Learning, Leaders, And STEM Skills: Adaptation Of The Supplemental Instruction Model To Improve STEM Success And Build Transferable Skills In Undergraduate Courses And Beyond.

Cindy Achat-Mendes, Chantelle Anfuso, Cynthia Johnson, Ben Shepler, Jennifer Hurst-Kennedy, Katherine Pinzon, Rashad Simmons, Sonal Dekhane, Jamye Savage, Elizabeth Sudduth, Allison D'Costa, Tirza Leader, David Pursell, Clay Runck, Judy Awong-Taylor

School of Science and Technology   Georgia Gwinnett College

Abstract

Georgia Gwinnett College, an access institution serving the most diverse student body of southeast colleges, was awarded National Science Foundation and University System of Georgia STEM-Education Improvement grants to help our students meet the evolving needs of STEM education. One of the initiatives emerging from these resources is the Peer Supplemental Instruction (PSI) program, a modified model of the traditional SI program. SI is a well-documented, high-impact practice in higher education that engenders collaborative learning among students. Since SI was not available on campus, STEM faculty developed the current PSI program, with the aim to support students as they transition from high school to college. PSI is thus offered to students in the gateway courses for biology, chemistry, mathematics, and information technology majors and study sessions incorporate STEM skills, thereby increasing opportunities for students to engage in, and develop, STEM competencies. In the last year, attendance was recorded at 4,123 interactions. Assessment of academic performance of PSI students revealed that participation increased GPAs in PSI-supported courses, particularly in students entering college with low high school GPAs. Moreover, student attitudes towards STEM learning improved and peer students serving as leaders benefited, based on reports of their development of professional skills that are critical to success in college and STEM careers. We present an innovative adaptation of the SI program that can be adopted by STEM faculty, and may be particularly useful to institutions serving underprepared populations, in surmounting the academic success predictability of low high school GPA.

Introduction

Institutional profile and challenges

Georgia Gwinnett College (GGC) is a four-year majority-minority institution that attracts students from varying backgrounds and life experiences. Approximately 60% of the 12,000 GGC students identify with a racial or ethnic minority. Over 50% of students are first-generation college students, 33% are part-time students, 32% work twenty or more hours/week, 78% receive some form of aid, 52% are eligible for Pell Grants, and 14% of students are non-traditional. Amongst this diversity, the number of STEM majors remains consistent, at over 3,000 students enrolled each semester between 2015 and 2017. While this diversity offers a rich tapestry for learning, bringing unique perspectives, creativity, and innovation, diversity at the undergraduate level can also give rise to some challenges. For example, expectations for independent study and college course work are much different at high school, and students with diverse backgrounds have varying foundations in study skills and subject knowledge. At GGC, many students entering as freshmen arrive underprepared for the rigor of certain courses, such as math, biology, and chemistry; the average high school grade point average (GPA) for incoming freshmen at GGC is 2.2 on a 4.0 scale. The percentage of students earning failing grades (DFW rates) for introductory courses in many majors in Science, Technology, Engineering, and Mathematics (STEM) are consequently high, ranging from 24 – 39%. These statistics reflect the major challenges faced by our first-year student population, which must be addressed in order to retain them past the first year, while building a strong foundation in their STEM education. To support our underprepared and diverse student body, a modified supplemental instruction (SI) program was implemented in select STEM courses. We refer to the modified SI program as Peer Supplemental Instruction (PSI) to distinguish it from the more traditional SI programs.

Peer Supplemental Instruction: The modified SI model

SI is a well-established, highly impactful learning paradigm that subscribes to the constructivist learning theory, in which student learning is constructed collaboratively, utilizing and building upon students' collective understanding (Zerger, 2008). At the center of SI are peer leaders who attend classes that they have already passed to take notes and prepare for SI sessions. In SI sessions, leaders host a variety of activities and discussions and serve as a facilitator, preparing a lesson plan for a group of students to collaboratively review and practice course material. This is in contrast to a tutor model, in which tutors customize activities around an individual student's needs and typically teach to aid understanding of material. SI is supported by copious amounts of evidence describing its effectiveness in improving student performance in college courses (Blanc et al. 1993; Henson and Shelley, 2003; Martin and Arendale, 1992). Thus, to serve a student body that possesses risk factors for low success rates in STEM education, we aimed to develop and pioneer an adaptation of the SI model to meet our unique needs. The pedagogical elements and modifications to the traditional SI model are described below and illustrated in Figure 1.

Targets Foundation Courses

PSI supports students enrolled in the foundation courses of STEM disciplines, including Principles of Biology I and II, Principles of Chemistry I and II, College Algebra, Precalculus, and Introduction to Programming, which all exhibit particularly high DFW rates at our College. To help students strengthen the foundation of their STEM major, PSI-supported learning is poised at a critical time, when students who enroll upon entry into college are most vulnerable to missing opportunities to understand, learn, and retain subject matter. This practice therefore targets the first-year learning experience for our students, which has been found through an analysis of National Survey of Student Engagement data to be a critical time for redirecting the trajectory of academic performance and promote social belonging for college students (Kuh 2008; Solanki et al. 2019; Stone and Jacobs, 2008).

Collaborative Learning with a Focus on STEM Skills

At this early stage, freshmen often lack the college skills and learning techniques that are needed to secure a successful transition from high school. Like the SI model, PSI engages students in study and metacognitive skills including note-taking, time management, critical thinking, and predicting exam questions (Martin and Arendale, 1993). Additionally, our PSI model places an emphasis on the incorporation and practice of STEM skills and engagement in discipline-specific vocabulary, in the session. This component was designed to enrich STEM majors' learning experience by designing lesson plans that incorporate one or more of the following STEM skills: scientific communication, quantitative analysis, concept mapping, problem-solving, and modeling. A meta-analysis study on STEM teaching revealed that active learning is a preferred way of teaching STEM concepts (Freeman et al. 2014). Thus, time spent in PSI sessions is capitalized upon as an opportunity to enhance STEM learning through actively practicing STEM skills.

