

## Impacts of Mentoring on Math and Leadership Self-Efficacy Among Civil Engineering Students

**Dr. Mary Katherine Watson, The Citadel**

Mary Katherine Watson is currently an Associate Professor of Civil and Environmental Engineering at The Citadel. She holds BS and MS degrees in Biosystems Engineering from Clemson University and a PhD in Environmental Engineering from The Georgia Institute of Technology. She enjoys, and has invested significantly, in the development of her undergraduate students, serving as past faculty advisor for numerous student groups. Dr. Watson is passionate about improving access to engineering education and serves as the faculty director for a scholarship program to recruit and support high-performing, low-income civil engineering students. Dr. Watson is also interested in understanding and assessing students' cognitive processes, especially development of cognitive flexibility and interactions with cognitive load. Dr. Watson is the proud recipient of seven teaching awards and six best paper awards. She was previously named the Young Civil Engineer of the Year by the South Carolina Section of ASCE and currently serves as a Senior Associate Editor for the Journal of Civil Engineering Education.

**Dr. Simon Thomas Ghanat P.E., The Citadel**

Dr. Simon Ghanat is an Associate Professor of Civil and Environmental Engineering at The Citadel (Charleston, S.C.). He received his Ph.D., M.S., and B.S. degrees in Civil and Environmental Engineering from Arizona State University. His research interests are in Engineering Education and Geotechnical Earthquake Engineering. He previously taught at Bucknell University and Arizona State University.

**Dr. Tara Hornor , The Citadel**

Dr. Tara Hornor currently serves as Associate Professor and Coordinator of Higher Education Leadership Programs at The Citadel. She holds a Ph.D. in Higher Education Administration from the University of Arizona and master's degrees in counseling, instructional design, and human resource management.

**Dr. William J. Davis P.E., The Citadel**

William J. Davis is Dept. Head, D. Graham Copeland Professor of Civil Engineering and Director of Construction Engineering at The Citadel in Charleston, SC. His academic experience includes: transportation infrastructure planning and design, infrastructure resilience, traffic operations, highway safety, and geographic information systems. His research interests include: constructing spatial databases for better management of transportation infrastructure, improving transportation design, operation, safety and construction, understanding long-term effects of urban development patterns, and advancing active living within the built environment for improved public health. He teaches courses in interchange design, transportation engineering, highway design, engineering management, geographic information systems, and land surveying. He has served in numerous leadership positions in ITE, ASCE and TRB.

# **Impact of Calculus Peer Mentoring on Leadership Development and Math Self-Efficacy**

## **Introduction**

### *Pilot ExCEL Calculus Sequence*

We have recently piloted a three-semester Calculus experience for scholars in the Excellence in Civil Engineering Leadership (ExCEL) program, which is sponsored through a National Science Foundation (NSF) Scholarships in Science, Technology, Engineering, and Mathematics (S-STEM) grant. The goal of the ExCEL program is to encourage persistence and performance of academically-promising students with financial need by providing opportunities to build community and self-efficacy.

During the summer before freshmen year, ExCEL scholars complete Calculus I in a small, learner-focused class with an accelerated format. In face-to-face sessions, students were introduced to traditional Calculus I topics with lectures and problem-solving sessions. In online sessions, students were challenged to engage conceptually with content through writing-intensive journal entries and discussion boards. Course instruction was enriched with a parallel civil engineering seminar where students conducted projects and demonstrations to connect Calculus content with future engineering courses and professional practice. Seminar deliverables, including a culminative project, were included as part of the course grade. Students were supported throughout the course with an academic coach and supplemental instructor. ExCEL scholars, with a range of math preparedness, all received the “C” or higher required to progress to Calculus II and a group GPA of 3.33, as compared to 2.17 for mainstream Calculus I sections [1].

During their freshmen year, ExCEL scholars completed Calculus II over two semesters to provide flexibility to adapt to the rigorous of engineering courses in a military college environment. Similar to Calculus I, course structure included face-to-face and online components, as well as a parallel civil engineering seminar. Also, students were supported by a supplemental instructor and their academic coach. ExCEL scholars all received a “C” or higher in the course with a group GPA of 3.25, as compared to 2.15 for mainstream Calculus II sections [2].

### *Expansion of ExCEL Calculus Sequence*

Based on the success of our pilot ExCEL Calculus Sequence, we are working to expand offerings to benefit additional students. We identified a small group of at-risk sophomores who were interested in engaging in a special Calculus I section that was closely modeled after the ExCEL Calculus I summer course. The major barrier to expansion of the Calculus sequence is availability of personnel to provide academic support and facilitate the civil engineering

seminars. We sought to leverage and train our ExCEL scholars to serve as peer mentors to the at-risk sophomore group. While we certainly sought to support the at-risk group, we were also interested in providing a unique academic and professional development opportunity for ExCEL scholars.

