more likely to be required to take remediation in their first year (Riehl, 1994; Hudley, et al., 2009).

With these characteristics in mind, this study aimed to improve the success of STEM majors at CSUF via a project called ASCEND STEM. Our results should provide insight to other HSIs around the country, looking to implement support programs to improve the postsecondary success of their first-generation, URM students.

The academic success of students entering the university for the first time, especially those who are first-generation and low-income (Lopez, 2009), is often derailed at one of five critical points in their paths to degree completion (Figure 1):

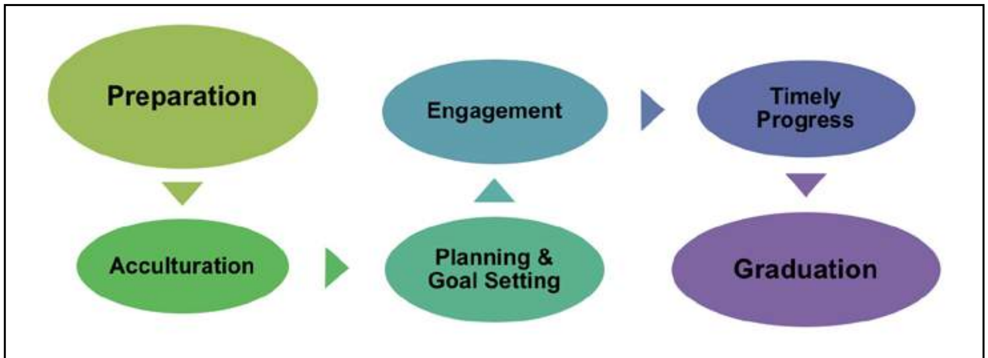

Figure 1. Five essential educational processes associated with student success. Graduation is the desired outcome and ultimate measure of academic success. The project sought to improve attainment of and reduce impediments to skills acquisition required for passage through each process.

- academic *preparation* (Adelman, 1999, 2006; Hoachlander et al., 2003; Warburton, Bugarin, & Nuñez, 2001; Balemian & Feng, 2013),
- academic and social *acculturation* (Tinto, 1993; Wassmer, Moore, & Shulock, 2004; Katrevich & Aruguete, 2017),
- academic and social *engagement* (Zhao & Kuh, 2004),
- *planning & goal-setting* (Choy, 2001; Terenzini et al, 1996), and
- *timely progress* toward the degree (Adelman, 2006; Moore & Shulock, 2009).

Failure to achieve or remediate any of these areas can increase attrition and withdrawal (see theoretical models from Lee, Mackie-Lewis, & Mark, 1993; Guiffrida, 2006; Nora et al., 2006; Tinto, 2006).

One aspect of the ASCEND STEM project was a first-year experience (FYE) designed to offer students the skills that would help them successfully traverse these potential barriers. In the FYE, we sought to strengthen the learning power, improve the academic achievements, and increase the postsecondary success of first-time, full-time freshmen majoring in a STEM discipline.

To achieve these objectives, we focused on helping first-time, first-year STEM majors, particularly non-traditional students, to take charge of their academic success by equipping them to engage in curricular and co-curricular campus activities using strategies proven to improve academic performance. Kuh et al. (2008) reported that student engagement in educationally meaningful activities—so-called high-impact practices (HIPs)—is positively related to academic outcomes like first-year grades and persistence to the second year of college. That study also concluded that while exposure to effective educational practices benefited all students, the effects were even greater for less-prepared students and students of color, compared to white students. In addition, Tierney (2004) noted the importance of cultural and social capital for student retention. Whereas, Jensen (2011) observed that factors influencing retention operate on the:

- individual level (academic performance, including GPA; course load; academic self-discipline; and attitudes and satisfaction, including positive attitude about academics, commitment to college and sense of belonging and social connectedness);
- institutional level (academic engagement, including undergraduate research, university size and opportunities to join clubs); and
- social and external level (social and family support, including faculty and staff support, a familiar and authentic cultural environment, a sense of belonging and community and a sense of importance).

Because low-income, first-generation students transitioning from high school to higher education experience profound doubts and fears about their identity and capacity as college students (Yeager & Dweck, 2012), this project employed interventions shown to be effective for aiding non-STEM students; these interventions were modified to address academic and social issues as they present in STEM majors. Additionally, the findings that mathematics intervention programs—even at pre-collegiate levels—have improved student success and persistence, influenced the intervention planned for science and mathematics majors (Wake, 2011; Dika & D'Amico, 2016). In response, the project developed first-year experiences designed to address impediments to graduation for three groups of STEM students: undeclared engineering majors (EGGN 100, *Introduction to Engineering*), female students in engineering or computer science majors (Women in Computing and Engineering Program, WICE), and science or math majors (CNSM 100, *Introduction to Learning and Thinking in Science and Math*). The goals for these first-year experiences (FYE) were to:

- prepare students for the academic rigors of STEM majors so that the high-performance expectations of their majors were not a surprise (Tinto, 2012);
- strengthen students' learning power and build readiness and competence as required to provide them with the academic momentum to traverse critical transition points in STEM majors (Buckingham Shum & Deakin Crick, 2012);
- expose students to curricular and co-curricular resources, activities, and opportunities that would build awareness of campus culture (Stephens et al., 2014; Katrevich & Aruguete, 2017);
- offer students peer mentoring and participation in learning communities—activities known to help all students improve success at the university (Moon, et al., 2013; Stephens et al., 2014);
- use the peer mentoring program to augment traditional faculty advising to provide a student-oriented perspective on the importance of planning and goal setting for fostering timely academic progress;
- involve students in collaborative, team-based applied projects to set the stage for future engagement in formal undergraduate research (Kuh, 2008; Moon et al., 2013) or service/community-based learning (Zhao and Kuh, 2004) experiences; and
- evaluate first-time freshmen's learning power and one-year persistence (Sujitparapitaya, 2006) as gauges of their preparation to succeed in the remainder of their academic career.

