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CCLI: Evaluation of a Mentoring Program for Delivering Engineering Content to Calculus Students

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Abstract

The use of peer mentors are an effective tool for increasing student persistence. One such program used peer mentors to deliver engineering content to calculus students. The mentors lead small groups discussions on the process of using calculus concepts to solve engineering problems. A peer training program is used to ensure the mentors have the knowledge needed to lead discussions, aid students in identifying needed campus resources, and help students connect to engineering. Data gathered from the mentors and mentees via surveys were analyzed to determine the impact of the training session and the mentoring program. The analysis showed that mentors were well-prepared to lead the discussions and that the program was mutually beneficial to the mentees and mentors.

Introduction

Recently President Barack Obama spoke on the importance of engineers as innovators that grow the economy[1]. In this same speech the President talked about the fact that less than 60% of students seeking undergraduate degrees in engineering persist to graduation. This fact was used to highlight the need for federal support for programs aimed at reforming science, technology, engineering and mathematics (STEM) education. This comes as little surprise to engineering educators who have been working for decades to identify and address the reasons students leave the STEM disciplines[2,3].

Much of the research on increasing persistence in engineering focuses on freshmen students because most students who leave, do so in their first year[4]. Students leave for a variety of reasons, but those most cited include a lack of quantitative skills (both perceived and real), poor study habits, and feelings of isolation/lack of connection to engineering[2,3,5,6]. Engineering educators have been working to address these and other issues by introducing mentoring programs[6,9], living/learning communities[10], and methods for improving student experiences in calculus[8,11]. The problem with many of these programs is the difficulty and expense of implementation.

Neubert et al.[11] presented a novel, low-cost program for augmenting calculus with engineering content in order to improve student learning. The program utilizes a set of engineering modules, delivered by peer mentors, to illustrate the importance of calculus to engineers. The combination of the modules and mentors allows the program to fulfill its mission to address the development of engineering students' quantitative skills, provide role models for navigating the engineering curriculum successfully, and increase student connectedness to engineering. Moreover, the program is constructed to be easily implemented with minimal cost and no modifications to the existing calculus courses.

One of the issues with implementing such a program is that there is relatively little research focusing on the training and experience of the peer mentors, such as that presented by Voyles et al.[10]. Specifically, there is a need to understand what tools and knowledge mentors need to maximize the positive impact they have on students, understanding that peer mentors require both academic and professional development. This paper presents a summary of a mentor training program and an assessment of mentors' experiences, from the perspective of the mentors as well as the mentees. Although still in development, assessment began during the fall 2011 semester and continued in the spring 2012 semester. The instruments created measure the preparedness of the mentors and the impact that the mentors have on the undergraduate students participating in the small group discussions.

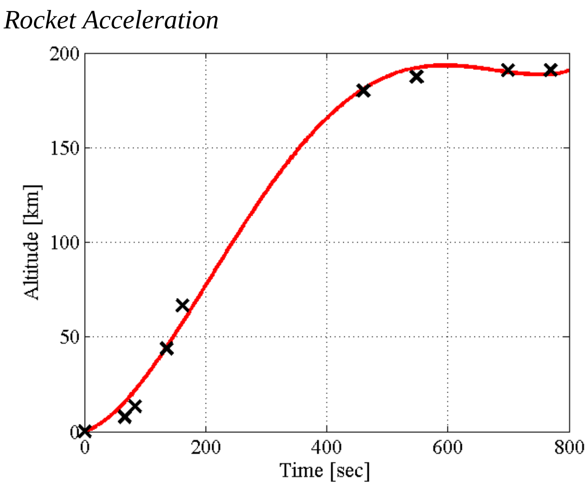
Peer Mentoring and Reciprocal Peer Coaching

Peer mentoring and reciprocal peer coaching are integral components of our project, as we expect the engineering peer mentors to provide real-time, instructive feedback as well as guidance on efficient study habits to students enrolled in calculus and who are considering engineering as an academic major. Moreover, we use peer mentors to connect students to campus resources as well as to one another. Peer mentoring is regarded as a successful intervention to address issues of student retention in academic programs[12]. Peer mentoring, as defined by Kram[13] is "a helping relationship in which two individuals of similar age and/or experience come together … in the pursuit of fulfilling some combination of functions that are career-related and psychosocial" (as cited in Terrion & Leonard[14] p. 150). For students in engineering, the act of pairing incoming students with peer mentors benefits students in a variety of ways, including reduction of feelings of isolation, improved academic performance, and increases in minority student persistence[5,6].

