Exploring Integrated Peer and Reverse Mentoring in Engineering Education: A Work in Progress

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Abstract

This Work-in-Progress (WIP) paper examines the introduction of integrated peer and reverse mentoring for first-year engineering students at a Hispanic Serving Institution (HSI). In this mentoring program, near-peer mentors—upperclassmen with relevant academic knowledge of the course—met weekly with mentees to provide guidance, share experiences, and address academic challenges. These near-peer mentors also participated in bi-weekly meetings with faculty and instructors, where they served as reverse mentors, providing insights into students' experiences, evolving trends, and areas where the curriculum could be better adapted to students' needs. This cyclical feedback fostered a deeper connection between mentors and mentees and created a feedback loop that allowed instructors to stay current with generational shifts in language, communication styles, technology use, and student perspectives. By integrating reverse mentoring in this multi-directional approach, faculty members gained a richer understanding of their students' academic and social environments, which influenced course design and teaching strategies. Preliminary results from this pilot mentoring program indicated that first-year mentees felt a stronger sense of belonging, were more engaged in their academic work, and demonstrated improved confidence and communication skills. Near-peer mentors benefited from the experience, gaining valuable leadership and mentoring skills as they helped bridge the gap between faculty and mentees. Instructors, in turn, reported that the reverse mentoring aspect kept them more in tune with student culture and emerging trends in education. The implications of this research extend beyond the immediate academic context, offering potential insights for broader applications in engineering leadership education, especially in diverse and underrepresented student groups.

Introduction

First Year Engineering Students

First-year engineering students face challenges transitioning from high school to college. These challenges may be derived from higher academic expectations, financial needs, major declaration, and college life familiarization [1-4]. Higher education institutions have developed their first-year engineering curriculum with a broad perspective that welcomes students and allows them to access relevant information and essential college resources to succeed in their chosen engineering discipline. To enhance the first-year learning experience of engineering students at a Hispanic-serving institution, Golding et al. [5] proposed a new design strategy derived from core values, including leadership, innovation, collaboration, and autonomy, to revamp introductory engineering courses. Similarly, Samsuri et al. [6] utilized the How People Learn framework to design an effective introduction to engineering courses. In addition, Nguyen et al. [7] investigated project-based learning strategies to improve the learning outcomes of diverse students enrolled in introductory engineering courses. As such, introductory engineering courses have played a crucial role in engineering education to motivate, prepare, and support the career decision-making of first-year students at a college level.

Impact of Peer Mentoring

Several studies have shown that peer mentoring positively impacts university students' academic performance and social integration. Eddy and Hogan [8] highlighted the impact of peer mentoring on improved academic performance, particularly those students struggling academically. Another study found that peer mentoring significantly improved the academic performance of first-year

students in a computer science course [9]. Other research identified that peer mentoring positively impacted students' mathematics self-efficacy [10]. Additionally, peer mentoring enhances students' confidence and sense of belonging, critical for their overall success in university courses [11]. Another study found that peer mentoring provided students with a sense of community and social support, which helped them navigate the challenges of university life [12]. Similarly, another study found that peer mentoring improved the social integration of first-year students in a large university [13]. Lim et al. [14] defined their mentoring program as a social space in which freshman students established strong bonding relationships with their peer-mentors based on shared and unshared academic and professional goals. Ultimately, peer mentoring programs have been paramount in helping freshman students integrate into the engineering program and college community.

Impact of Reverse Mentoring

Reverse mentoring has also positively impacted university students' learning outcomes. For instance, a study found that reverse mentoring improved the digital skills of senior business students in a university [15]. Similarly, another study found that reverse mentoring improved the communication skills of first-year students in a journalism course [16]. Furthermore, using reverse mentoring, a study showed an improved intergenerational relationship among students in a university [17]. Reverse mentoring also helped faculty members better understand their students' needs and perspectives and enhanced their technological skills, essential for delivering effective instruction in the digital age [18]. Furthermore, reverse mentoring has been found to improve intergenerational communication and relationships between students and faculty [19].