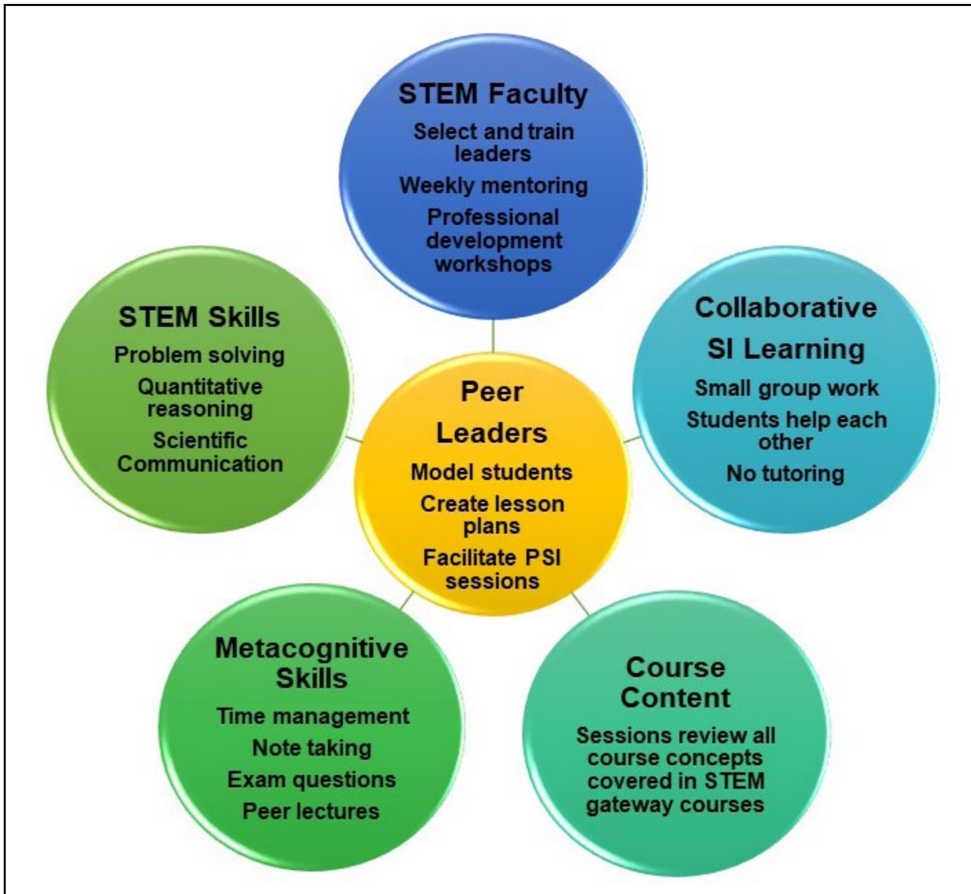

Figure 1. Pedagogical elements of the PSI model. PSI sessions are enriched, collaborative learning sessions, facilitated by peer leaders. STEM faculty take an active role in coordinating the program, and selecting and training leaders in preparing lesson plans that incorporate STEM skills, active learning strategies, and metacognition. Leaders attend classes or labs in these multi-section courses, providing them the opportunity to build relationships with students taking the course.

PSI Peer Leaders

As with all SI programs, peer leaders are central to the success of PSI. Constructivism, a learning theory which now provides a theoretical framework for understanding SI, was first proposed by Vygotsky (1978), who suggested that learners can bridge the gap in their understanding through the guidance and encouragement of a skilled partner. In SI, students who have mastered course content are selected to prepare lesson plans and lead their peers in study sessions on this material. PSI peer leaders are STEM majors, interviewed and selected by a panel of PSI faculty. They have typically attended previous PSI sessions and are identified as potential candidates either by senior PSI leaders or other STEM faculty, based on their conscientiousness for learning, mastery of course concepts, and ability to communicate with peers. Importantly, because GGC is a majority-minority institution, the demographics of the PSI leader team reflect this diversity seen in our student body. Leaders are thus model students with a strong foundation in STEM courses. PSI leaders are primarily paid positions, but in an effort of sustainability we have developed a STEM service learning course (STEM Leadership) for which leaders can earn course credit in lieu of payment. Leaders typically attend either two-thirds of lecture for the assigned course or weekly lab sessions, as requested by the instructor.

Multi-Section Course Content in Each PSI Session

GGC's STEM classes are capped at 30 students, resulting in 15-60 sections of each course offered each semester. Invariably, different sections will cover the same course with different pacing. In traditional SI, one leader typically facilitates one class of 100-300 students, in which the same chapter or learning objective is being covered for all students (Arendale, 1994). The one-to-one leader-to-course mapping in SI is therefore not feasible, giving rise to another major adaptation in which two to three leaders facilitate one PSI session. In this way, students from multiple sections of a course, taught by different instructors, could be accommodated. Variations in the pacing and topic alignment within specific courses therefore requires additional tailoring of PSI sessions, necessitating that each PSI leader prepares a different lesson plan to cover different topics in that course. Over the span of a semester, PSI leaders use faculty course schedules to create a bank of lesson plans for each topic covered in that course. In this way, leaders are able to easily retrieve lesson plans and tailor sessions to facilitate students' needs. Approximately two or more weekly PSI sessions for each course are offered, providing multiple opportunities for traditional and non-traditional college students to attend sessions each week.

Program Supported by STEM Faculty

Traditional SI programs are overseen, coordinated, and funded via an institution's academic support center, and faculty involvement may typically include developing session materials (Preszler 2009). In contrast, GGC's PSI program is managed solely by STEM faculty who teach PSI-supported courses. PSI faculty were trained by the original developers of SI. Experts from the University of Missouri Kansas City (Blanc et al. 1983) conducted an on-site intensive training workshop during which 26 STEM faculty members actively participated in learning how to supervise, coordinate, and evaluate an effective SI program. In turn, faculty train and mentor leaders throughout the year.

PSI leader training involves a faculty- and leader-led workshop in which traditional SI principles (wait time, redirecting, and checking for understanding) are introduced. To customize PSI sessions to meet our specific needs (STEM focus, diverse student backgrounds, multi-section courses), concerted training activities were conducted on STEM skill lesson planning and role playing to prepare leaders for the diverse needs of students. Follow-up training occurs at weekly faculty-leader meetings, during which time leaders receive guidance on lesson plan design and learning objectives, to address potential problem areas and common student misconceptions. PSI faculty also coordinate monthly seminars in which leaders receive professional development training on writing resumes, negotiating at interviews, implicit bias in the workplace, and metacognition.

Goals of the PSI Model

The PSI model described here was conceptualized around specific goals that address the needs of our unique student body to: 1) provide a structured learning environment in which all students enrolled in foundation STEM courses could have the opportunity to reinforce course content through engagement in active learning and 2) equip students with transferrable skills that would promote success as they progress in their STEM education and career. Achieving these goals at this time could potentially lay the seeds for a firm foundation and foster resilience in STEM students in college and beyond. Because this PSI program is an adaptation of the traditional model, we sought to determine the impact of these adaptations, and hence the effectiveness of PSI, on participants' academic performance in PSI-supported courses, attitudes on STEM learning, and the development of new skills in PSI leaders.