Peer mentoring has been shown to positively impact self-confidence and interest in the subject matter. Studies have demonstrated that the cognitive processing used to study the material to teach is different from those used to study for a test [3, 4]. The ability of peer mentors to teach at the right level benefits the mentees. In general, both mentor and mentee seem to benefit from the cooperative relationship that peer mentoring generates [5]. One study summarized a few beneficial cognitive processes that may occur in preparation for teaching, such as the mentor must review the material and this review may help the mentor grasp it more deeply. This process may lead the mentor to seek out examples to help explain the material [6]. Another study observed that peer mentoring increased mentor self-esteem and motivation to learn [7]. Furthermore, other studies have shown that peer mentors not only gain knowledge in the topic, but also improve their communication/teamwork/leadership skills, and develop empathy towards at-risk students [8-10]. Given the potential benefits of peer mentoring, we were interested in studying the impacts of the experience on ExCEL scholars' math self-efficacy and leadership development.

### *Math Self-Efficacy*

Self-efficacy is one's own personal judgements about their abilities to achieve specific goals [11]. Indeed, some work has shown that students' beliefs about their past achievement well-predicts their future performance [12]. Math self-efficacy refers to one's specific beliefs about understanding math concepts and applying related skills [13]. For engineering students, math self-efficacy is important because it may impact general engineering self-efficacy and in turn retention and performance [14-16]. The Mathematics Self-Efficacy and Anxiety Questionnaire (MSEAQ) is one instrument available for quantifying math self-efficacy. The MSEAQ considers five dimensions of math self-efficacy, including: General Mathematics Self-Efficacy, Grade Anxiety, Future Courses/Careers, Asking In-Class Questions, and Completing Assignments [13].

### *Social Change Model of Leadership Development*

The Social Change Model of Leadership Development views college student leadership development as values-based, process-oriented, collaborative, and inclusive [17, 18]. The Social Change Model centers on service to others as the key pathway for fostering positive change and generating experiential learning gains [18]. The model was constructed in 1993 as part of a UCLA Higher Education Research Institute grant project sponsored by the US Department of Education to create a leadership development model for college students [18]. It espouses two overarching goals, including enhancing student learning through the acquisition of self-

knowledge and leadership competence through collaborative service as well as fostering positive social change [18]. The Social Change Model provides a framework for viewing students' leadership development through multiple perspectives, including individual, group and community lenses. Central to the model's framework are seven core values, commonly referred to as the 6 C's (Table 1) [17, 18]

Table 1. Core values of the Social Change Model of Leadership Development [19].

|                   |                           |                                                                                                                           |
|-------------------|---------------------------|---------------------------------------------------------------------------------------------------------------------------|
| Individual Values | Consciousness of Self     | Demonstrating self-awareness of the beliefs, values, attitudes, and emotions that motivate behaviors.                     |
|                   | Congruence                | Thinking, feeling, and behaving with consistent with values. Demonstrating authenticity and honesty.                      |
|                   | Commitment                | Possessing a commitment to service that is significant in duration, passion, and intensity.                               |
| Group Values      | Collaboration             | Working with others toward a common effort, capitalizing on different perspectives and talent areas.                      |
|                   | Controversy with Civility | Recognizing that differences in viewpoint are inevitable and that differences must be addressed openly and with civility. |
| Community Values  | Citizenship               | Utilizing a process that connects individuals and groups to a broader community through service.                          |

The Multi-Institutional Study of Leadership, which leverages the Socially Responsible Leadership Scale, is an international research collaborative that studies the role that higher education plays in developing social responsible leaders. Among other issues, the Multi-Institutional Study of Leadership examines students' leadership self-efficacy, students' perceptions about their likelihood for leadership effectiveness, as an important predictor of gains in leadership capacity over time. Growth in leadership self-efficacy is important because it fosters enhanced motivation to engage in leadership behaviors and strengthens overall leadership capacity [19].

### *Study Overview*

ExCEL scholars collaborated with faculty to offer a modified version of the ExCEL Calculus I course to a group of peers who were at-risk of exiting engineering due to poor math performance. As peer mentors, scholars facilitated class sessions, provided tutoring, and led civil engineering seminars. Scholars completed math self-efficacy and/or leadership-focused surveys at the beginning and end of the Fall 2020 semester. Also, scholars participated in a focus group to share insights about their experiences as peer mentors. Using this data, we address the following questions:

1. Which dimensions of math self-efficacy (if any) were impacted by ExCEL students' roles as peer mentors?

2. How might serving as peer mentors have impacted ExCEL students' leadership development?
3. How did mentee performance in the Calculus I course compare to ExCEL students' prior performance?