Reciprocal peer coaching, a form of peer-assisted learning, shares many characteristics with peer mentoring, as it "encourages individual students in small groups to coach each other … so that the outcome of the process is more rounded understanding and a more skillful execution of the task in hand than if the student was learning in isolation" (Asghar[15], p. 403). Reciprocal peer coaching encourages and motivates students to work toward a common goal; there is also an opportunity for students to give and receive feedback in a small group setting, a learning environment that is less "risky" than the traditional classroom setting.

Mentor Training Program

As previously mentioned, the engineering peer mentors perform multiple roles in the program. For example, they provide support to students in understanding the engineering content of the calculus problems. They facilitate group discussions, aid students in being successful during their first year in engineering, and to make students aware of opportunities to connect with other like-minded individuals in environments such as the student chapters of the Institute of Electrical and Electronics Engineers (IEEE) and the American Society of Mechanical Engineers (ASME). It is essential that mentors have an understanding of each of these areas including: calculus concepts, student learning, campus resources, and engineering student groups.



(a) *(b)*

Fig. 1: (a) The Saturn V rocket—the only vehicle ever constructed capable of putting a man on the moon. In over 40 years man has failed to repeat this task. (b) A plot of the altitude of Apollo 11 as it ascends into orbit.

The Saturn V rocket, shown in Fig. 1(a), was used to put men on the moon and launch Skylab. Now with the end of the shuttle program, NASA would like to develop a new rocket using a propulsion system similar to that of the Saturn V. One of the concerns of NASA scientists is that this propulsion system may generate excessive accelerations. Many modern scientific instruments are sensitive to accelerations and would be damaged if subjected to accelerations that exceed four times that of Earth.

The new rocket being designed is expected to have a similar mass and ascend to orbit in at the same rate of speed as the Saturn V. Thus, data from launches of the Saturn V during the Apollo program can be used to estimate the acceleration likely to be encountered with the new rocket. A function relating time to the altitude of the rocket was found by fitting a polynomial to a series of altitude measurements, depicted as black X's in Fig. 1(b), taken during the launch of Apollo 11. The altitude of the rocket in meters is

$$y(t) = 2.67 * 10^{-6} * t^4 - 0.00472 * t^3 + 2.23 * t^2 + 105 * t,$$

where t is the time of flight in seconds.

1. *The second derivative with respect to time of $y(t)$ describes the acceleration of the rocket. Find $\left.\frac{d^2y}{dt^2}\right|_{t=40}$ and $\left.\frac{d^2y}{dt^2}\right|_{t=475}$. These values are the acceleration produced by the SaturnV in $\frac{m}{s^2}$. The total acceleration felt by items on the rocket is the sum of the acceleration created by the rocket and that due to gravity ($9.8\ \frac{m}{s^2}$).*
2. *If NASA would like to maintain a safety factor of two to accommodate for un-modeled vibrations, does the rocket exceed the maximum acceleration of four times that of earth. Essentially, does the acceleration of the rocket exceed $19.6\ \frac{m}{s^2}$—four times the acceleration due to gravity divided by the safety factor of two.*

Figure 1: An example module problem.

To that end, peer mentors participated in training exercises prior to facilitating group sessions. There were three specific mentor training exercises. First, students received an *overview of the project*. In this discussion, mentors learned about objectives of the project with regard to confronting attrition in engineering as an academic discipline. They also learned about overall project evaluation goals to: (1) assess student learning of engineering-specific calculus concepts;

(2) assess student comfort levels with engineering-specific calculus concepts; (3) compare engineering retention rates of students enrolled in the engineering-specific calculus course and those who were not enrolled and; (4) implement problem-based learning (PBL) modules and mentor-led discussion as teaching tools.