Methodology

Pilot study

Based on the high DFW rates observed in biology, chemistry, and mathematics foundation courses, PSI was initially implemented in 4-5 sections of Principles of Biology I (BIOL 1107K) and Principles of Chemistry I (CHEM 1211K) in the Fall 2015 semester. The number of visits and exam scores of PSI participants were collected throughout the semester, as well as exam scores of their non-participant cohorts. The difference in scores between the first and third exams were calculated and then averaged for each group (Figure 2). Student attendance was tracked by daily online logs, in which participants registered at the beginning of each PSI session. Each entry throughout the semester was counted as a PSI visit. If students arrived late or left early, as indicated by the leader, this entry was not used in the analyses.

Expansion of the PSI program

Based on the preliminary success of the pilot study, the PSI program was expanded to support additional foundation courses in the 2016 - 2017 academic year. Table 1 provides a summary of the expansion phase and the foundation courses in which PSI sessions were administered and customized to help students with STEM course material. To illustrate the scale of the current PSI program, the number of leaders, faculty, and sessions hosted are summarized for Spring 2017 and Fall 2017. The number of visits are aggregated for Spring and Fall 2017 semesters.

GPA analysis in PSI-supported courses

Following the expansion of the PSI program, tracking exam grades became too cumbersome, and instead final course grades were monitored. For all PSI participants, grades earned in PSI-supported courses are presented as a function of PSI attendance. Each participant was placed into one of four PSI attendance bins: attending 1-2, 3-5, 6-9, or 10+ PSI sessions.

To better understand the effects of PSI, further analyses investigating the interactions between PSI participation and high school GPA were conducted. High school GPA has been identified as a reliable academic indicator for first-year STEM majors (Dorta-Guerra et al. 2019). The average high school GPA of students attending each session attendance bin was calculated to determine if a correlation existed between high school GPA and PSI attendance. In a separate analysis to determine the effect of PSI on underprepared students, each participant was placed into one of three high school GPA bins: greater than a GPA of 3.5, GPAs of 3.5 to 2.5, and GPAs less than 2.5. The grades earned in PSI-supported courses for each GPA bin were then aggregated into each PSI attendance bin. In each type of quantitative analysis, data from individual students, such as GPA in PSI-supported courses and DFW rates were averaged to obtain group means. Statistical significance of participation in PSI was determined by one-way or two-way analysis of variance (ANOVA). Significant main effects were followed by pairwise comparisons by using Bonferroni tests. Criterion for significance was $p < 0.05$ for these analyses.

Observations of STEM skills in the PSI session

To improve training and mentoring and maintain quality control of the program, faculty observations of PSI sessions were conducted twice per semester. Standard observation forms captured information on leaders' preparedness and effectiveness and the use of active learning techniques including group board work, peer lecture, predicting test questions, think-pair-share, group problem solving, note taking, and other metacognitive and study skills, as well as the classic SI techniques: wait time, redirecting, and checking for understanding. In addition, faculty observations monitored the application of STEM skills in sessions. The STEM skills identified by PSI faculty include mathematical and logical problem solving, concept mapping, modeling, scientific communication, using models or simulations, and creativity. The session observation form used was adapted from the University of Missouri Kansas City's Supplemental Instruction program. Since all PSI faculty participated in SI training, they were in a unique position to observe both the technical and academic aspects of PSI sessions. Faculty observed leaders within their discipline (focused on content appropriateness) and outside of their discipline (focused on PSI technique).

Analyses on student and leader attitudes

Attitudinal surveys were administered to examine the impact of participation in the program on students' subjective thoughts on their STEM education. Surveys were administered in class at the end and beginning of the semester, and in the absence of the course instructor. Participants responded to questions using a Likert scale ranging from strongly agree to strongly disagree. Responses were aggregated and the percentage of the total number of responses was calculated for each survey question.

To investigate the emergence of skills in our leaders, PSI leader reflection surveys were administered during monthly team meeting times at the end of each semester. Responses were collected anonymously and in the absence of PSI faculty. Data analyzed and presented here are responses to the question "Describe any new skills you developed while serving as a PSI leader". All skills reported by leaders were tallied and similar skills and selected quotes were coded into skill set categories using NVivo software.

Results

Improvement in exam grades

PSI attendance and exam grades for students in BIOL 1107K and CHEM 1211K showed that as the frequency of PSI visits increased to 4 or more sessions, students' course GPA increased. To normalize for individual differences in student preparedness, analysis of the differences between exams 1 and 3 found that PSI participants produced a significant improvement in exam grades (defined by the grade difference between exam 3 and exam 1) as illustrated in Figure 2. BIOL1107K and CHEM 1211K students who participated in PSI improved their exam scores by 4% and 1% respectively, while non-participants' grades declined an average of 8% and 2% in biology and chemistry, respectively. Two-way ANOVA revealed a significant effect of PSI participation on the improvement in exam performance compared to controls or non-participants, regardless of the course ($F(1, 251) = 3.89$; $p<0.05$), with a significant increase in performance observed in BIOL 1107K students, Bonferroni test ($p<0.05$). Based on these encouraging results, the PSI program was expanded and implemented in 5 additional foundation courses.

PSI expands to support seven STEM courses

Table 1 summarizes the expanded structure of the PSI program in the Spring and Fall of 2017. At this time, students enrolled in foundation courses were served by 31 PSI leaders, holding 38 sessions per week. This expansion in the program led to a dramatic increase in the number of student visits, totaling 4,123 visits for the seven courses over two semesters. Biology and chemistry courses were the highest served as 44% and 25%, respectively, of the total number of PSI visits were by students from these disciplines. The inclusion of additional STEM courses and leaders also resulted in an increase in faculty support from four to ten PSI faculty who met weekly with leaders in discipline-specific meetings and monthly with leaders in interdisciplinary professional development and training workshops.