The peer mentoring program described and assessed in this work is the first step in sustaining large-scale expansion of the ExCEL Calculus Sequence. We believe that employing ExCEL scholars as peer mentors may lead to a sustainable model for expansion, while providing them with experiential academic and professional development opportunities.

## **ExCEL Peer Mentoring Program**

### *Program Summary*

ExCEL scholars (peer mentors) helped to administer a version of the ExCEL Calculus I course to six peers who were significantly behind in their programs because they received a D, F, or W in more than one math course. ExCEL scholars were divided into three groups to provide each other support as they worked to mentor at-risk peers. One ExCEL scholar group attended each of the three weekly Calculus I classes to enrich in-class problem-solving sessions. Each ExCEL scholar group also held one supplemental instruction session per week and was assigned one civil engineering applications seminar to host during the semester. Scholars met weekly with an instructional strategist to counsel them on the fundamentals of effective teaching.

Each ExCEL scholar group was assigned a civil engineering seminar to facilitate. The seminars were adapted based on the scholars' own Calculus I seminars that they completed during the summer prior to their freshmen year. Seminar topics included: applications of linear and trigonometric functions; applications of derivatives; and application of antiderivatives. A civil engineering faculty, the original developer of the seminars, worked closely with ExCEL scholar groups as they prepared for seminars. The faculty provided calculus application worksheets and discussed content with scholars prior to their assigned seminars. The faculty provided insight into problems and peer mentors asked for clarification on aspects of the problems that they were unsure about. Seminar preparations provided more opportunities for scholars to practice specific skills and to gain a deeper understanding of calculus topics by teaching it to their mentees. Further, peer mentors took on leadership roles that introduced them to challenges they were unlikely to face during regular coursework. These challenges included overcoming gaps in mastery of subjects and explaining calculus concepts to struggling students.

### *Example of a Day in Civil Engineering Application Seminar*

The first topic of the day was "linear functions application (the force-displacement of a spring)." Scholars provided mentees with a spring, several water bottles, and a tape measure. Scholars tasked mentees with designing an experiment to determine stiffness of the spring. Mentees

worked in teams (see Figure 1A) to find the force-displacement of the spring and the spring constant. All mentees participated and discussed the best way to measure displacement. Mentees determined that they needed to measure the initial length of the spring with no force applied and then measure the length of the spring with different weights applied. From the collected data points, the mentees were able to determine a linear equation and thus the slope of the linear function (i.e., spring constant).

The second topic of the day was trigonometric applications. Scholars took the mentees outside to measure angles on trusses and other structures using protractors and tape measures (see Figure 1B). Scholars divided mentees into groups and designated students to: (1) measure, (2) draw a picture of the triangle, (3) record data. After taking several measurements of triangles, students came inside to work in their groups to calculate the angle measurements and compare their measurements to the calculated values using the laws of cosines and sines, as well as the right triangle principles for each triangle. Mentees then explained their group findings to the other groups.



Figure 1A. Mentees are measuring the length of the spring.



Figure 1B. Mentees are measuring angles on trusses.

At the end of the day, mentees shared that the scholars helped them to make the course material more interesting and more understandable. A representative mentee commented...“I just wanna speak for a few of us who were in Math seminar class and just let you know that we found it to be extremely helpful. I wanted to thank you all for helping us with the Gateway exam. We had been studying hours a day to make sure we knew how to solve all the problems and realized we mostly had trouble typing them in correctly, but after your review with the Gateway it seemed to give us a boost and within the next couple days, we were able to pass it and I wanted to thank you for that because it was a big stress on us at the time. Thanks for all help provided in the supplemental instruction sessions. We appreciate all you did for us this semester.”

## Study Methods

Numerous research designs and methodologies have been employed to investigate leadership development and self-efficacy. However, few research studies have focused on simultaneous development of content-area self-efficacy and leadership development during peer mentoring experiences. The complexity of student development, leadership self-efficacy, as well as the myriad of environmental variables working in combination mandate thoughtful construction of the research design [20]. Scholar perceptions of peer mentorship experiences also necessitate in-depth consideration in the research strategy. For these reasons, this study employs a mixed methods research design, including both quantitative instruments and qualitative focus groups.

A mixed methods design was utilized in this research study because the research questions focused on students' math self-efficacy and leadership development, often through comparison with previous peer populations. Levy [20] asserts that utilizing a mixed methods research strategy is particularly powerful in gaining broader perspectives and a more comprehensive understanding of the research topic. This research strategy enabled both statistical analysis of participants' quantitative ratings, as well as individual student's rich personal reflections on their own experiences and leadership development to be compared with other participants [20, 21]. Our study adheres to an approved Institutional Review Board (IRB) protocol.