Learning power can be described as the personal power to learn. Deakin Crick et al. (2004) conducted a substantial literature review to identify dispositions, attitudes, and values found to impact an individual's capacity and motivation to learn (e.g., self-determination theory, goal orientation, learning dispositions, locus of control, self-esteem, etc.). Once consolidated, the researchers explored the dimensionality of these constructs; the result: seven conglomerates or dimensions of variables that they define as learning power. The study also resulted in a psychometrically sound assessment to measure learning power and dimensions, and to provide a dimensional learning profile to aid self-awareness and self-instruction: the Effective Lifelong Learning Inventory (ELLI).
The seven dimensions of learning power include (Figure 2):

- *changing and learning* – a sense of oneself as someone who learns and changes as a result;
- *critical curiosity* – an orientation to want to probe a concept beyond the superficial;
- *meaning making* – making connections and understanding that learning matters personally;
- *creativity* – propensity to be imaginative and intuitive and to be playful and take risks while learning;
- *learning relationships* – being comfortable of learning independently as well as from or with others;
- *strategic awareness* – being aware of how and why one learns and actively managing one's own learning;
- *resilience* – the orientation to persevere when facing a challenge to the progress in one's learning processes (Deakin Crick, R., Broadfoot, P. & Claxton, G. 2004).

The conception of learning power and its assessment tool have been found valuable for education, business, and corporate organizations to support individual and collaborative learning. Studies have found the ELLI instrument and profile to improve self-directed learning and teacher-facilitated pedagogical change but only with coaching conversation and/or skilled pedagogical interventions (e.g., inquiry-based learning and authentic pedagogy). From a critical review of these studies, Deakin Crick, Huang, Shafi and Goldspink (2015, p. 124) concluded:

> The coaching conversation created 'space' for individuals to identify their unique sense of identity as a learner and to begin to 'own' and formulate a particular purpose or desired outcome. With skilled pedagogical interventions, these conversations formed a starting point for the individual to determine what they wanted to achieve in a learning context (why) and how they would go about achieving that purpose (how). The responsibility for the processes of learning shifted from the teacher to the learner.

An excellent summary of how the ELLI operates in the context of a STEM discipline can be found in Godfrey, Deakin Crick, & Huang (2014). In that pilot study, the researchers focused on engineering students who needed to apply knowledge already mastered to demonstrate competence in systems thinking and design. Students began with a specific engineering problem and were challenged to construct a framework that defined the boundaries of and connections within the space of engineering practices that would foster a functional solution to the problem. Thus, no specific knowledge or rote learning could be used to reach a solution. Instead, resolving the issue required considering the problem as a part of a whole system and reaching an outcome within the boundaries of that system. The process depended "...on the ability to learn, and to progress through an open-ended, formative, dynamic learning process." This required a cumulative application of a unique assembly of knowledge from multiple sources to reach a novel conclusion—a process that is driven by and challenges the limits of a student's learning power. Students who undertook this approach showed a trend of growth (rise in median scores) in all dimensions of learning power and a significant increase in strategic awareness—a key dimension of learning power. Creativity and resilience showed the smallest growth. In general, these factors prove to be among the most difficult learning power dimensions to positively impact, even in courses in science and technology where both are seriously challenged.

Building upon the existing research, we explored if FYE courses with high-impact practices would improve the learning power and academic achievement of low-income, first-generation students who are majoring in a STEM discipline.

Method

We evaluated the impact and outcomes of three different FYEs implementing high impact practices and literacy skill building, and compared student outcomes to a control course that did not offer any coaching in learning literacy skills. We collected data across all groups through student surveys, the ELLI, and performance/enrollment records. We then employed inferential and regression analytic techniques to determine key findings.

First-Year Experience (FYE)

Three different FYEs were offered to incoming first-time, full-time STEM-majoring students in Fall 2015 and 2016—these three FYEs utilized one of two different models for adding new learning strategies to discipline-based curricula. Model one *integrated* literacy building concepts and discipline-based content in a single course, whereas model two *paired* a literacy building course with a discipline-based course or program.

In the integrated model, one FYE, CNSM 100: *Introduction to Learning and Thinking in Science and Math*, aimed to integrate literacy building concepts with a curriculum focused on enhancing quantitative reasoning skills. Elements of CNSM 100 were also based on a course proven to have high-impact on student success and to promote timely graduation by participants, the Cal State Fullerton Freshman Programs course (UNIV 100) (Moon et al., 2013). Thus, we incorporated strategies to acclimate students to university life, opportunities to engage in campus activities, and tools for goal setting; e.g., students gained an understanding of career opportunities, developed a thorough awareness of the learning resources available to them, and connected with faculty, staff, and peers who could support them through graduation (Padget et al., 2013). Also, CNSM 100 offered the unique learning goal to strengthen quantitative reasoning and improve literacy skills in the context of a hands-on, problems-based, team-oriented curriculum. This course was available to any science or mathematics student regardless of specific disciplinary major and was co-taught by instructors from the Department of Mathematics and the Department of Literacy and Reading.

The other two FYEs shared a common strategy; i.e., the pairing of a literacy skill building course, READ 201A: *New Literacies for Academic Success*, with discipline-oriented curricula. The first example of a paired-model FYE included a course, EGGN 100: *Introduction to Engineering*, which was offered to undeclared engineering majors. EGGN 100 focused on introducing essential concepts in civil, computer, electrical, and mechanical engineering and was paired with READ 201A. EGGN 100 was co-taught by four engineering instructors and READ 201A was taught by an instructor from the Department of Literacy and Reading. In the second example of a paired-model FYE, READ 201A was paired with a student support program targeting first-year female engineering and computer science majors—the Women in Computing and Engineering (WICE) program. WICE included acculturation, engagement, and goal setting components as well as special lectures that focused on how to succeed in engineering and computer science as a female professional.

There was one additional variation between the FYE for science and math majors compared to those for engineering majors—science and math majors experienced peer mentoring. Each section of CNSM 100 had four peer mentors who worked with ten students each. Students had at least one-hour sessions with their peer mentor three times per semester. The goal for the peer mentors was to make and maintain a personal contact with their mentees, offer them informal coaching on cultural and academic aspects of college life as a science or math major, and provide feedback on how to interpret and respond to their ELLI data.

