Workshop Collaborative Calculus for Underrepresented Engineering Students

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***Abstract* - In this study, Summer Bridge students participate in a Supplemental Cooperative Learning class (SCLC) structured as Peer-led teaching and learning (PLTL) in Calculus (Calc I) and Calculus II (Calc II) of their freshman year. The Emerging Ethnic Engineers (E3) Summer Bridge Scholars Program has been dedicated to increasing the number of underrepresented students who enroll in and graduate from the College of Engineering and Applied Science. The undergraduate students participated in the 7-week summer bridge program prior to the start of their freshman year and enrolled in the collaborative learning calculus course. This course is a 1- credit hour course which meets 2 hours per week to supplement regular courses. The Collaborative Calculus Course includes the following:**

1. A weekly 1 hour peer-led study-group session that is integral to the course and coordinated with the course's other elements (e.g., lectures and recitations).
2. The course instructor closely involved in selecting materials to be covered by the students.
3. The students conduct workshop sessions in each class, highlighting a main concept covered in the regular class and then conducting an interactive problem solving activity in which students participate as a group. The instructor will give attention to content, leadership skills and the cooperative learning process.
4. The problems are challenging, and at the appropriate level for students, integrated with regular course components, and designed to encourage active and collaborative learning. Each week the class is split into groups and group leader responsibility is rotated to give each student leadership experience.

The course was designed to have student instruction, collaborative projects, and engineering content modules. Student performance and mathematics self-efficacy were analyzed. Students Grades for the course are based on mandatory attendance and participation in the cooperative learning process.

Index Terms - Calculus, Freshman, Mathematics, Workshop Calculus

INTRODUCTION

For 28 years, the Emerging Ethnic Engineers (E3) Summer Bridge Scholars Program has been dedicated to increasing the number of underrepresented students who enroll in and graduate from the College of Engineering and Applied Science. The program includes academic enrichment and tours at local companies that are partners with the university's cooperative education program. After the E3 summer bridge program, these students continue to receive formalized academic year support such as:

- Monthly Socials
- Community Outreach
- Cooperative Learning
- Mentoring

More than 500 students have participated in the program since it started in 1988. The graduation rate for participants is 23% higher than the national rate for underrepresented ethnic students and on par with the majority students. Over the last four years, more than 50 percent of the program's graduates earned dean's list honors after completing their first fall courses at the university. The 2012 freshman fall semester GPA for students in the program was 3.22. In comparison, the overall GPA for the peer cohort was 2.88.

The Summer Bridge Scholars Program at The University of Cincinnati has been offered for the last 25+ years. It is a 7–week residential summer program recommended for all incoming freshmen students in science, technology, engineering and math (STEM). Over the past four years, the summer bridge program has expanded to include underrepresented students exploring STEM disciplines in the College of Allied Health Sciences and the College of Arts and Sciences (A&S) [1].

The objective of the program is to create a "learning community" of students and to help them develop the academic and social skills necessary for achieving academic excellence, while at the same time building their self-confidence, strengthening their academic skills, and acclimatizing them to the campus environment. In these courses students spend time working in 4-6 member groups during organized study sessions. For seven weeks, students focus from 9 a.m.-4:50 p.m., attending classes and study sessions covering biology, physics, pre-calculus, calculus, chemistry and English. After dinner, they attend mandatory study sessions from 6-8 p.m [1].

For Calculus courses in particular, Bridge students are required to complete a math pre-test prior to arrival to determine whether they will take Pre-Calculus (Calc 0) or Calculus I (Calc I) during the Bridge program. This test is not a multiple-choice test, but requires the students to present their complete solution steps/process. It is designed and graded by one of the Bridge math instructors. The students are also required to complete the respective Assessment and LEarning in Knowledge Spaces (ALEKS) tests to assist them in determining their skill level in the course [18]. ALEKS is a web-based artificially intelligent mathematics-learning product that institutions implement for assessment and that students use to improve their knowledge and facility with pre-calculus, calculus and chemistry topics [18].

After completing the Bridge program, students enroll in a calculus class. The class is selected based upon their scores on the placement test that is administered by the University. These tests are taken online prior to the start of the fall semester. Students who score 750 or higher on the test may skip Calc 0 and start in Calc I.

Over 650 students are enrolled in each class, respectively. Each section of the course has 50-100 students, with almost no tutoring centers. Consequently, there are no academic mentoring and guidance available to the students from the faculty teaching the course. There is also no community of students created to work as a group so that they can help each other. These problems have resulted in low performance of the majority of the students.

Many colleges of engineering have implemented summer bridge programs to help students improve their mathematics skill [7]. Research has shown that when students participate in math courses, even if it is a review, there is an increase in math assessment scores. The improved scores allow students to test into higher mathematics courses [19]. At the university, summer bridge scholars are required to participate in a yearlong collaborative learning calculus class regardless of their math placement to supplement their regular math course.