The second exercise focused on *preparing to be a mentor*. Mentors participated in an exercise where they thought about their first years of college. They responded to questions, such as:

- What do you know about first-year students?
- What was the first year of college like for you?
- What do you like about math?
- What do you dislike about math?
- Did you take Calculus at [this institution]? When?
- What do you remember about the class?
- What did you like about the class?
- What did you not like about the class?

During this exercise, mentors also explored their own strategies for learning, including how they best retain information as well as what they find frustrating about studying calculus. They then reviewed characteristics that they felt were important to bring to the mentor-led study sessions: sincerity, respect, and active listening skills. The instructors at the training session also emphasized the importance of confidentiality during this portion of the training.

The third training exercise focused on *facilitating the mentor sessions*. Discussions centered on how to facilitate active learning, or "learning by doing". Mentors then participated in an informal role-playing exercise where they took turns leading each other through solving a module problem such as the one provided in Figure 1. Also included was a discussion on the importance of recognizing different learning styles, and how the mentors might connect students to the appropriate campus-based resources if they needed to do so.

In summary, the training sessions provided mentors with information on group facilitation and leadership, in addition to instructions as to how to distribute the module problems and schedule small group meetings. Mentors were also guided by a member of the grant research team on how to create a safe learning environment and meet the needs of individuals with different learning styles. A summary of mentor responsibilities includes:

- Schedule mentor sessions with students
- Facilitate group discussions
- Provide general support for learning engineering content
- Serve as a resource to help students connect with each other and to engineering as a discipline
- Provide feedback to project faculty on students' levels of participation in sessions
- Provide process-related feedback to project faculty on the modules and mentor sessions

At each session, mentors were instructed to:

- Create an atmosphere that is comfortable for learning
- Select a student to share her/his process for solving the problems in the module
- Encourage other students in attendance to comment in a positive manner and ask questions as they go through the process
- Guide student discussions that help them identify the most efficient, correct methods for solving the problems

Assessment Methods

Data was collected from peer mentors and the students participating in the discussions. In the fall 2011 and spring 2012 semesters, experiences of mentees in the program was measured using two instruments: the Calculus Knowledge and Perspectives (CKP) survey and the Modules and Mentors (MM) survey. The CKP survey was administered after the fourth mentor-led study session (n=89). The MM survey was administered after all of the mentor-led study sessions were completed (n=51). The instruments measured the mentees' attitudes toward the mentors and their feeling of connectedness to engineering as an academic discipline.

Data was collected from the mentors immediately following the mentor training sessions and at the end of the semester in fall 2011 through two surveys (n=4 for each survey). In subsequent semesters data will also be collected at the midpoint of the program. In addition, individual interviews will be conducted upon completion of the program to allow for probing questions that will provide an in-depth understanding of the mentors' experiences and the their ability to connect with mentees.

Results

The focus of this study is determining how students were impacted by the human component of the pilot study. Specifically, the data is being used to measure the impact of training and the small group discussions on both student and mentor. As previously stated, peer mentors led each study session and facilitated group work toward exploring and finding solutions to engineering-related calculus problems. At the midpoint of the semester, approximately 25.8% of participating students reported that they turned to the peer mentor when they needed help with calculus. At this point in time, about half of the students preferred to visit with the course instructor (58.4%) or other students in the calculus course (49.4%). By the end of the semester, Calculus I students (n=28) felt that working with engineering peer mentors was "somewhat helpful" (25.0%), "helpful" (35.7%), "very helpful" (25.0%) or "extremely helpful" (10.7%) in learning calculus. See Figure 2 for an illustration of the Calculus I distribution. In comparison, Calculus II students (n=23) felt that working with engineering peer mentors was "somewhat helpful" (39.1%), "very helpful" (26.1%) or "extremely helpful" (26.1%) in learning calculus. See Figure. 3 for an illustration of the Calculus II distribution.