### *Participant Demographics*

Our first cohort of ExCEL scholars consisted of six male students, with two identifying as Hispanic/Latino. Scholars varied in terms of their math preparedness, with two previously completing Advanced Placement (AP) Calculus, one completing honors Calculus, and three completing Precalculus. Upon entry to The Citadel, scholars' average score on a math placement exam was 66.7%, with scores ranging from 47.1% to 82.3%. Five students were designated as "high" financial need, while one was designated as "medium" financial need. Scholars had an average merit rating (quantitative assessment of a student's preparedness for college) of 22.7, with scores ranging from 16 to 28.

ExCEL scholars mentored six at-risk peers during their sophomore year. All mentees were male, with one identifying as Hispanic/Latino. Though not incoming students, mentees completed a math placement exam at the beginning of the semester to benchmark their math preparedness. The average math placement score was 39.8%, with scores ranging from 14.7% to 52%. Two mentees were designated as "high" financial need and remaining mentees were without financial need or did not complete a Federal Application for Federal Student Aid (FAFSA).

### *Survey Administration and Analysis*

Two survey instruments were administered to ExCEL scholars to quantify outcomes of their peer-mentoring experience. The MSEAQ, a 38-item instrument that requires students to use a

five-point Likert-type scale, was administered via Google Forms at the beginning (pre-) and end of the Fall 2020 semester (post-) to capture changes in math self-efficacy [13]. MSEAQ responses were processed to calculate normalized scores for each dimension and overall math self-efficacy. We reverse-coded all items that expressed negative self-efficacy and summed responses by student (TOT). Next, we summed “no responses” by student (NR). We calculated the normalized self-efficacy score as:  $TOT / [(28 - NR) \times 5] \times 100$ . We categorized a 5% change in pre- and post- normalized scores as potentially meaningful. We also conducted matched-pairs *t*-tests, but recognize that a small sample size limits power to detect significant changes in scores.

The Socially Responsible Leadership Scale, a 37-item instrument that requires students to use a five-point Likert-type scale, was administered via the Socially Responsible Leadership Scale Online Platform to benchmark leadership development. Output from the online platform are Consciousness of Self, Congruence, Commitment, Collaboration, Controversy with Civility, and Citizenship scores for each student. We qualitatively compared scholars’ Socially Responsible Leadership Scale scores to institutional and national averages [19].

### *Focus Group Protocol and Analysis*

The qualitative component of this study employed a focus group approach and posed 11 structured questions to the scholars. The focus group questions were aligned to the study’s overarching research questions and utilized probes to encourage research participants to elaborate on their own perceptions of their experience as a peer mentor as well as its impact on their knowledge of the subject matter and leadership skills. Throughout the focus group, open-ended questions were utilized to gain insight about students’ experiences. The focus group was recorded to increase data trustworthiness.

In the focus group analysis, coding techniques were utilized to identify developing themes and patterns associated with students’ perceptions about their peer mentoring experience. In addition to the benefits gained through coding the focus group data, an analysis of the current research literature was also instrumental in better understanding emerging themes and patterns in the research findings and helped in contextualizing the study’s findings.

## **Results**

### *Math Self-Efficacy of Mentors*

After the peer mentoring experience, ExCEL students felt less anxious about math (Table 2). In fact, the normalized anxiety score decreased for all six scholars. Blake, despite showing the lowest math anxiety prior to peer mentoring, reported a further 62.5% anxiety reduction. Cody and Ryan, with the highest math anxiety prior to peer mentoring, reported 30% or more reduced anxiety after serving as peer mentors. Despite the small sample size, the decrease in anxiety



after the peer mentoring experience ( $M = 68.8$ ), as compared to before ( $M = 78.8$ ), was statistically significant [ $t(5) = -5.86, p = 0.002$ ].

Trends in overall math self-efficacy varied by scholar (Table 2). Cody and Ryan demonstrated the greatest gains in math self-efficacy, with increases of 16.9% and 18.2%, respectively. Jason was the only ExCEL student who demonstrated a loss of math self-efficacy, with a decrease of 6.0%. Blake, Glenn, and Luke demonstrated less than a 5% change in math self-efficacy. Change in math self-efficacy over the peer mentoring experience was not statistically significant [ $t(5) = -1.65, p = 0.159$ ].