LITERATURE REVIEW

The SCLC offers a different approach to teaching. The teachers are merely a component of the educational experience [9]. Students are expected to serve as the teachers for their classmates during the lectures. The learning technique also incorporates project assignments, role-playing exercises and study plans. Peer relationships have an increased role in the collaborative learning pedagogy in comparison to the traditional teacher-led classroom [12].

Peer-led teaching and learning (PLTL) is a form of cooperative learning that uses learning teams in which each team has a leader who serves as a facilitator [8]. The team leader is typically an undergraduate who previously took the course, but in this pilot study the team leader role was rotated between the students enrolled in the SCLC course. Research indicates that workshop-style pedagogies promote the retention of women and underrepresented minorities in STEM [5][15][17].

Another goal of SCLC is to improve students' mathematics self-efficacy. Mathematics self-efficacy is commonly defined as individuals' beliefs or perceptions regarding their abilities in mathematics. Bandura [3] suggested that students with higher levels of self-efficacy tend to be more motivated to learn and more likely to persist when presented with challenging tasks. Bandura identified four main sources of self-efficacy: mastery experiences, vicarious experiences, social persuasion, and physiological states. Students generally gauge their own ability and performance on their success in understanding the material [16]. Students' successes in math courses are expected to lead to successful performances in future courses. Collegiate students who have lower mathematics self-efficacy often are not as inspired to learn and, as a result, experience a decrease in their overall performance in mathematics courses. In a study of college freshmen enrolled in a developmental mathematics course, Higbee and Thomas [11] cited several sources that can negatively impact student performance including, but not limited to: Test anxiety and perceived usefulness of mathematics, influenced students' mathematical performances. The results of their study suggest that some students are incapable of succeeding simply from teacher-lead course instruction. It is important for instructors to consider emotional or attitudinal factors and how those impact the students' ability to learn the material.

Closely related to mathematics self-efficacy, mathematics anxiety can also affect students' performances in mathematics classes. Like traditional anxiety, mathematics anxiety is specifically related to an individual's fear of mathematics, specifically [10][13]. Cate and Rhymer [6] found a relationship between mathematics anxiety and mathematics performance. The same students had significantly lower computational fluency in all areas of mathematical computations.

Students

The students enrolled in the collaborative calculus class are students that participated in the summer bridge program and tested into Calculus I. The yearlong supplemental calculus is a course that is worth 1 credit hour a semester and meets 2

– 3 hours/week. The class was composed of ten male students and one female student. All eleven students self-reported that they had completed calculus in high school, all achieving a B or better. The average math ACT score for ten of the eleven students is 28. This does not include a student who opted to take the SAT instead of the ACT.

DATA COLLECTION PROCEDURE

The content from exams, quizzes, two self-efficacy surveys and a student satisfaction survey were analyzed.

DATA SOURCES

Exams

All students enrolled in Calc 1 take common exams and a common final. Each exam were scored and compared to the students to their peer cohort.

Mathematics Self-Efficacy Survey

The Mathematics Self-Efficacy and Anxiety Questionnaire (MSEAQ) is used in the study. The students are polled prior to the start of the school year and again at the end of the semester.

For the entire MSEAQ, the obtained Cronbach's coefficient alpha of .94, which measured the internal consistency of the MSEAQ, was considered to be very good. Also, Cronbach's coefficient alphas were calculated for the mathematics self-efficacy and mathematics anxiety subscales, which were .90 and .91, respectively. Therefore, the MSEAQ is highly reliable in terms of its internal consistency.

IMPLEMENTATION

The SCLC is supplemental to the students' traditional lecture style course. The course is taught with a collaboration integrated throughout the course. At the beginning of the first session of the week students spend the first five minutes writing on the white board one thing they have learned and one thing with which they still need support. Students then review items and answer each other's questions. If no one can answer a question the course instructor then provides the necessary information. After the first review, the class starts with students identifying the main concepts covered in their regular calculus session. A student then lectures the next 20 minutes of the class session. Students are required to teach a minimum of one lecture to their peers per semester. The students' lecture must include a minimum of three example problems. Once the main topics are identified students work together to solve problems using the concepts. The second session of the week is for the students to work in groups of three to solve pre assigned group work problems.

Students' grades in the SCLC were dependent on attendance and class participation. An unexcused absence in the SCLC led to a reduction in the letter grade.

RESULTS

Student Impacts

At the end of the course eight students remained, two students withdrew from the course and one from participating in this study.

In the calculus course, students completed three exams and a final. All exams are common exams administered to all students registered in the course regardless of teacher or major. As seen in Table I, students that participated in SCLC scored higher on all three exams throughout the semester than their peer co-hort. Data for the final exams could not be collected but overall course grades are reported below. Seven of the eight students passed the calculus 1 course. The one student that did not pass the calculus course had full attendance and participation at SCLC.

TABLE I: STUDENT COURSE GRADES FOR CALC 1 AND SCLC

Student	T1	T2	T3	Overall Course Grade	SCLC Grade
1	85	75	77	B+	A
2	68	91	78	B+	A
3	70	92	90	A	A
4	92	57	81	C	A
5	75	74	82	B-	A
6	87	72	90	B+	B
7	43	65	43	F	A
8	92	91	94	A	A
SCLC Average	76.5	77.125	79.375		
Class Average	65	70	68		

In Table II, the students' MSEAQ scores pre and post SCLC are presented. Out of the eight students that participated in the study three students had a decrease in MSEAQ scores, two students had an increase and three students remained the same.