In summary, we offered three groups of STEM students FYEs that combined discipline content with literacy skill building, critical reading, analytical thinking, and other strategic learning skills such as setting short-term obtainable academic expectations and long-term academic and career goals. The FYEs also incorporated the high impact practices (HIPs) of learning communities, community service, peer mentoring, and undergraduate research components.

We were also interested in comparing the two models (integration vs. pairing) to determine whether the way that literacy skill building components were coupled with discipline knowledge-based curricula made a difference. In CNSM 100, because it was developed as a new course, the concepts were integrated with the discipline-based curriculum and were practiced by the students in the context of quantitative reasoning and the problem-oriented, team-based projects. Whereas for engineering students, the concepts were taught in a separate but paired course that ran in parallel to either EGGN 100 or the WICE program. This supplemental course (READ 201A) brought skills in reading and learning processes, reading interpretation and critical thinking strategies as they applied to various readings and presentations in engineering. Although the material was not embedded in the course, the instructor made a pointed effort to create direct relevance by shaping content around experiences offered in the EGGN 100 course or WICE program.

Participants

CSUF offered both models of FYEs in the fall semesters of 2015 and 2016 to incoming STEM students. The number of participants increased in the second semester cohorts (Table 1).

The CNSM 100 takers were more likely to include underprepared students than anticipated—we had expected that the participants, although taking the course voluntarily, would represent a cross-section of entering science and math majors. However, due to unanticipated difficulties concerning the offering of general education credit, compared to science and math first-time freshman in general (NSM FTF), CNSM 100 participants exhibited very different characteristics (Table 2).

This unanticipated situation made the nonparticipating NSM FTF cohort a less precise control group for the CNSM 100 treatment group than the unpaired EGGN 100-02 was for the paired EGGN 100-01 + READ 201A treatment group.

Data Collection

Surveys: With assistance from faculty and program staff, participating students completed surveys throughout the program, including a pre-course survey and an end-of-course survey. The pre-course survey collected additional background data from respondents, such as number of hours working and work location for the upcoming school year, residency plans, and degree of concern for affording college. Post-surveys measured students' perception/satisfaction with participating course activities, degree of student engagement, and major plans.

Learning Power: Immediately following the online student pre- and post-surveys, respondents were redirected to take the ELLI. The ELLI is a 75-item validated tool by which a learner can assess his or her own learning disposition in seven dimensions that reveals the student's depth of intellectual engagement in learning (Deakin Crick & Yu, 2008). The assessment has been validated with both child and adult learners alike (Deakin Crick et al., 2013). Students are provided their scores on each dimension at the end of the assessment, as well as a learning diagram or profile, indicating their strengths and weaknesses along each dimension (Figure 2). The ELLI and its resulting learning profile can serve several purposes: provide students a critical reflection of their learning strengths and weaknesses (or power); inform faculty of

First-Year Experience	Fall 2015	Fall 2016
CNSM 100 (integrated model treatment)	27	66
NSM FTF (proposed integrated model control)	409	NA*
EGGN 100-01 + READ 201A-01 (paired model treatment)	17	35
EGGN 100-02 (paired model control)	19	30
WICE program + READ 201A-01 (paired model treatment)	0	37
* Only Fall 2015 data were analyzed as shown in Table 2.		

Table 1. Number of students in each FYE during pilot semesters.

Demographic Characteristic	CNSM 100 Participant	NSM FTF
Required remediation during summer	13%	37%
Required remediation during first year	9%	22%
Not from college-ready high school	76%	40%
First-generation college student	81%	56%
Underrepresented minority	59%	48%
Pell grant recipient	70%	49%

Table 2. Comparative demographics of all NSM first-time, full-time freshman (NSM FTF) and CNSM 100 participants for Fall 2015.

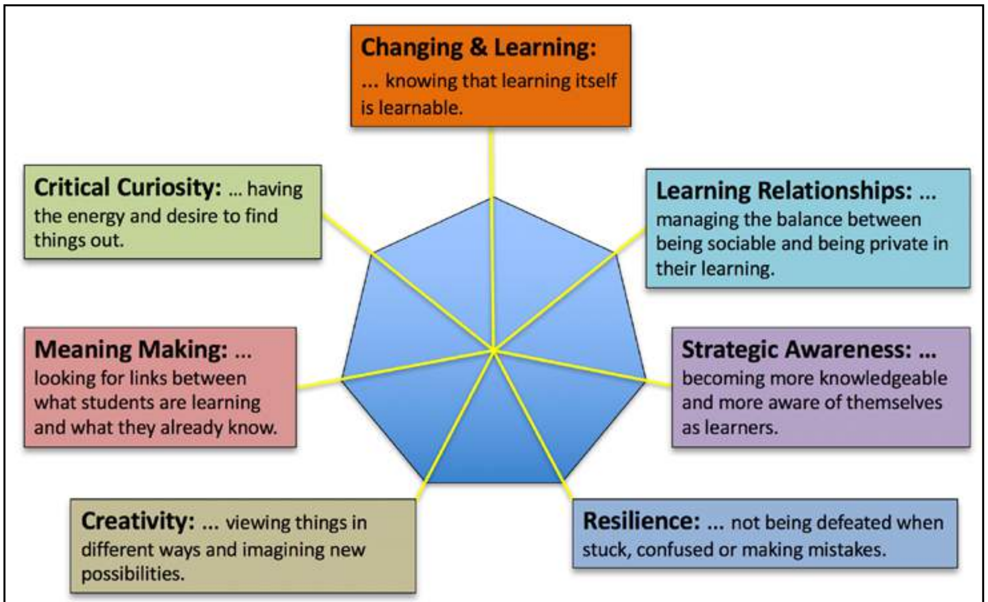

Figure 2. Seven dimensions of the Effective Lifelong Learning Inventory (ELLI). The seven axes show the relative level of assurance each student reports based on responses to questions that relate to learning in each dimension.

the student learning characteristics of the class, and thus help design or tailor effective instruction; and facilitate program evaluation or research.