Table 2. Math self-efficacy and related dimensions for ExCEL students before and after serving as Calculus peer mentors to at-risk peers (Green: >5% increase; Yellow: <5% change; Orange: >5% decrease).

|       | In-Class Questions & Assignments |       | Grade Anxiety <sup>1</sup> |      | Future Courses/Careers |      | General Math Self-Efficacy |      | Overall Math Self-Efficacy <sup>1</sup> |      |
|-------|----------------------------------|-------|----------------------------|------|------------------------|------|----------------------------|------|-----------------------------------------|------|
|       | Pre                              | Post  | Pre                        | Post | Pre                    | Post | Pre                        | Post | Pre                                     | Post |
| Blake | 88.0                             | 96.0  | 20.0                       | 7.5  | 85.0                   | 77.5 | 100                        | 100  | 87.9                                    | 90.0 |
| Cody  | 56.0                             | 80.0  | 40.0                       | 27.5 | 55.0                   | 72.5 | 91.4                       | 88.0 | 65.7                                    | 76.8 |
| Glenn | 88.0                             | 88.0  | 27.5                       | 22.5 | 70.0                   | 70.0 | 88.6                       | 94.3 | 78.6                                    | 81.4 |
| Jason | 88.0                             | 80.0  | 27.5                       | 17.5 | 85.0                   | 75.0 | 94.3                       | 80.0 | 84.3                                    | 79.2 |
| Luke  | 88.0                             | 92.0  | 22.5                       | 17.5 | 80.0                   | 82.5 | 100                        | 100  | 85.7                                    | 88.6 |
| Ryan  | 56.0                             | 100.0 | 50.0                       | 35.0 | 55.9                   | 60.0 | 97.1                       | 90.0 | 64.3                                    | 76.0 |

<sup>1</sup>A lower anxiety score is interpreted as lower anxiety about math. Anxiety scores were reverse coded when calculating overall math self-efficacy.

### *Leadership Development of Mentors*

Results from the Socially Responsible Leadership Scale indicate the majority of ExCEL students scored higher than the institutional average in at least half of the value constructs, especially in the areas of Commitment, Collaboration, and Citizenship. Table 3 presents the findings on the Social Change Model of Leadership Development values examined in this study.

Table 3. Social Change Model of Leadership value constructs for each scholar collected using the Socially-Responsible Leadership Scale.

|       | Conscious-<br>ness of Self | Congruence | Commit-<br>ment | Collab-<br>oration | Controversy<br>with<br>Civility | Citizen-<br>ship |
|-------|----------------------------|------------|-----------------|--------------------|---------------------------------|------------------|
| Blake | 3.22                       | 3.71       | 4.50            | 4.62               | 4.36                            | 3.88             |
| Cody  | 3.67                       | 4.00       | 4.00            | 3.75               | 3.91                            | 4.12             |
| Glenn | 3.89                       | 4.00       | 4.00            | 3.88               | 3.82                            | 3.75             |
| Jason | 4.11                       | 4.00       | 4.67            | 4.12               | 4.00                            | 4.12             |
| Luke  | 4.00                       | 4.57       | 4.50            | 4.38               | 4.18                            | 4.25             |
| Ryan  | 4.11                       | 4.71       | 5.00            | 4.75               | 4.55                            | 4.25             |

An examination of the ExCEL cohort aggregate scores indicate the group scored higher than the institutional average in four out of six categories, including Commitment, Collaboration, Controversy with Civility, and Citizenship (Table 4). This is particularly noteworthy given the ExCEL students are sophomores, as compared to the institutional average of freshmen through senior year students. In addition to exceeding institutional averages, the ExCEL cohort also scored higher than the national average on half of the value constructs, including Commitment, Collaboration, and Citizenship.

When compared to the institutional freshmen average, the ExCEL cohort aggregate scored higher in all six Social Change Model of Leadership Development categories, including Consciousness of Self, Congruence, Commitment, Collaboration, Controversy with Civility, and Citizenship (Table 4). In addition to exceeding institutional freshmen averages, the ExCEL cohort also scored higher than the institutional senior average in two areas, including Commitment and Collaboration.

Table 4. Comparing average ExCEL cohort Social Change Model of Leadership value constructs to institutional and national averages [Green shading indicates that the ExCEL cohort is qualitatively, not statistically, above the benchmark].

|                              | ExCEL<br>Cohort<br>( <i>n</i> = 6) | Freshmen<br>Institut-<br>ional Avg | Senior<br>Institut-<br>ional Avg | Institut-<br>ional<br>Avg | National<br>Avg | Carnegie<br>Peers |
|------------------------------|------------------------------------|------------------------------------|----------------------------------|---------------------------|-----------------|-------------------|
| Consciousness of Self        | 3.83                               | 3.71                               | 4.20                             | 4.07                      | 3.98            | 4.01              |
| Congruence                   | 4.17                               | 3.99                               | 4.33                             | 4.21                      | 4.22            | 4.23              |
| Commitment                   | 4.45                               | 4.04                               | 4.37                             | 4.28                      | 4.37            | 4.39              |
| Collaboration                | 4.25                               | 4.00                               | 4.23                             | 4.12                      | 4.16            | 4.17              |
| Controversy with<br>Civility | 4.14                               | 3.75                               | 4.18                             | 4.10                      | 4.22            | 4.21              |
| Citizenship                  | 4.06                               | 3.81                               | 4.07                             | 3.98                      | 3.91            | 3.93              |