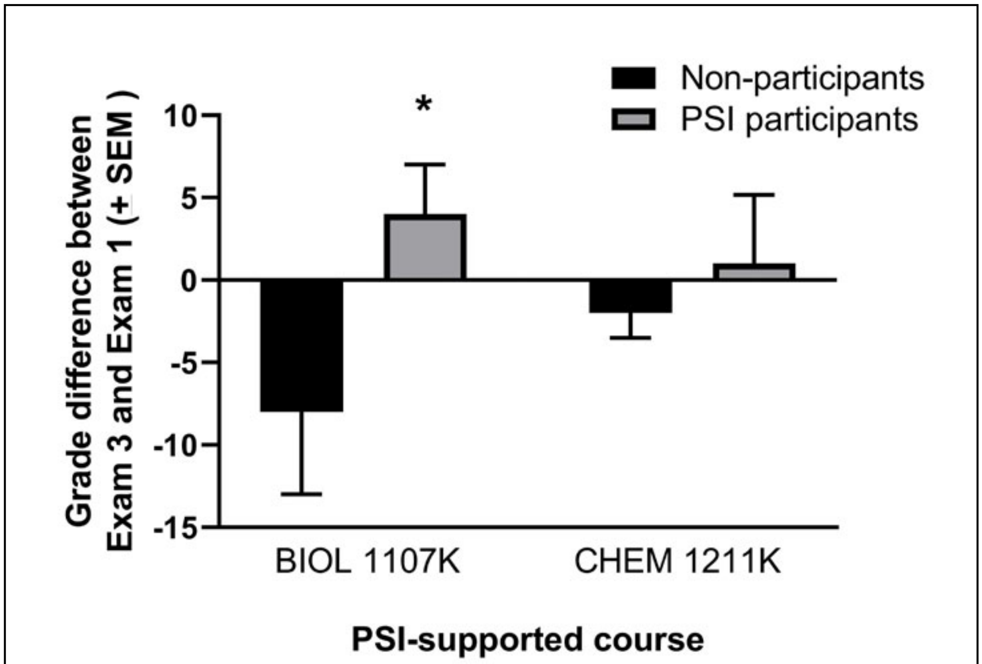

Figure 2. Exam grades in pilot courses, BIOL 1107K and CHEM 1211K. Points are means + standard error mean (SEM) comparing grade differences in exam performance. PSI participants (n=45) to non-PSI participants (n=211).

Overall course grades improve as a function of attendance

Final course grades for PSI participants in foundation courses in Spring and Fall 2017 were aggregated into PSI attendance bins to investigate the impact of attendance on course grade (Figure 3). These data reveal an increasing trend toward a greater percentage of students earning A's and B's as the frequency of session participation increased. A two-way ANOVA revealed a significant interaction between PSI participation and grades earned, $F(9, 778) = 5.517$; $p<0.0001$ and Bonferroni post-hoc tests comparing the percentage of students earning A's vs C's and A's vs DFW grades, for 1-2 or 10+ groups of session visits, revealed significant differences, $^*p< 0.05$. Furthermore, Pearson's coefficient revealed a significant correlation between the frequency of participation and the percentage of students earning A's ($r =.958$, $p = 0.04$) and B's ($r =.956$, $p = 0.04$). Conversely, a downward trend was observed for the percentage of students earning C's and failing grades. Pearson's coefficient revealed a very strong negative association between the percentage of students earning C's ($r = -.93$, $p = 0.06$) and DFWs ($r = -.92$, $p = 0.07$) and the number of sessions attended. For comparison, aggregate data also revealed that 71% of PSI participants earned A's, B's, or C's (n=665) while only 64% of all students taking these STEM courses earned passing grades.

PSI attendance improves course grades, particularly for students with low high school GPAs

The grade distribution above revealed that only 29% of PSI students earned below a C, raising the possibility that self-selection bias could play a role in these results. To delve into the profile of PSI participants and investigate the impact of PSI across a range of academic backgrounds, final course grades of PSI participants over two semesters were again aggregated in PSI attendance bins and further separated by participants' high school GPA (Figure 4). Course GPAs were consistently highest for PSI participants with the highest category of high school GPA (>3.5) and lowest for PSI participants with the lowest category of GPA (<2.5) within each attendance bin. Two-way ANOVA revealed a significant effect of attendance $F(3, 1227) = 19.07$; $p<0.0001$ and high school GPA $F(2, 1227) = 48.90$ $P<0.0001$ on final course GPA (Figure 4A). The inset shows no effect of average high school GPA on PSI attendance (Figure 4B). Intriguingly, course GPAs were significantly greater for participants who attended 10+ sessions versus 1-2 sessions for the lower categories of high school GPAs (< 3.5); $^*p <0.0001$, Bonferroni post-hoc analysis. Two-way ANOVA revealed a significant effect of attendance $F(1, 728) = 42.24$ $p<0.0001$ and high school GPA $F(2, 728) = 21.34$ $p<0.0001$, on final course grade (Figure 4C).

PSI sessions incorporate one or more STEM skills

Two of the unique elements of the PSI program are the focus on STEM skills and the robust faculty mentoring. As shown in Figure 5, faculty observations of sessions revealed that scientific communication was the most frequently employed skill, occurring in 71% of sessions observed, followed by critical thinking (58%) and mathematical problem solving (55%). Fifty percent of sessions simultaneously utilized concepts from different STEM fields, e.g. using chemistry to explain biology, using math concepts to understand information technology. Creativity was observed in only 13% of sessions. Lastly, two or more of these STEM skills were employed in 84% of sessions.

PSI participation improves student confidence in STEM abilities

In mapping the perception of PSI on individual student behavior, post-semester survey responses based on a Likert scale (1-4) showed that 70% of participating students believed that PSI helped them improve study skills, course content, and confidence in their abilities to participate and achieve their goals in STEM courses (Figure 6). Approximately 80% of students agreed that their understanding of the course content increased; 79% agreed that confidence in their ability in the class increased; and 81% agreed that if offered in future classes, they would attend PSI sessions. Of note, a two-way ANOVA on the effect of number of visits on benefits ($F(1, 3) = 24.55$, $p=0.0158$) revealed a significant difference in recognition of PSI benefits between students who

PSI program components	Foundation Courses currently supported by PSI: Principles of Biology I and II	Principles of Chemistry I and II	College Algebra and Precalculus	Introduction to Programming
Leaders ***(31)***	10	10	7	4
Sessions per week ***(38)***	10	12	11	5
Number of student visits ***(4123)***	1792	1048	894	389
Faculty ***(10)***	3	3	2	2

Table 1. Structure and scale of the PSI program. The sample size of leaders, faculty, and sessions offered per semester; the numbers in parentheses indicate the totals across all courses. Total number of student visits for each foundation course is aggregated for Spring and Fall 2017.