Data Analysis

To explore learning power and academic gain differences between the FYE treatment group (EGGN 100-01) and control group (EGGN 100-02), we explored and controlled for baseline equivalence and then used mean difference tests to compare student outcome variables of interest. We also explored the impact of CNSM 100 on academic outcomes compared to a group of non-participating first-year students who were as similar as possible to CNSM 100 participants using propensity score matching (see caveat under *Participants*).

For both CNSM 100 and EGGN 100-01 FYE courses, we conducted within-group regression analyses to explore the effects of supplemental literacy skills instruction, as well as the effects of the FYE on students with different degrees of learning power. The course analysis examined the impact of a student participating in supplemental instruction, and whether that supplemental instruction was integrated into the FYE course or delivered as a paired, stand-alone course (e.g., integrated READ 201A [CNSM 100] vs. paired READ 201A [EGGN 100-01 and WICE] vs. no READ 201A [EGGN 100-02]) (Schaffer, 2014). We also explored baseline equivalence to indicate whether a comparison of CNSM to EGGN students could be made.

Results

Impact on Learning Power

FYE courses for first-year STEM students significantly increased student learning power. This was true for both the Fall 2015 and Fall 2016 semesters.

In Fall 2015, treatment group students (EGGN 100-01 and CNSM 100) increased learning power while control group students (EGGN 100-02) did not (Table 3). For example, students in CNSM 100 experienced about a 10-point increase, and students in EGGN 100-01 experienced about a 7-point increase from pre-to-post administration (or from beginning to end of the semester). EGGN 100-01 students grew about 14 percentage points in Creativity and about 10 percentage points in Strategic Awareness dimensions. CNSM 100 students grew $\geq$10 percentage points across all dimensions except Resilience.

In Fall 2016, students in all intervention courses (EGGN 100-01, WICE, AND CNSM 100) significantly improved in learning power over the semester (Table 4). Average student ELLI scores increased pre-to-post from 61$\pm$10% (M$\pm$SD) to 71$\pm$12% ($p<0.001$) for FYE students. Two groups showed similar changes: CNSM 100 improved from 61$\pm$11% to 71$\pm$12% ($p<.001$) and EGGN 100-01 improved from 61$\pm$7% to 71$\pm$12% ($p<0.001$) from beginning to end of the fall semester. The latter was a two-fold greater improvement over the EGGN 100-02 control group (58$\pm$12 to 62$\pm$13; $p=0.04$). The WICE group significantly improved as well from pre (59 $\pm$9%) to post (71$\pm$14%; $p<0.001$).

A majority of students who participated in FYEs that included learning literacy strategies in Fall 2015 or 2016 showed improvement in each dimension of learning power (Figure 3). WICE + READ 201A data were combined with the EGGN 100-01 + READ 201A data and, thus, together represent outcomes for the course pairing model; whereas CNSM 100 represents outcomes for the knowledge integration model. Compared to controls (EGGN 100-02), more engineering students in the paired literacy skill building course (EGGN 100-01 + READ 201A and WICE + READ 201A) improved in creativity than in any other dimension (32%); but, the percentage who improved in changing and learning, meaning making, and strategic awareness was $\geq$20%. A higher percentage of science and math students (CNSM 100) reported improvements higher than or equal to engineering students in each category—unfortunately no comparison data are available because non-participating students (the control for this group) only took the pre-course survey.

When other influential variables were controlled, FYE participation predicted learning power growth. We ran a multiple regression model to determine if participation in a FYE course predicted ELLI growth while controlling for

Program Activity	Admin	Mean (%)	SD (%)	D	*t* (df)	p
CNSM 100	Pre	59.3	13.6	9.8	5.37 (27)	<.001
	Post	69.1	12.2			
EGGN 100-01	Pre	58.3	10.7	6.6	3.55 (32)	<.01
	Post	64.9	11.9			
EGGN 100-02	Pre	59.2	12.5	-1.0	2.10 (18)	.632
	Post	58.2	12.5			

Table 3. Overall ELLI Scores by FYE Program Participation, Fall 2015

Program Activity	Admin	Mean (%)	SD (%)	D	*t* (df)	p
CNSM 100	Pre	61.4	10.8	9.3	7.2 (19)	<.001
	Post	70.7	11.8			
EGGN 100-01	Pre	61.0	7.2	9.8	3.6 (23)	<.001
	Post	70.8	11.8			
EGGN 100-02	Pre	57.8	12.3	4.6	2.2(17)	.042
	Post	62.4	13.3			
WICE	Pre	58.5	9.4	12.9	5.2 (29)	<.001
	Post	71.4	14.1			

Table 4. Overall ELLI Scores by FYE Program Participation, Fall 2016

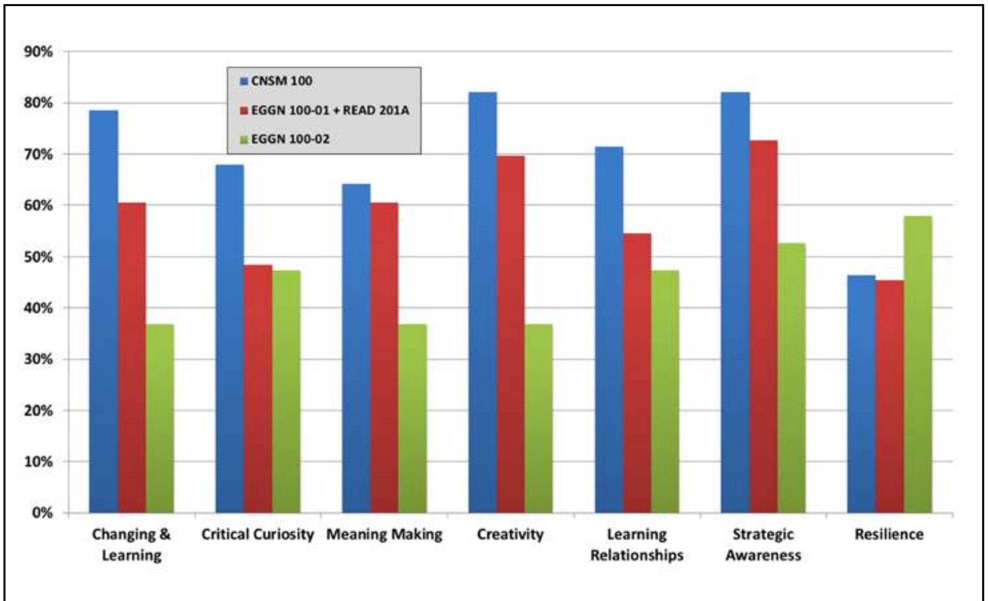

Figure 3. Percentage of students whose score improved in each learning power dimension. Data from Fall 2015 and 2016 participants were pooled and the number of surveys showing a positive change in pre-to-post-course ELLI scores in a given dimension compared to total number of survey takers was determined. WICE + READ 201A data were combined with EGGN 100-01+READ 201A as these groups used the same paired-course model.