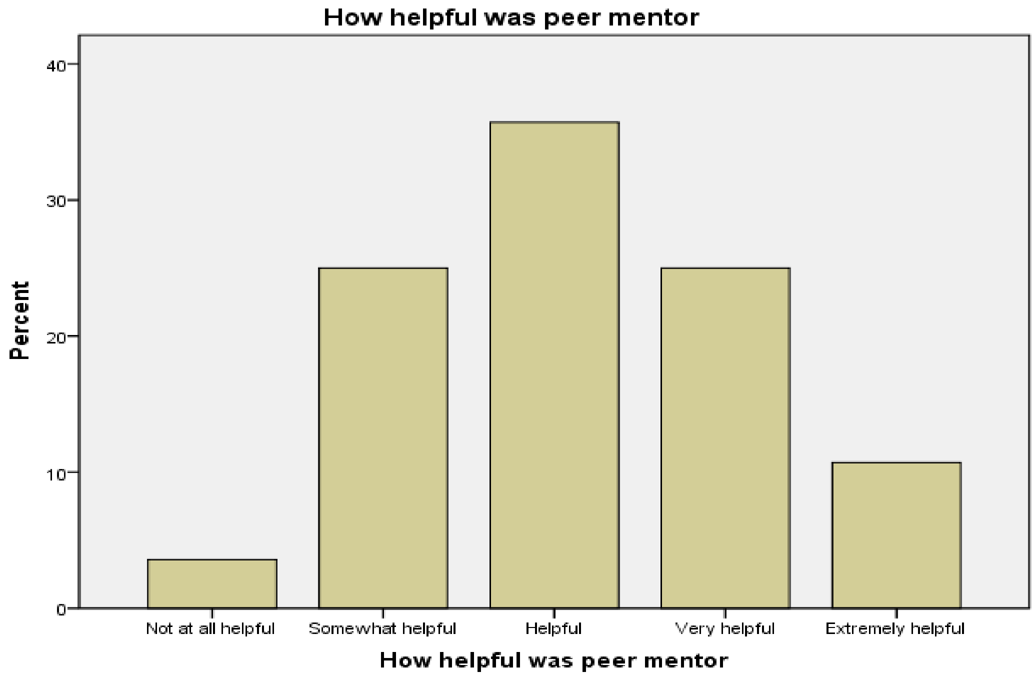


Figure 2: Calculus I students' perception of peer mentors' helpfulness in learning calculus