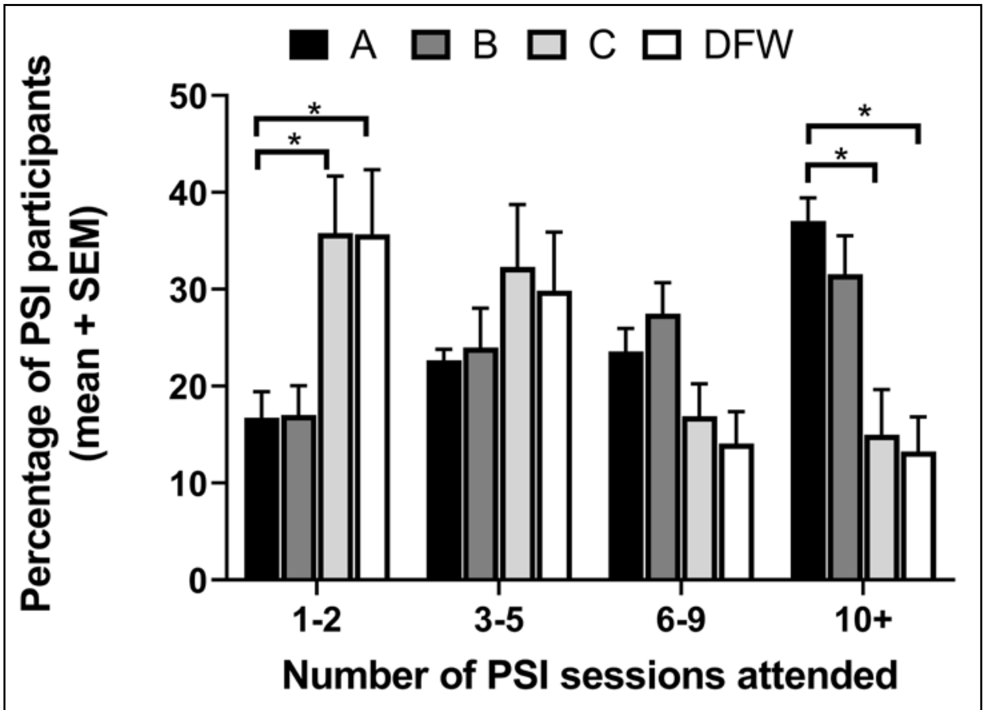

Figure 3. Grade distribution of PSI participants in foundation course. The percentages of PSI participants earning grades of A, B, C, or DFW are grouped by the number of PSI sessions attended. Points are aggregate means ± SEM of students from seven foundation courses. Total number of PSI students, n= 794. For students attending 1-2, 3-5, 6-9, and 10+ sessions, n= 182, 213, 170, 229, respectively. For students earning A, B, C, DFW, n= 385, 182, 127, 100, respectively. *p< 0.05, Bonferroni test comparing % students earning As vs Cs and As vs DFW grades, for 1-2 or 10+ sessions.

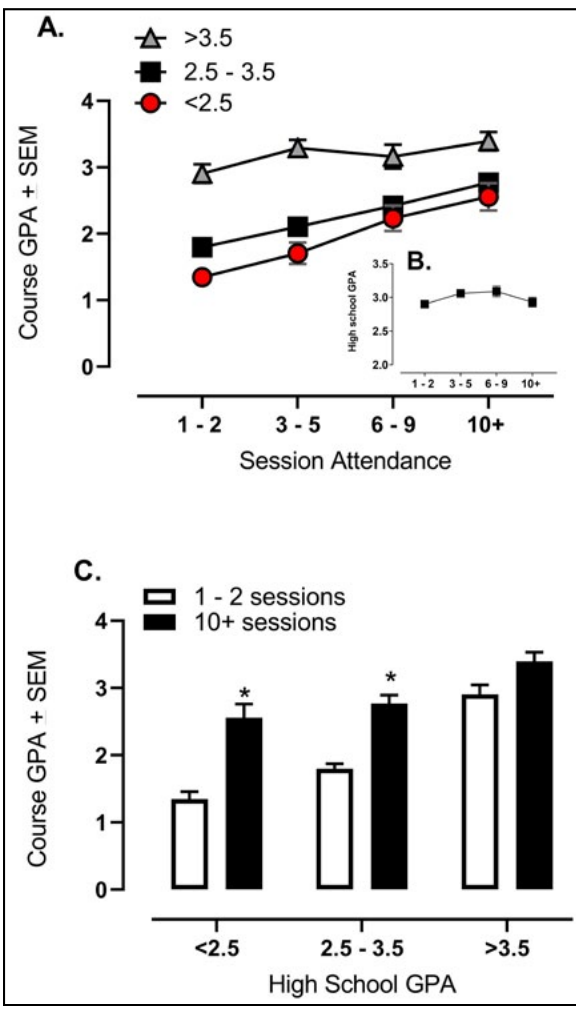

Figure 4. Comparison of grade distribution of PSI participants, grouped by high school GPA and session attendance. The GPA earned in PSI-supported courses by PSI participants are grouped by the number of sessions attended for each of the three levels of high school GPA (greater than 3.5, 3.5 to 2.5, and below 2.5). A) Points are aggregate means + SEM of course GPA from seven foundation courses over 3 semesters. Total number of PSI students, n = 1239; B) Inset shows the average high school GPA of students attending each session attendance bin; C) Comparison of course GPA earned for each high school GPA group attending 1-2 sessions or 10+ sessions. Bonferroni post-hoc analysis revealed significant differences in course GPAs between participants who attended 10+ sessions versus 1-2 sessions for groups with a high school GPA < 3.5; *p <0.0001.

attended 1-2 sessions versus 10+ sessions. For frequent attenders, 81-92% agreed with the benefits of PSI whereas 63-77% of students who attended only 1-2 sessions agreed. One major obstacle expressed by participants and identified from the survey was student and PSI conflicting schedules.

Serving as a PSI leader develops professional attributes needed in STEM careers

Lastly, in end of semester free response surveys, leaders reported and described the emergence of new skills that were classified into four main categories: scientific communication, leadership and confidence, organization, and adaptability (Table 2). Sixty-nine percent of responses to the question on new skills referred to enhanced understanding and use of scientific concepts, and confidence in using conventional terms and scientific jargon, in sessions. The second most common skill reported was leading or coordinating groups of people and a sense of becoming more effective over time. Leaders also reported the need to be organized and to plan ahead in preparing lesson plans for sessions. They also noted that this skill was useful in situations outside of PSI. Multiple students stated that combining multiple sections of a course into one PSI session required them to work on becoming more flexible to adapt to the changing needs of students in a session.

Discussion

A primary goal in the implementation of the PSI program was to create a culture of collaborative learning that supports students in the transition from high school to college-level STEM education. PSI is grounded in SI principles, which place the responsibility of learning on students rather than on instructors or tutors. This model incorporates two high-impact practices in improving STEM education and retention: 1) early engagement and exposure to college survival skills (Kuh et al 2008; Veenstra, 2009), and 2) collaborative learning so that students can discover an array of study styles and perspectives while learning and problem-solving in groups (Tapscott and Williams, 2010). These high-impact practices, combined with the focus on STEM skill development and robust STEM faculty mentoring, offer students an enriched SI learning experience (Figures 1 and 7). Furthermore, our challenge of catering to multi-section courses has developed into an opportunity for leadership training in our peer leaders. The data presented here provide evidence that our adaptation of the SI model is effective in increasing student performance in STEM courses (particularly for underprepared students); increasing opportunities to practice STEM skills; and improving students' attitudes and confidence in STEM. Thus, the current PSI model is sustainable and suitable for adoption by other institutions with similar student demographics and multi-section courses.