prior achievement, gender, race, and number of semester units enrolled (Table 5). The ELLI model results indicate that participation in the CNSM 100, EGGN 100-01 and WICE FYE (coded as 1 = participation or 0 = nonparticipation) led to a statistically significant 12-point (FYE b = 11.98 ± 5.55; $p<0.05$) increase in the average ELLI score, compared to EGGN 100-02 students.

Survey findings from FYE students indicated that the ELLI and learning profile were a helpful self-awareness and diagnostic tool. For example, 75% of FYE students agreed or strongly agreed that the ELLI profile (the diagram showing their strengths and weaknesses) identified learning areas in which they needed to improve. And 68% agreed or strongly agreed that the ELLI helped them engage in reflection and become more self-aware about their learning. As one student reported, "It has helped me learn what improvements I need to make in different areas of my current thinking and learning skills." At least two out of three CNSM 100 students reported the class helped them from a moderate to great extent. For example, 72% reported the class moderately to greatly helped them to connect with other students in their major. Meeting new people, having a peer mentor, and learning "learning strategies" were the most valuable aspects openly reported from CNSM 100 students. For EGGN 100-01 specifically, these students openly reported that learning "learning strategies" was the most valued component of the course.

Impact on Academic Outcomes

We explored the academic impact of participating in CNSM 100 in Fall 2015 compared to all Fall 2015 CNSM first-time, full-time freshman, while controlling for influential variables like high school GPA, socioeconomic status, race/ethnicity, and first-generation attending college variables. The results indicate that, unlike for the growth of learning power as tested by the ELLI, participation in CNSM 100 was not a significant predictor of improved student performance as measured by first-year STEM GPA. Subsequent cross-tab analyses indicated that CNSM 100 participation will likely not predict other student outcomes as well (first-year overall GPA, number of degree applicable units earned in the first year, or second-year university retention). We therefore did not continue to conduct our planned quasi-experimental design using a statistical matching procedure, such as propensity scores with CNSM students. The unexpected demographics of the CNSM 100 takers may have been responsible for this outcome, so any future analyses will have to incorporate a better control group for that population.

Although student participation in EGGN 100-01 + READ 201A (treatment group) during Fall 2016 predicted learning power growth, it did not result in first-semester GPAs higher than those of students in EGGN 100-02 (control group that did not take READ 201A) in Fall 2016. Whereas without controlling for influential variables like high school GPA (HSGPA), the average Fall 2016 GPA for

Predictors	ELLI Model	
	b	SE b
(Intercept)	5.06	23.81
High School GPA	-0.05	4.75
Asian/PI Race/Ethnicity	7.07**	3.26
Other Race/Ethnicity	0.80	3.26
White Race/Ethnicity	1.10	3.46
Number of College Units	-0.60	0.88
Female	1.44	2.36
FYE (CNSM, EGGN-01 and WICE) Participant	11.98**	5.55
Summer Orientation	1.99	5.26
Summer Research Experience	-5.13	6.25

Note: ELLI model: R^2=.21, $F(9, 72)=2.063$, $p<0.05$.

Table 5. Regression Summary: Program Participation Effects on ELLI Growth

Program	Group	Mean	SD	t (df)	p
Change Score GPA	EGGN 100-01 (TX)	-0.99	0.46	0.26 (33)	0.80
	EGGN 100-02	-1.05	0.53		
Change Score STEM GPA	EGGN 100-01 (TX)	-1.21	0.73	0.92 (31)	0.36
	EGGN 100-02	-0.97	0.41		
Change Score Math GPA	EGGN 100-01 (TX)	-0.78	0.42	0.32 (19)	0.76
	EGGN 100-02	-0.70	0.29		

Note: Overall HSGPA was used for all three change score calculations. TX represents the treatment group.

Table 6. Difference between High School and Fall 2016 CSUF GPA for EGGN 100 Students

students in EGGN 100-01 was 2.80, compared to 2.37 for the control group, once we controlled for HSGPA there were no statistical differences between groups in Fall 2016 GPA, STEM GPA, or Math GPA (Table 6).

Besides GPA, a slightly higher percentage of full-time students participating in EGGN 100-01 FYE Fall 2015 course earned 24 or more credits by the end of Spring 2016 compared to control group students. The percentage of full-time, first-time STEM FYE students who earned 24 or more credits by Spring was 67.9% (EGGN-01), compared to 65.2% of control students (EGGN-02). However, the difference was not statistically significant.

Persistence outcomes for students taking EGGN 100-01 and EGGN 100-02 courses in the Fall 2015 semester were also monitored from Fall 2015 to the beginning of Spring 2017. Students in EGGN 100-01 had higher rates of persistence in both the university and their STEM-major compared to their EGGN 100-02 counterparts (Figures 4 and 5, respectively).

Discussion

Targeted academic programs for first-time underrepresented students can help their STEM retention and college persistence. Matsui and colleagues (2003) found such programs can help URM science majors attain similar retention and graduation rates compared to non-URM peers. Maton and colleagues (2009) even found such programs to increase graduate education rates for URM students. We found similar benefits in the FYE programs for the ASCEND STEM project: participating engineering students had higher retention and persistence rates than their non-participating peers. As shown in Figures 4 and 5, students in the FYE EGGN 100-01 course had substantially higher university persistence (97% from Fall 2015 to Fall 2016) and STEM major persistence (77.1%) than its control cohort group (EGGN 100-02) of 80% and 63%, respectively.