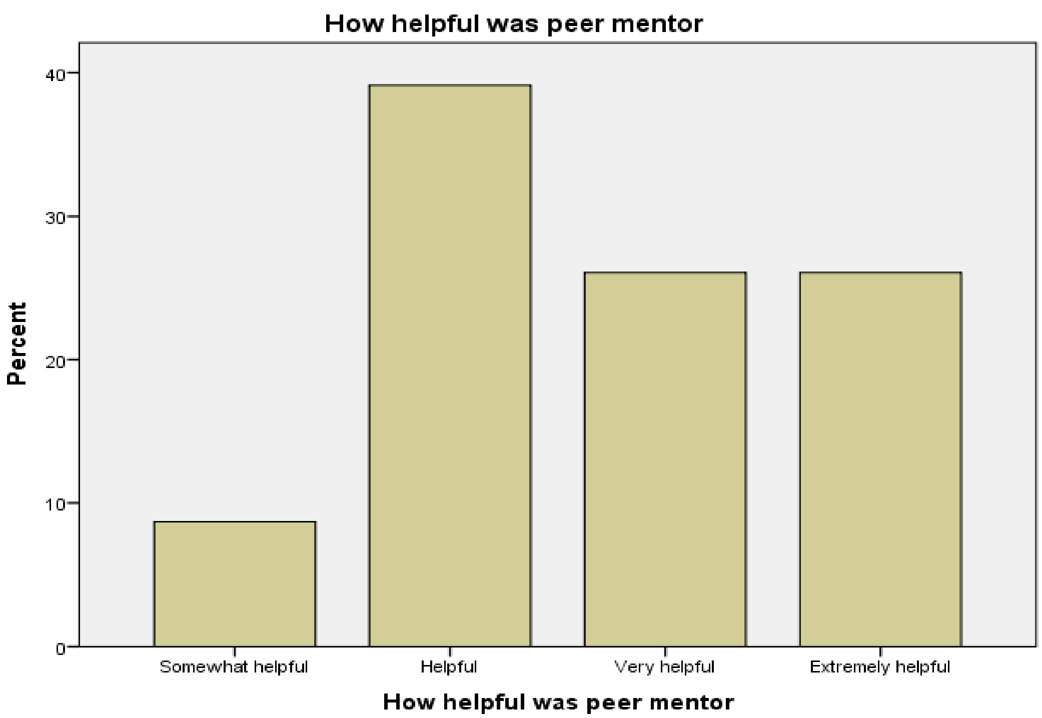


Figure 3: Calculus II students' perception of peer mentors' helpfulness in learning calculus

Calculus I students felt “somewhat confident” (21.4%), “confident” (25.0%), and “very confident” (28.6%) in their abilities to succeed in engineering after participating in mentor-led study sessions. Calculus II students felt “somewhat confident” (13.0%), “confident” (39.1%), “very confident” (26.1%), and “extremely confident” (13.0%) in their abilities to succeed in engineering after participating in mentor-led study sessions. The majority of students (Calculus I = 53.6%; Calculus II = 87.0%) indicated that they would take engineering classes in the following semester.

Results of the mentor survey following the training reveal that all mentors (n=4) found the following components to be “very helpful”: overview of the project, mentor session expectations, preparing to be a mentor and; how to facilitate mentor sessions. Subsequent data will be analyzed to characterize mentor experiences with the intent of improving the training paradigm to deliver positive mentor experiences and encourage mentors to make personal connections with mentees.

Results of the final mentor survey conducted after the last mentoring session indicated that the mentors (n=4) felt the act of mentoring was a positive experience. Specifically, they felt that the experience gave them a better understanding of calculus, strengthened their problem-solving abilities, allowed them to improve their interpersonal skills, and prepared them to be leaders. All but one of the mentors felt the experience had a positive effect on their concurrent coursework. Additionally, the mentors also reported that they liked being able to help others succeed. The results of the survey also showed that students felt connected to the mentors and would ask them for advice on a variety of topics. “Sometimes” or “Often” students asked for input on course and instructor selection. Mentors reported that students wished to discus getting involved with student groups, both inside and outside engineering, to a lesser extent (“Sometimes” or “Rarely”).

One of the important findings from the final survey was an indication by two mentors that they did not prepare themselves well enough prior to meeting students. This leads the authors to believe that the training session should instruct mentors on how to better assess their preparedness and to what degree they should prepare themselves. Additionally, it may be beneficial to provide mentors with a list of likely questions and issues that they may encounter. This will ensure that the mentors are properly prepared for the discussions.

Conclusion

The data collected from mentors and participants indicate that the training program was important and met its objectives. Specifically, the mentors felt prepared to lead discussions with the students and to guide them through the process of solving module problems. Students also indicated that their experiences with the mentors were positive. There is, however, a need to emphasize the impact of the peer/mentor roles in the student learning process. We believe that the opportunity for students to participate in reciprocal peer coaching and get direct instructive feedback on their problem-solving methodologies is not always possible in a traditional calculus course. To that end, it is anticipated that students’ performance as well as attitudes about calculus and the study of engineering will be impacted with this approach to learning calculus, but peer mentors need to be aware of this outcome.

There is also an opportunity to strengthen the mentors' impact on connecting students to engineering. Group construction is an important factor to the success of any mentoring program. Pairing mentors with a compatible group of mentees that share commonalities has been shown by Koehler et al.[16] to be very beneficial. In the future, each group will be assigned a mentor from their specific engineering discipline. In addition, special efforts will be made to match mentees of an underrepresented group with a mentor of a similar group. We will also modify the mentor training program to ensure that mentors are aware of engineering student groups and work harder to connect students to these groups. Finally, mentors will be encouraged to get mentees to interact socially as well as academically in an effort to increase their feelings of connectedness.

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