### *Focus Group with Mentors*

At the conclusion of their second fall semester, students participated in a focus group to reflect on their cohort experience and role as peer mentors. The facilitator asked students' to "describe [their] experience this semester." Unvaryingly, students used the words "closer" and "increased connection" to describe the strengthening of the relationship bonds within the cohort. Students also expressed a connection between peer mentoring and leadership development. For example, Cody shared, "I felt like we had leadership positions for tutoring and academics as well [as other campus leadership roles] which was a good thing."

Valuable insights about the development of students' leadership self-efficacy were gained from the focus group participants. The facilitator asked students: "I've heard that many of you served as peer mentors to other students outside of the cohort this semester. Please tell me about that experience." Immediately, the students expressed that it was a growth experience learning how to approach helping peers their own age. Luke recounted that he was able to build trust by conveying the intention of "being there to help." Glenn also described the challenge of "motivating others" his own age and the importance of communicating "I'm here to help you." Students shared anecdotes about learning to lead peers their own age and continuing the peer mentoring relationships that were established through this program.

When describing the impact of peer mentoring on their own leadership skills, Blake shared his "confidence is a lot better now. Just being able to help people that are the same age as you. I think that's a hard skill to learn." Similarly, Ryan commented, "I think it helped my leadership skills with being able to teach and help people my same age. Not letting [age] get in the way." Luke stated, "it helped me be more confident...it definitely increased my leadership skills." Jason also shared peer mentoring "helped with confidence...I can stand in front of people and show them what I know confidently."

Students also described peer mentoring as a broadening experience. For example, Cody shared it helped "broaden his tutoring" expand to helping other student groups. Similarly, Blake stated it helped "broaden how I'm able to help people." The students also highlighted the value of the peer mentoring experience on their own learning and knowledge of the subject matter. For example, Luke asserted that peer mentoring increased his knowledge and caused him to "retain more." Glenn recounted that it "helped refresh everything. If I didn't know an answer, I'd have to look it up, but it would come back immediately." Glenn also noted that it enabled him to anticipate where "others may struggle" and "help in preparing for it."

### *Performance of Mentees*

Math preparedness of all mentees was low, and performance in Calculus I varied (Table 5). Mentees performed below the threshold required to enroll in Calculus I; however, all mentees had previously passed Pre-Calculus with a "C" or higher, which required that they progress to

Calculus I. Overall, the section GPA was 1.60 and only three of the six students earned the required “C” or higher to progress to Calculus II.

Table 5. Mentee math preparedness and Calculus I performance.

|        | MPE Score (%) | Calculus I Grade |
|--------|---------------|------------------|
| Brad   | N/A           | B                |
| Jack   | 38.3          | D                |
| Kyle   | 52.0          | F                |
| Melvin | 14.7          | B                |
| Milo   | 44.1          | C                |
| Rick   | 50.0          | F                |

ExCEL Scholars and at-risk sophomores took similar versions of the enhanced Calculus I course; however, math preparedness and performance varied between groups (Table 6). The average score on the math placement exam was lower for at-risk sophomores (39.8%) in Fall 2020, as compared to ExCEL scholars (66.3%) in Summer 2019. Subsequently, the cohort GPA of the ExCEL scholars was higher (3.33), as compared to at-risk sophomores (1.60) in Fall 2020.

Table 6. Mentee math preparedness and Calculus I performance.

|                        | ExCEL Scholars<br>(“Mentors”) | At-Risk<br>Sophomores<br>(“Mentees”) |
|------------------------|-------------------------------|--------------------------------------|
| Average MPE Score      | 66.3%                         | 39.8%                                |
| Range of MPE Scores    | 47.1% – 82.4%                 | 14.1% – 52.0%                        |
| No. High Need Students | 83.3%                         | 16.7%                                |
| Calculus I GPA         | 3.33                          | 1.60                                 |

## Discussion

*Which dimensions of math self-efficacy (if any) were impacted by ExCEL students’ roles as peer mentors?*

Most notably, grade anxiety among ExCEL scholars decreased significantly over the course of the peer mentoring experience. All six ExCEL scholars showed reduced normalized grade anxiety scores, based on MSEAQ responses. While mentoring at-risk peers in Calculus I, scholars themselves were enrolled in Calculus III, which was their first mainstream math class in college. Perhaps, serving as peer mentors increased scholars’ own beliefs about their abilities to perform well in their own math course.