We also found that the FYE can significantly increase student learning power (as measured by the ELLI) for participating students in comparison to control students across two different cohorts. Compared to controls, learning power increased for students enrolled in a FYE course during either the Fall 2015 or Fall 2016 semester (Table 4 and 5; Figure 3) . These findings indicate that either the integration of literacy skill building concepts with discipline-based course material or the pairing of a literacy skill building course with a separate discipline-based course improves learning power. Additionally, for undeclared engineering students, improved learning power is a predictor of both university and STEM major persistence.

Although peer mentoring was found to be valued by the CNSM 100 takers, it seems not to have had the anticipated effect of helping those students to feel informed and connected to their major and, although coupled with improved learning power, it did not increase students' likelihood of persisting even if their grades were good enough to do so. The intention of the project was to couple peer mentoring with proactive comprehensive advising by professional staff. This type of advising was expected to have been synergistic with peer mentoring benefits. Together they would have addressed all aspects of university life (this support would have augmented the required academic schedule advising done by faculty). However, because participation in proactive advising was voluntary, many students elected not to engage. This finding offers evidence that, if the proactive advising is to have an impact, participation must be mandatory for students judged to be at-risk by criteria shown to be accurate for their major.

While this study highlights the positive impact of the ASCEND STEM project's FYE program on student learning power and persistence in both STEM major course and university enrollment during their first two-years at CSUF, project continuation and longitudinal study are needed to more fully understand the impact of the project on graduation rates and other indicators of long-term academic success. In addition, longitudinal monitoring of students who exhibited increased learning power would provide evidence of the impact of improved learning power on post-university outcomes like entry into STEM careers or related graduate programs for URM and first-generation students.

This research was supported by a subaward (CSU STEM Collaborative Project #X0085114-FLAUX) from the California State University Chancellor's Office of a grant from the Leona M. & Harry B. Helmsley Charitable Trust (2014PG-EDU36).

Acknowledgements

We thank Hope Weiss (Department of Mechanical Engineering) and Garrett Struckhoff (Department of Civil and Environmental Engineering) for contributions in designing

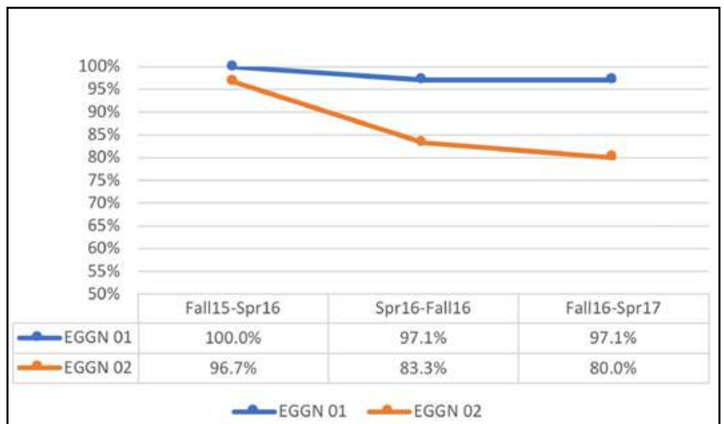

Figure 4. University Persistence of Fall 2015 Cohort, Fall 2015 to Spring 2017. The EGGN 100 treatment group (EGGN 100-01) had a higher rate of persistence than the control group (EGGN 100-02). WICE student data were not collected in Fall 2015.

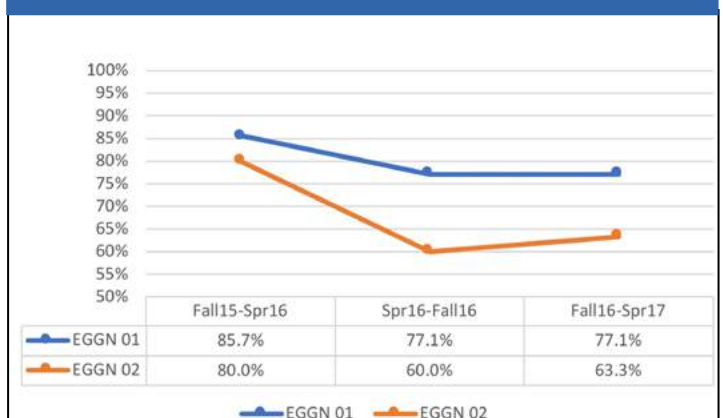

Figure 5. STEM Major Persistence of Fall 2015 Cohort, Fall 2015 to Spring 2017. The EGGN 100 treatment group (EGGN 100-01) exhibited a higher rate of persistence in their major than the control group. WICE student data were not collected in Fall 2015.

EGGN 100 and Kimberly Mundala (Department of Literacy and Reading) for modifying and teaching READ 201A in Fall 2016. We are also indebted to the many members of the ASCEND STEM Management Team (and regret that there are too many to acknowledge individually) for their active engagement in the development and oversight of the ASCEND STEM project.

References

Adelman, C. (1999). Answers in the toolbox: Academic intensity, attendance patterns, and bachelor's degree attainment. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement. Retrieved from https://files.eric.ed.gov/fulltext/ED431363.

Adelman, C. (2006). The toolbox revisited: Paths to degree completion from high school through college. Washington, DC: U.S. Department of Education. Retrieved from https://eric.ed.gov/?id=ED490195.

Balemian, K., & Feng, J. (2013). First generation students: College aspirations, preparedness and challenges. Research College Board. Retrieved from http://research.collegeboard.org/publications/first-generation-students-college-aspirations-preparedness-and-challenges.

Buckingham Shum, S. & Deakin Crick, R. (2012). Learning dispositions and transferable competencies: pedagogy, modeling, and learning analytics. *Proc. 2nd International Conference on Learning Analytics & Knowledge*, (29 Apr-02 May, Vancouver, BC). ACM Press: New York. Retrieved from http://oro.open.ac.uk/32823/1/SBS-RDC-LAK12-ORO.pdf.