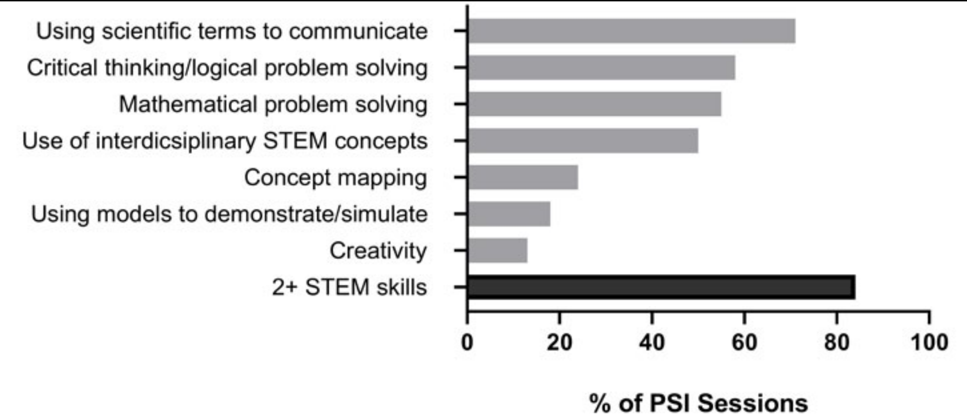

Figure 5. Faculty observations of STEM skills. Quantification of STEM skills during faculty observation of 38 PSI sessions over two semesters. Ten faculty participated in observations.

Impact on academic performance

Despite the fact that GGC's PSI model does not maintain the traditional one to one leader to class ratio, course grade data analyses indicate a promising impact of participation in the program on student performance in PSI-supported courses. The data presented in Figure 3 indicate significant correlations between the number of sessions attended by students and their course GPA and significant interactions between PSI participation and grades earned as revealed by a two-way ANOVA. These results suggest that the course grades earned depended greatly on session visits. For example, of the students who attended 10 or more PSI sessions, 38% earned As while 13% earned DFW grades and conversely, of the students who attended one or two sessions, only 17% earned As while 36% earned DFW grades. These findings are consistent with previous research on the impact of SI on academic performance (Blanc et al. 1993; Henson and Shelley, 2003; Martin and Arendale, 1992) and provides compelling evidence that, although modified in structure, our PSI program has been successful in helping students learn in their first-year STEM courses.

Notably, many of the students enrolled in these PSI-supported courses also benefit from another high-impact practice that stimulates STEM education. At GGC, a four-year undergraduate research initiative, in which STEM majors engage in course-embedded undergraduate research experiences (CUREs) at each level of matriculation, has been implemented (Awong-Taylor et al. 2016). Thus, it is likely that the sample of students in this study have participated in both PSI and CUREs. Our findings could also reflect a synergistic effect of these two interventions on performance in STEM.

Potential to close the achievement and diversity gap in STEM education and careers

It could be conceived that higher attending participants were generally more successful in their academic performance, irrespective of PSI. However, further analyses into the relationship between course performance, high school GPA, and academic background revealed no significant differences in attendance across a range of high school GPAs (Figure 4B), indicating that high school GPA is not a good predictor of participation in the PSI program and that students who earned passing grades exhibited a range of high to low high school GPAs. Indeed, it was found that students with GPAs greater than 3.5 earned higher grades in the PSI-supported course regardless of session visits (Figure 4A). This is in agreement with recent findings via linear regression analyses of multiple potential predictors (Dorta-Guerra et al., 2019) that high school GPA is a generally good predictor of academic performance. However, the finding that gains in course grades were significantly improved within the cohort of students with low and intermediate high school GPA, following participation in ten or more sessions is striking (Figure 4C). These data provide evidence to support the utility of our PSI model to surmount the value of high school GPA as a predictor of academic success. Furthermore, that students with low and intermediate high school GPAs who frequently participate in PSI sessions can perform at a similar standard as their peers with high school GPAs greater than 3.5, indicates that participation in the program may be particularly effective in supporting underprepared students as they transition from high school. This is consistent with reports by Peterfreund et al. (2007), in which SI students who performed better than their non-SI counterparts were not academically advanced students, as indicated by their SAT scores and high school GPAs. These results therefore show the effectiveness of PSI in helping to close the performance gap for students who are underprepared for college.

It is well-established that students from diverse populations continue to be underrepresented in STEM fields, particularly women, ethnic minorities, and persons with disabilities. For example, while Hispanics and African Americans make up approximately 35% of the total US population (US Census Bureau, 2017), they comprise only 13% of the science and engineering workforce (National Center for Science & Engineering Statistics, 2015). Bringing together students of diverse backgrounds, particularly in an enriched learning environment as in the PSI model, could potentially diminish these dismal statistics and help in also closing the diversity gap in STEM professions. Relevant to this is the finding that engagement in educationally purposeful activities, particularly during the first year of college, can make a positive impact on GPA, particularly for African American students (Kuh et al., 2008). In addition to dif-