TABLE II: STUDENTS MSEQA SCORES PRE AND POST SCLC

	Pre	Post
Student 1	3.46	3.39
Student 2	3.19	3.22
Student 3	3.14	3.14
Student 4	3.32	3.29
Student 5	3.18	3.18
Student 6	3.11	3.11
Student 7	3.11	3.22
Student 8	3.36	3.32

The MSEAQ has five factors, General Mathematics Self Efficacy, Grade Anxiety, Future Factor, In-Class Factor, and Assignment Factor.

Factor 1 is the General Mathematics Self-Efficacy factor, with items on this factor being related to the self-efficacy of students with respect to general mathematics abilities. Questions 9, 12, 13, 16, 20, 21 and 23 correspond to Factor 1.

Factor 2 is the Grade Anxiety factor and contained items related to the self-efficacy and anxiety of grades in their mathematics classes. Questions 2, 6, 8, 15, 19, 24 and 26 correspond to factor 2.

Factor 3 is the Future factor, with these items being related to self-efficacy and anxiety regarding future courses and careers. Questions 3, 5, 10, 11, 17, 22, 25 and 28 correspond with factor 3.

Factor 4 is the In-Class factor, with items covering students' self-efficacy and anxiety related to asking questions in class.

Factor 5 is the Assignment factor, with items involving students' self-efficacy and anxiety related to completing assignments. Questions 1, 4, 7, 14, 18 and 27 correspond to factors 4 and 5.

Comparing the mean value score in the pre-tests with the mean value score in the post-test questions 1, 4, 7, 14, 19, and 28 had an increase in mean. Questions 2,3,5,6 and 27 have a decrease in mean value. Most of the questions with the increase are from the in-class and assignment factor. Whereas the questions with an overall mean decrease did not correspond with a specific factor. The sample size from the SCLC is too small to test for statistical significance.

MSEAQ Survey Questions

1. I feel confident enough to ask questions in my mathematics class.
2. I get tense when I prepare for a mathematics test.
3. I get nervous when I have to use mathematics outside of school.
4. I believe I can do well on a mathematics test.
5. I worry that I will not be able to use mathematics in my future career when needed.
6. I worry that I will not be able to get a good grade in my mathematics course.
7. I believe I can complete all of the assignments in a mathematics course.
8. I worry that I will not be able to do well on mathematics tests.
9. I believe I am the kind of person who is good at mathematics.
10. I believe I will be able to use mathematics in my future career when needed.
11. I feel stressed when listening to mathematics instructors in class.
12. I believe I understand the content in a mathematics course.
13. I believe I can get an "A" in a mathematics course.
14. I get nervous when asking questions in class.
15. Working on mathematics homework in stressful for me.
16. I believe I can learn well in a mathematics course.
17. I worry I do not know enough mathematics to do well in future mathematics courses.
18. I worry I will not be able to complete every assignment in a mathematics courses.
19. I feel confident when taking a mathematics courses.
20. I believe I am the type of person who can do mathematics
21. I feel I will be able to do well in future mathematics courses.
22. I worry I will not be able to understand the mathematics.
23. I believe I can do the mathematics in a mathematics course.
24. I worry that I will not be able to get an "A" in a mathematics course.
25. I worry that I will not be able to learn well in a mathematics course.
26. I get nervous when taking a mathematics course.
27. I am afraid to give an incorrect answer in a mathematics class.
28. I feel confident when using mathematics outside of school.

Instructor Observations

Students have become a strong cohort and work collaboratively not only in Calculus but also in their other engineering courses. Throughout the semester, instructors have observed that students are becoming great peer instructors as they master the material in their Calculus class.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE STUDY

Evaluating the test performance we can see that the cohort of students in SCLC out performed their peer group on all three semester exams. From the cohort two students withdrew and one student did not pass the course. The two students who dropped the course participated in the summer bridge program but did not embrace participation in the SCLC. They often times did not show up to the course or participate in the group activities. The student who failed the course also did not embrace the program and often felt that he was proficient with the material and withdrew from class and group activity.

We cannot make statistical inferences in this study due to the small sample to population ratio. However, we can observations based off of trends in the data. Self-efficacy scores for five scores did change while three remained the same. It is unclear if participating in SCLC created the change. Instructors noted that students became more comfortable with their "In Class and Assignment Factor" meaning they feel more comfortable asking questions in class and completing the workload assigned.

More studies are needed to compare if the SCLC helps prepare them for their subsequent math courses. It will also be important to note the effect of Summer Bridge compared to SCLC. Since all the students in the SCLC participated in the summer bridge program it is unclear if the positive effects are from the summer bridge or the SCLC or a combination of both. In future studies it will be important to open a section of the calculus SCLC to students who did not participate in the summer bridge program to assess the difference.

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