Choy, S. (2001). Students whose parents did not go to college: Postsecondary access, persistence, and attainment. Findings from the Condition of Education, (NCES 2001–126). Washington, DC: U.S. Department of Education, National Center for Education Statistics. Retrieved from https://nces.ed.gov/pubs2001/2001126.pdf.

Deakin Crick, R., Broadfoot, P. & Claxton, G. (2004). Developing an effective lifelong learning inventory: the ELLI project, *Assessment in Education 11*, 248-272.

Deakin Crick, R. & Yu, G. (2008). The Effective Lifelong Learning Inventory (ELLI): is it valid and reliable as a measurement tool? *Education Research 50*(4), 387-402.

Deakin Crick, R. E. (2009). Inquiry-based learning: reconciling the personal with the public in democratic and archaeological pedagogy. *Curriculum Journal 20*(1), 73-92.

Deakin Crick, R. E. (2012). Deep Engagement as a complex system: identity, learning power and authentic enquiry. In: C. S. Reschly, & C. A. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp 675-694). Springer, Boston, MA.

Deakin Crick, R., Haigney, D., Huang, S., Coburn, T. & Goldspink, C. (2013). Learning power in the workplace: the effective lifelong learning inventory and its reliability and validity and implications for learning and development. *The International Journal of Human Resource Management, 24* (11), 2255–2272.

Deakin Crick. R., Huang, S., Shafi, A. A., & Goldspink. C. (2015). Developing resilient agency in learning: The internal structure of learning power. *British Journal of Educational Studies, 63*(2), 121-160.

Delen, D. (2010). A comparative analysis of machine learning techniques for student retention management. *Decision Support Systems, 49*(4), 498-506.

Dika, S.L. & D'Amico, M.M. (2016). Early experiences and integration ion the persistence of first-generation college students in STEM and non-STEM majors. *Journal of Research in Science Teaching, 53*, 368-383.

Godfrey, P., Deakin Crick, R., & Huang, S. (2014). Systems thinking, systems design and learning power in engineering education. *International Journal of Engineering Education, 30*(1), 112-127.

Guiffrida, D. A. (2006). Toward a cultural advancement of Tinto's theory. *The Review of Higher Education, 29*(4), 451-472.

Hochlander, G., Sikora, A. & Horn, L. (2003). Community college students: goals, academic preparation and outcomes. Washington, DC: US Department of Education National Center for Educations Statistics. Retrieved from https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2003164.

Hudley, C., Moschetti, R., Gonzalez, A., Su-Je, C., Barry, L., & Kelly, M. (2009). College freshmen's perceptions of their high school experiences. *Journal of Advanced Academics, 20*(3), 438-471.

Jensen, U. (2011). Factors influencing student retention in higher education. Summary of influential factors in degree attainment and persistence to career or further education for at-risk/high educational need students. Pacific Policy Research Center. Honolulu, HI: Kamehameha Schools–Research & Evaluation Division. Retrieved from http://www.ksbe.edu/_assets/spi/pdfs/Retention_Brief.pdf.

Katrevich, A.V. & Aruguete, M. S. (2017). Recognizing challenges and predicting success in first-generation university students. *Journal of STEM Education, 18*(2), 40-44.

Kuh, G.A. (2008). High-impact educational practices: What they are, who has access to them, and why they matter. AAC&U Report. Retrieved from www.aacu.org/store.

Kuh, G.A., Cruce, T.M., Shoup, R., & Kinzie, J. (2008). Unmasking the effects of student engagement on first-year college grades and persistence. *Journal of Higher Education, 79*(5), 540-563.

Lee, V. E., Mackie-Lewis, C., & Marks, H. M. (1993). Persistence to the baccalaureate degree for students who transfer from community college. *American Journal of Education, 102*(1), 80-114.

Lopez, M. H. (2009). Latinos and Education: Explaining the attainment gap. Pew Hispanic Center. Washington, D.C. Retrieved from http://pewhispanic.org/reports/report.php?ReportID=115.

Maton, K.I., Domingo, M.R.S., Stolle-McAllister, K.E., Zimmerman, J.L. & Hrabowski, F.A., III (2009). Enhancing the number of African-Americans who pursue STEM PhDs: Meyerhoff Scholarship Program outcomes, processes, and individual predictors. *Journal of Women and Minorities in Science and Engineering.*15:15–37.

Matsui, J., Liu, R. & Kane, C.M. (2003). Evaluating a science diversity program at UC Berkeley: more questions than answers. *Cell Biology Education 2*:117–121.

Moon, H.S., Sullivan, E., Hershey, J., Walker, S., Bonsangue, M., Filowitz, M., Fernandez, C., Unnikrishnan, R., & Delgado, V. (2013). High-Impact Educational Practices as Promoting Student Retention and Success. *The Proceedings of the 9th Annual National Symposium on Student Retention*, (San Diego, CA, November 4-6, 2013). CSRDE-Consortium for Student Retention Data Exchange. Retrieved from http://www.fullerton.edu/analyticalstudies/_resources/pdfs/CSRDE2013_hip.pdf.

Moore, C., & Shulock, N. (2009). *Student progress toward degree completion: Lessons from the research literature.* California State University, Sacramento, Institute for Higher Education Leadership & Policy. Retrieved from http://edinsightscenter.org/Publications/Research-Reports-and-Briefs/ctl/ArticleView/mid/421/articleId/2049/Student-Progress-Toward-Degree-Completion-Lessons-from-the-Research-Literature.

Nora, A., Barlow, E. & Crisp. (2006). An assessment of Hispanic students in four-year institutions of higher education. In: J. Castellanos, A. Gloria & M. Kaminura (Eds.), The Latin/o pathway to the Ph.D. (pp. 55-78). Sterling, VA: Stylus Publishing, LLC.

Padget, R.D., Keup, J.R., & Pascarella, E.T. (2013). The impact of first-year seminars on college students' lifelong learning orientations. *Journal of Student Affairs Research and Practice, 50*(2), 133-151.