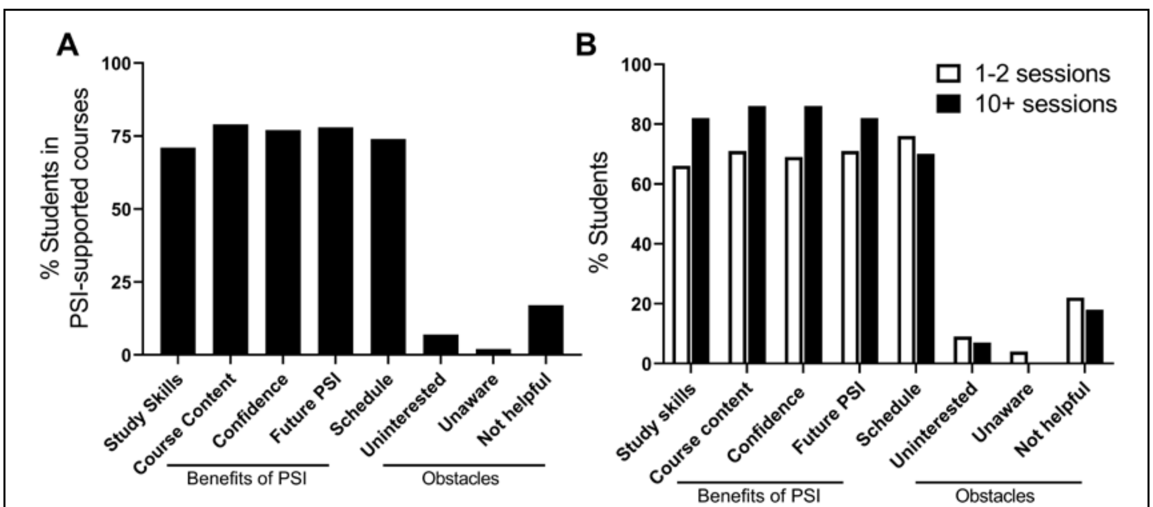

Figure 6. Post-semester survey responses from all students on PSI participation. A) Over 70% of students agreed that participating in PSI helped them improve in study skills, course content, and confidence in their abilities, and intended to utilize the program in future courses. The major obstacle identified in participating was student and PSI conflicting schedules; n = 332 from seven PSI-supported courses. B) Student responses on the benefits of participating in PSI is grouped by session attendance; 1-2 sessions (n=156) or 10+ (n=44) sessions; n=233 from a sample of each STEM disciplines.

Attributes developed	Leader responses
Scientific communication (69% responses)	❖ I'm better at explaining things or making examples that would help the students. ❖ I developed scientific communication while serving as a PSI leader. I can now better explain why certain technical terms are used. ❖ Breaking down problems into explainable pieces ❖ Break a concept down to help others understand it. ❖ I further developed my ability to explain questions in meaningful ways to the students. ❖ One new skill is scientific communication. I've learned to use scientific jargon from PSI.
Leadership and confidence (37% responses)	❖ I had a hard time at first getting the students to do what I asked them to but eventually I learned how to better communicate and get their attention ❖ I was a bit timid toward stubborn students who wouldn't want to participate, but now I try to assert myself a bit more. ❖ I am able to speak in front of a crowd and not be as nervous as before. ❖ One skill I developed more is patience. Being a leader means being able to listen to students and speak less. By putting the focus on the students, I learned to be a better listener.
Planning, organization, time management (26% responses)	❖ The whole process of planning, proofreading, editing the lesson plans were beneficial in a way that it engendered or reinforced attention to detail ❖ My biggest new skill would be planning. Weekly lesson plans strengthened my organization and time management as I prepared to plan out my session ❖ The lesson plan template helped me not only organize my lesson, but also it helped me in planning activities in my everyday life. ❖ My time management improved as a student and in my personal life.
Adaptability (9% responses)	❖ I learned to be more adaptive this semester. A lot of students were on different subjects/material and I had to alter my lesson plan. ❖ Making unexpected decisions as quickly as possible to accommodate different situations. ❖ I became more adaptable last semester since there were a lot of students that were in different places content wise.

Table 2. Building new skills as a PSI leader. Sample of leader responses in an end of semester PSI Leader survey. Selected responses answered the question "Describe any new skills you developed while serving as a PSI Leader", n=35.

ferences in academic backgrounds, the GGC student body comprises a rich diversity in ethnicity, culture, age, and socioeconomic backgrounds. Studies in higher education have provided evidence to support the idea that diversity can significantly contribute to students' learning outcomes (Hurtado et al. 1992) and that different underrepresented minority groups of students may respond differentially to various engagement practices (Sweat et al. 2013). It is also conceivable that students coming from similar experiences are able to learn better with each other since they may understand common challenges and associated techniques to overcome these challenges while learning together (Allen, 1992). Future work on PSI's impact will investigate these and other hypotheses on the roles that diverse demographics might play in STEM learning in the context of the PSI session.

Preparing students for STEM careers

A second objective of the enrichment effort in the PSI program was to cultivate in PSI leaders transferable career skills and confidence in their STEM subject area. Student quotes in the end of semester leader reflections survey revealed the emergence of soft skills, including time management, public speaking, patience, and a heightened understanding of the STEM field, which are all vital for success in STEM careers (Table 2). Leaders indicated that the program fostered and improved their communication skills, confidence to lead groups, and organizational skill sets. Interestingly, an unexpected outcome of the program's modification to serve multi-section courses turned out to be an opportunity for leaders to work on adjusting to change. Leaders reported that they learned to quickly adapt to the changing needs of students from different course sections. A recent report in Science, in which several life science companies were interviewed, concluded that top employers in the industry seek employee profiles that are built on strong foundations and are able to embrace a "change" environment (Tachibana, 2018). Thus, a developing need in the professional STEM world is adaptable employees. The qualitative data collected from leader surveys clearly demonstrate that serving as a PSI leader unlocks talents and engenders new skills, preparing STEM students for future professional careers.

Students participating in PSI also benefited from the incorporation of STEM skills into lesson plans, providing multiple opportunities to practice quantitative reasoning, scientific communication, critical thinking, and multidisciplinary approaches in their sessions (Figure 5). Coupled with this is the finding that there was a significantly greater appreciation for the benefits of participating in the

Figure 7. Photo of a typical PSI session. Students collaborate and draw on various STEM skills to solve problems designed and facilitated by a PSI leader (student at the forefront in red).

PSI program and students' confidence gained between frequent participants (attending 10+ sessions) and students who attended no more than two sessions (Figure 6). These data indicate the effectiveness of the program in generating change in students' confidence and attitudes towards STEM learning. Taken together, the increased application of STEM subject skills, building of STEM career skills, reinforcing of STEM content, and boosting of confidence in the ability to succeed in STEM, the PSI program can be viewed, not only as a symptomatic treatment for high DFW rates, but also as a skill-building vaccine that will endure with students through undergraduate school and into the STEM career of their choice.

Conclusions and Future Directions

Both quantitative and qualitative data presented here reveal insightful strengths and opportunities of this enriched SI model. Participation in the program increases the likelihood of performing well in PSI-supported courses, particularly in students underprepared for college. The innovations and adaptations described in our PSI model have been effective in enhancing STEM knowledge, transferable competencies, and confidence in both student participants and leaders. It is well-known that learning communities benefit students both academically and psychologically, so our future studies will examine the impact of this PSI learning community to promote social belonging, retention, and persistence, as has been observed by other first-year STEM learning communities (Solanki et al. 2019).