Peer mentoring may have had the greatest impacts on students who demonstrated the lowest math preparedness upon entry to college. Cody and Ryan, who scored among the lowest on the math placement exam prior to college, were the only scholars to show a positive increase in

overall math self-efficacy of more than 5%. Even still, Cody and Ryan initially reported the highest grade anxiety; however, both students' grade anxiety dropped by 30% after the peer mentoring experience. Cody and Ryan also initially reported the lowest self-efficacy related to their abilities to succeed in future math courses and use math in future careers (courses/careers). Cody and Ryan were the only students to show an increase in their self-efficacy related to courses/careers over more than 5%.

*How might serving as peer mentors have impacted ExCEL students' leadership development?*

Upon completion of the ExCEL Calculus Sequence and subsequent peer mentoring experience, ExCEL scholars demonstrated promising leadership development. Of note, ExCEL scholars (sophomores) demonstrated higher Commitment and Collaboration scores on the Socially Responsible Leadership Scale than seniors at their institution, students of all academic classes nationally, and students of all academic classes at Carnegie peer institutions.

The values-based, service-orientation of positive change makes the Social Change Model of Leadership Development an ideal framework in which to better understand the influence of peer mentorship on students' leadership development. Building students' leadership self-efficacy is a complex process that occurs over a broad time spectrum [19]. Results from the Multi-institutional Study of Leadership indicate two higher education high impact practices foster gains in leadership self-efficacy across all student groups, including socio-cultural conversations with classmates and positional leadership roles [19]. Peer mentoring experiences provide a robust opportunity for students to gain additional practice serving as a leader and engaging in socio-cultural conversations. These opportunities can cultivate increased student confidence in their own leadership abilities [19]. Findings from the focus group, were consistent with these findings from the previous research literature. Focus group results indicate this peer mentoring experience increased student confidence, broadened their commitment to peer mentoring additional students, and strengthened their math efficacy.

*How did mentee performance in the Calculus I course compare to ExCEL students' prior performance?*

While the peer mentoring experienced helped to develop ExCEL scholars' math self-efficacy and leadership skills, impacts on at-risk mentees were less significant. Despite engaging in a very similar Calculus I experience as the ExCEL scholars – including the same instructor, access to dedicated supplemental instruction, and integration of civil engineering seminars into the course – only three of the six mentees earned the “C” or higher required to progress to Calculus II. For the students who did not earn a “C” or higher, it was their third time earning a D/F/W in a math course in college.

Mentees' scores on the math placement exam were indeed lower than those of the ExCEL scholars before beginning Calculus I and may explain their poor performance to some extent.

However, we note that the math placement exam had no bearing on mentees' course placement since they had already completed Precalculus at the institution. As such, ExCEL scholars' math placement exam scores may have been higher due to increased motivation and effort to perform well in order to enter the ExCEL program.

Furthermore, while mentees' Calculus I course only included six students, they did not bond in the same way that ExCEL students did during their summer Calculus I course. Mentees did not seem to form study groups together nor provide any type of support for each other. In contrast, ExCEL students quickly formed a tight-knit network when they completed the same Calculus I course during the summer before their freshmen year.

We believe that mentees' poor performance in the course may underscore the importance of offering math interventions early in students' academic careers before poor performance damages self-efficacy. In addition, summer experiences may afford more opportunities for community building that further support academic performance.

## **Conclusions**

A study was conducted to explore the impacts of a peer mentoring experience on civil engineering students participating in a competitive scholarship program. During the summer before their freshmen year, ExCEL scholars completed an enhanced version of Calculus I. Based on scholars' success, we sought to expand offering of ExCEL Calculus I course to a group of sophomores who had previously received a D/F/W in more than one math class. Scholars served as peer mentors and collaborated closely with faculty to offer the course to their at-risk peers. The following conclusions were made based on the results.

1. Serving as peer mentors improved some aspects of ExCEL scholars' math self-efficacy, especially related to grade anxiety. Impacts of peer mentoring on math self-efficacy were most profound for scholars who had demonstrated the lowest math preparedness upon entry to college.
2. Based on the Social Change Model of Leadership Development, ExCEL scholars showed higher Commitment and Collaboration than peers at their own institution and at Carnegie peer institutions upon completion of the ExCEL Calculus Sequence and peer mentoring experience.
3. Efforts to expand ExCEL Calculus course offerings should engage students early in their academic careers, perhaps even before their freshmen year.

Calculus is a barrier to engineering student persistence across disciplines and institutions [22]. As such, the ExCEL Calculus Sequence may be broadly beneficial. Based on the study reported here, we believe that our scholars' freshmen summer experience was essential to their success, as we were not able to reproduce calculus success among at-risk sophomore peers during the academic year. In our next iteration, we will be recruiting a new ExCEL cohort to begin with a

similar summer calculus experience, and current ExCEL scholars will again serve as peer mentors. We expect high achievement among the new cohort based on the opportunity to focus on calculus during the summer months. Similarly, we expect additional gains in leadership skills among peer mentors.