President's Council of Advisors on Science and Technology (PCAST). (2012). Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering and Mathematics. Washington, DC: U.S. Government Office of Science and Technology; 2012. Retrieved from https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/pcast-engage-to-excel-final_2-25-12.pdf.

Riehl, R. J. (1994). The academic preparation, aspirations, and first-year performance of first-generation students. *College and University, 70*(1), 14–19.

Schaffer, S. (2014). Use of paired courses in environmental science and reading to improve science learning based on data from ELLI. Personal Communication.

Stephens, N. M., Hamedani, M. G., & Destin, M. (2014). Closing the social-class achievement gap: A difference-education intervention improves first-generation students' academic performance and all students' college transition. *Psychological Science*. Retrieved from http://ies.ed.gov/ncee/wwc/quickreview.aspx?sid=20012.)

Sujitparapitaya, S. (2006). Considering student mobility in retention outcomes. *New Directions for Institutional Research*, 131, 35-51.

Terenzini, P., Springer, L., Yaeger, P., Pascarella, E., & Nora, A. (1996). First-generation college students: Characteristics, experiences, and cognitive development. Research in Higher Education, 37, 1–22.

Tierney, W. (2004). Power, identity, and the dilemma of college student departure. In *Reworking the student departure puzzle,* J. M. Braxton, ed. Nashville, TN: Vanderbilt University Press.

Tinto, V. (1993). Leaving college: Rethinking the causes and cures of student attrition. (2nd ed.). Chicago: The University of Chicago Press

Tinto, V. (2006). Research and practice of student retention: What next? *Journal of College Student Retention, 8*(1), 1-19.

Tinto, V. (2012). *Completing College: Rethinking Institutional Action*. University of Chicago Press.

Wake, G. (2011). Deepening engagement in mathematics in pre-university education. *Research in Mathematics Education*, 13, 109-118.

Warburton, E., Bugarin, R., & Nuñez, A. (2001). Bridging the gap: Academic preparation and postsecondary success of first-generation students (NCES 2001–153). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Wassmer, R., Moore, C., & Shulock, N. (2004). Effect of racial/ethnic composition on transfer rates in community colleges: Implications for policy and practice. *Research in Higher Education*, 45, 651-672.

Yeager, D. & Dweck, C. (2012). Mindsets that promote resilience: When students believe that personal characteristics can be developed. *Educational Psychologist, 47*(4), 302-314.

Zhao, C. & Kuh, G. (2004). Adding value: Learning communities and student engagement. *Research in Higher Education, 45*(2), 118-138.

Robert A. Koch, Ph.D., enjoyed a 40-year career at California State University, Fullerton supporting student success. As a faculty member, he and his students studied and published on cell-cell communications in sea squirt fertilization. His service as director of undergraduate research training programs targeting nontraditional students triggered an interest in STEM education research. And, his roles as department chair of biological science, dean of the college of natural sciences and mathematics, chair of electrical engineering, and special assistant to the provost brought new perspectives to that interest. He capped his career by serving as director of the ASCEND STEM project.

John Kucsera, Ph.D., is a Senior Associate at Arroyo Research Services where he leads program evaluations for universities, school districts and state education agencies across the nation. Kucsera has years of education research experience providing evaluative, psychometric, and quantitative services to organizations seeking to determine the impact of interventions designed to provide more equitable educational opportunities for historically disadvantaged youth. John has a MA in Program Evaluation and a PhD in Educational Psychology from the University of Texas at Austin. He also completed a post-doctoral fellowship in Educational Policy at the University of California, Los Angeles.

Kathryn Bartle Angus, M.S., is an emeriti lecturer in the College of Education at California State University, Fullerton. She specialized in development and teaching of courses in critical thinking, reading, and writing in the disciplines. Kathryn also worked collaboratively with multiple campus departments and K-12 school sites to foster student success in under-represented populations. She is currently the Director of the Hazel Miller Croy Reading Center.

Kimberly Norman, M.A., M.Ed., is an adjunct faculty member in the Mathematics Department. She completed her M.A. in Mathematics at California State University, Fullerton, and her M.Ed. in Single Subject Mathematics at the University of California, San Diego. She has been involved in many student success programs, in secondary and post-secondary education, including Upward Bound Math and Science, Advancement Via Individual Determination (AVID), Supplemental Instruction (SI), the General Education Pathways program, ASCEND STEM, and the Course Redesign with Technology (CRT) program.

Dr. Erica Bowers is the Director of the Faculty Development Center and a Professor in the Department of Literacy and Reading Education. She completed her Ed.D. in Literacy and Language at the University of Southern California. Her research agenda includes academic language, English language learners, struggling readers and assessment practices. She has several publications including a book entitled, "Building Academic Language through Content Area Texts: Strategies to Support English Language Learners." She has chaired both the Planning, Resource, and Budget Committee and the University Extended Education Committee and served on several other university level committees.

Sunny Moon, Ph.D., currently holds Director for Institutional Research and Analytical Studies at Cal State Fullerton, and has worked as an institutional researcher and educational researcher for more than fifteen years, with expertise in student retention and student success in higher education. Conducting strategic analyses and providing actionable data, she made significant contribution to policy-making in CSU and developed meaningful recommendations for student success in higher education. Dr. Moon received her Ph.D. in Education from the University of Southern California and worked as a post-doctoral researcher in USC's Center for Higher Education Policy Analysis.

Afshin Karimi is a Senior Research Associate in the Office of Institutional Research and Analytical Studies at California State University, Fullerton. His interest and expertise are in the areas of data analytics and software engineering. Afshin has an MS degree from The Ohio State University and a BS degree from University of California, Irvine – in Electrical & Computer Engineering.

Dr. Susamma Barua is the Interim Dean of the College of Engineering and Computer Science and Professor of Computer Science and Computer Engineering at California State University, Fullerton. She is a leader in engineering educational reform and is an experienced developer of innovative education programs for facilitating graduation rate and narrowing the opportunity gap. Dr. Barua has been actively involved in mentoring female and underrepresented students in computing for most of her career. She is a Golden Core Member of the IEEE Computer Society and currently an Associate Editor of IEEE Transactions on Education.