One major challenge that persists is the low percentage of student attendance. Currently, only about 20% of students in PSI-supported courses choose to participate. Due to the promise of this strategy in enhancing STEM education, future work on PSI will seek to cultivate a climate of PSI learning by expanding to include sophomore-level STEM courses as well as non-STEM courses that are poised to support STEM students e.g. English composition. Additionally, to deepen the impact of the program, and potentially address participation issues, future work will capitalize on the time spent in sessions to incorporate academic mindset interventions. Our findings of a significant correlation between students with low scores and low participation in PSI, and the evidence that mindset interventions could promote achievement in math and science (Yeager et al., 2019), presents an opportunity to explore and foster growth mindset in PSI participants. For example, it has been found that praising good efforts can promote growth mindset (Mueller CM, Dweck, 1988; Reavis et al. 2018). A simple strategy to cultivate academic mindset and self-efficacy during PSI sessions is to train leaders to encourage and praise strong efforts and hard work when exhibited by PSI participants. Students' perceptions of a social context can enhance or inhibit their achievement (Spitzer B, Aronson, 2015), so creating a sense of belonging by providing name tags and referring to PSI participants by name might also promote growth mindset, self-efficacy values, and participation in PSI sessions. Since this model appears to engender attributes that are in high demand in the science and engineering workforce, PSI and other high impact learning strategies will continue to seek evidence-based practices to evolve and meet the changing demands of the modernizing STEM world.

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Cindy Achat-Mendes is an Associate Professor of Biology at Georgia Gwinnett College where she teaches foundation level biology courses as well as neurobiology and cell biology. Her research interests in STEM education include the development of programs that enhance student learning experiences, such as Peer Supplemental Instruction, and bench research with undergraduates in neuroscience. She earned her PhD in neuroscience at the University of Miami Miller School of Medicine.

Chantelle Anfuso is an Associate Professor of Chemistry at Georgia Gwinnett College. She earned her B.S. in Chemistry from the University of Georgia and her Ph.D. in Physical Chemistry from Emory University. Since joining the faculty at Georgia Gwinnett College, her research interests have focused on developing low-cost spectroscopic experiments for physical chemistry courses and investigating methods for supporting students in STEM courses.

Cynthia Johnson is an Associate Professor of Information Technology at Georgia Gwinnett College. She earned her BSEE at the University of Miami and a MSE and PhD in Computer Engineering from the University of Central Florida. She has focused her research in STEM education focusing on developing problem solving and critical thinking skills.

Benjamin Shepler is an Associate Professor of Chemistry at Georgia Gwinnett College. He earned his B.S. in Chemistry from the University of Tennessee and his Ph.D. in Physical Chemistry from Washington State University. Before joining the faculty here, he carried out postdoctoral research at Emory University. His research interests include computational quantum chemistry and improving student success in undergraduate STEM courses.

Jennifer Hurst-Kennedy is an Associate Professor of Biology at Georgia Gwinnett College. She earned her B.S. in Biochemistry and Molecular Biology from the University of Georgia and her Ph.D. in Applied Biology from the Georgia Institute of Technology. She teaches cell biology and biotechnology courses. Her research interests include STEM pedagogy and molecular cancer biology.

Sonal Dekhane is a Professor and Chair of Faculty of Information Technology at Georgia Gwinnett College. She earned her B.E in Electronics Engineering from University of Mumbai, M.S. in Computer Science from Louisiana Tech University and Ph.D. in Computer Science from Tulane University. She works in the areas of computer science education and broadening participation in computing.

Rashad Simmons is an Assistant Professor of Chemistry at Georgia Gwinnett College. He received his B.S. in Environmental Chemistry from Kettering University and his Ph.D. in Analytical Chemistry and Environmental Toxicology from Michigan State University. His research interests consist of the determination of environmental contaminants and the development of course-embedded undergraduate research experiments for Analytical Chemistry courses.

Tirza Leader is an Associate Professor of Social Psychology at Georgia Gwinnett College. She earned her B.S. in psychology and religion from Columbia College in S.C., and her Ph.D. in Social Psychology from the University of Kent, Canterbury, U.K. Before coming to Dr. Leader led a consultancy group at the University of Kent. Dr. Leader designs, implements, and analyzes various assessments for government agencies, community organizations, and private business.

Jamye Curry Savage is an Assistant Professor of Mathematics at Georgia Gwinnett College. She earned her B.S. in Mathematics from the University of Mississippi, her M.S. in Mathematics from Mississippi State University, and her Ph.D. in Mathematics with a concentration in Statistics from the University of Mississippi. She teaches mathematics and statistics courses that serve the general education core majors in the areas of STEM at Georgia Gwinnett College, and her research interests include nonparametric statistics and STEM education with an emphasis on gateway courses.

Katherine Pinzon is an Associate Professor of Mathematics at Georgia Gwinnett College. She earned her B.A. in Mathematics and Physics, along with an M.A. in Mathematics, from the State University of New York College at Potsdam and her Ph.D. in Mathematics from the University of Kentucky. She focuses her current research on CUREs designed for real-world applications in gateway mathematics courses, along with motivation, study skills and self-efficacy in co-requisite mathematics courses.

Elizabeth Sudduth is an Associate Professor of Biology at Georgia Gwinnett College. She earned her BA in Liberal Arts from St. John's College, MS in Ecology from the University of Georgia, and PhD in Ecology from Duke University. Dr. Sudduth's research interests are in urban stream ecosystem ecology and in effective teaching of data analysis skills in biology and environmental science classes.

Allison D'Costa is Associate Professor of Biology at Georgia Gwinnett College. She has focused her research in STEM education to developing laboratory curriculum that provides students with research experiences while building essential STEM skills. She earned a B.Sc in Chemistry from the University of Mumbai, India, and a Ph.D. in Molecular and Cell Biology from Hahnemann University, Philadelphia.

Dave Pursell served world-wide for 25 years in the U.S. Army before joining higher education. He is currently Professor of Chemistry with research interests in environmental chemistry and chemistry education. Dave earned his Ph.D. in Chemical Physics from the University of Pennsylvania under the direction of Hai-Lung Dai.

Clay Runck is Assistant Professor of Biology at Georgia Gwinnett College. He holds a BSc in biology from Northland College, as well as an MSc and PhD in biology from Northern Arizona University. Dr. Runck's teaching interests include CUREs designed for campus-based outdoor classroom settings for introductory biology, ecology, and limnology.

Judy Awong-Taylor is Professor of Biology at Georgia Gwinnett College. She holds a BSc in zoology and botany from the University of the West Indies, and a MSc and PhD in environmental microbiology from the University of Florida. Before joining Georgia Gwinnett College, Judy was professor and interim department head at Armstrong Atlantic State University, and Director of the University System of Georgia's STEM Initiative. Her interests include using High Impact Practices and system-level approaches to improving undergraduate STEM education.