## Acknowledgement

This material is based upon work supported by the National Science Foundation under Grant No. 1741611: Encouraging Civil Engineering Retention through Community and Self-Efficacy Building. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

## References

- [1] M. K. Watson *et al.*, "A summer calculus experience to encourage development of community and self-efficacy building of civil engineering students," in *American Society for Engineering Education Annual Conference Proceedings*, Virtual, 2020.
- [2] M. K. Watson, S. T. Ghanat, T. A. Wood, W. J. Davis, T. Hornor, and K. C. Bower, "GIFTS: Reimagining the Early Calculus Experience," in *First Year Engineering Experience Conference Proceedings*, Virtual, 2020.
- [3] Bargh, J.A., and Y. Schul, "On the cognitive benefits of teaching," *Journal of Educational Psychology*, vol. 72, no. 5, pp. 593-604.
- [4] C. A. Benware and E. L. Deci, "Quality of learning with an active versus passive motivational set," *American Educational Research Journal*, vol. 21, no. 4, pp. 755-765, 1984.
- [5] W. R. Whipple, "Collaborative learning: Recognizing it when we see it," *AAHE Bulletin*, vol. 4, p. 6, 1987.
- [6] A. Gartner, M. Kohler, F. Riessman, "Children teach children: Learning by teaching," New York: Harper & Row, 1971.
- [7] B. Goldschmid and M. L. Goldschmid, "Peer teaching in higher education: A review," *Higher Education*, vol. 5, no. 1, pp. 9-33, 1976.
- [8] Lipsky, S.A., and M. Kapadia, "Effect of work experiences on undergraduate peer educators," *Synergy*, vol. 6, pp. 1-10, 2013.
- [9] J. Galbraith and M. Winterbottom, "Peer-tutoring: What's in it for the tutor?," *Educational Studies*, vol. 37, no. 3, pp. 321-332, 2011.
- [10] A. J. Y. Loke and F. L. Chow, "Learning partnership—The experience of peer tutoring among nursing students: A qualitative study," *International Journal of Nursing Studies*, vol. 44, no. 2, pp. 237-244, 2007.
- [11] A. Bandura, "Self-efficacy: Toward a unifying theory of behavioral change," *Psychological Review*, vol. 84, no. 2, p. 191, 1977.
- [12] G. Hackett and N. E. Betz, "An exploration of the mathematics self-efficacy/mathematics performance correspondence," *Journal for Research in Mathematics Education*, pp. 261-273, 1989.

- [13] D. K. May, "Mathematics Self-Efficacy and Anxiety Questionnaire," *Unpublished doctoral dissertation, University of Georgia, Athens, USA*, 2009.
- [14] E. L. Usher, N. A. Mamaril, C. Li, D. R. Economy, and M. S. Kennedy, "Sources of self-efficacy in undergraduate engineering," in *American Society for Engineering Education Annual Conference Proceedings*, Seattle, WA, 2015. Available: <https://peer.asee.org/24723>.
- [15] O. Eris *et al.*, "Outcomes of a longitudinal administration of the persistence in engineering survey," *Journal of Engineering Education*, vol. 99, no. 4, pp. 371-395, 2010.
- [16] M. A. Hutchison-Green, D. K. Follman, and G. M. Bodner, "Providing a voice: Qualitative investigation of the impact of a first-year engineering experience on students' efficacy beliefs," *Journal of Engineering Education*, vol. 97, no. 2, pp. 177-190, 2008.
- [17] H. S. Astin, "Leadership for social change," *About Campus*, vol. 1, no. 3, pp. 4-10, 1996.
- [18] H.S. Astin, A.W. Astin, K. Boatsman, M. Bonous-Hammarth, T. Chambers, S. Goldberg, "A social change model of leadership development: Guidebook (Version III)," *Higher Education Research Institute*, University of California, Los Angeles. <http://www.heri.ucla.edu/PDFs/pubs/ASocialChangeModelofLeadershipDevelopment.pdf>.
- [19] J. P. Dugan, C. Kodama, B. Correia, and Associates, "Multi-Institutional Study of Leadership insight report: Leadership program delivery," National Clearinghouse for Leadership Programs: College Park, MD, 2013.
- [20] P. Leavy, "Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches," Guilford Press, New York, NY (2017).
- [21] J. W. Creswell and J. D. Creswell, *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage Publications, 2017.
- [22] R. Suresh, "The relationship between barrier courses and persistence in engineering," *Journal of College Student Retention: Research, Theory & Practice*, vol. 8, no. 2, pp. 215-239, 2006.