Benefits of Dual-Form Mentoring

The combination of near-peer and reverse mentoring leads to the formation of dual-form mentoring (hereafter referred to as "Integrated Peer and Reverse Mentoring" in this paper). This unique multi-directional mentoring approach fosters the exchange of knowledge and experiences between mentors and mentees. Several studies have demonstrated the positive impact of integrated peer and reverse mentoring on learning outcomes and skill development among university students. The reciprocal nature of the mentoring relationship promotes active engagement and the exchange of diverse perspectives, leading to enhanced critical thinking, problem-solving abilities, and self-reflection [20, 21]. Furthermore, integrated mentoring encourages intergenerational connections, bridging the gap between experienced mentors and younger mentees. Research suggests that these relationships contribute to increased social integration, emotional support, and a sense of belonging within the university community. Mentors also benefit from learning from their mentees' fresh perspectives and technological expertise [18, 22].

Integrated peer and reverse mentoring have been found to challenge traditional hierarchies within academic settings. It provides a platform for mentees to voice their ideas and concerns, contributing to a more inclusive and participatory environment. Mentoring relationships based on mutual respect and open communication foster a sense of equity and empowerment among participants [23; 24]. Research indicates that the benefits of integrated mentoring extend beyond the immediate mentoring period. Mentees who engage in this form of mentoring tend to develop long-lasting relationships with their mentors, resulting in ongoing support and guidance even after the formal mentoring relationship concludes. These enduring connections can positively impact mentees' personal and professional growth over time [25, 26].

Objectives

The objective of this paper is to report on the implementation of a mentoring model consisting of near-peer mentoring in tandem with reverse mentoring for engineering programs. The integrated mentoring practice was applied to a group of engineering students enrolled in an introductory engineering course at a Hispanic-Serving Institution. Online surveys were distributed to mentors and mentees to draw conclusions from this educational mentoring program.

Methodology

Education Program

The University of Texas at El Paso is America's leading Hispanic-serving university. With approximately 83% Hispanic and 94% minority enrollment, it has the highest percentage of Hispanic students of any R1 university in the United States. An emerging engineering department, Engineering Innovation & Leadership (also known as "E-Lead"), has been changing how engineering is taught at a university level. In collaboration with the Center for Research in Engineering and Technology Education (CREaTE), the E-Lead department has developed innovative curricula to provide students with a diverse foundation of engineering knowledge, leadership theory, innovation skills, and an understanding of business. Introductory E-Lead courses equip freshman students with foundational engineering knowledge they will build upon in their following years of instruction. In addition, the introductory E-Lead course provides the perfect teaching and learning environment to evaluate new and innovative interventions by testing new models for engineering education.

Integrated Mentoring Model

The impact of peer mentoring has been significant at our university for entering engineering students to succeed academically during their freshman year [27]. Building upon previous interventions, the impact of an integrated mentoring strategy was investigated during the Fall of 2022 and 2023. The integrated mentoring strategy consisted of near-peer mentoring in conjunction with reverse mentorship. The layout of the multi-directional mentorship model is shown in Figure 1. The mentoring environment is fostered by the interaction of professors and senior mentors, who engage in traditional and reverse mentoring with near peers. Near-peer mentors were upper-level students who had demonstrated success in lower-division coursework. The students acting as near-peer mentors also exhibited and voiced a desire to obtain an opportunity for professional development and leadership skills within the E-lead department and CREaTE program. The professors assigned to the introductory engineering course actively supported the recruitment of near-peer mentors.

Integrated Mentoring Program

Figure 2 illustrates the design of the integrated mentoring program. The integrated mentoring program was first implemented during the Fall 2022 in the curriculum design of an introductory engineering course. The mentoring program continued during Fall 2023 and Fall 2024. The assessment of the mentoring program was strategically planned to ensure complete datasets were collected to investigate the experiences of mentees and near-peer mentors, and the effectiveness of the integrated mentoring model. Therefore, the first semester (Fall 2022) was dedicated to studying the experience and feedback from mentees, and the second semester (Fall 2023) was focused on examining the learning experience and mentor identity development of the near-peer mentors. The results from the third semester will holistically inform the experiences of the three acting groups, including mentees, peer-mentors, and professors, as well as the effectiveness of the integrated

mentoring program. But these results will soon be incorporated into the study, given the timeframe and deadlines followed during the development of this paper.

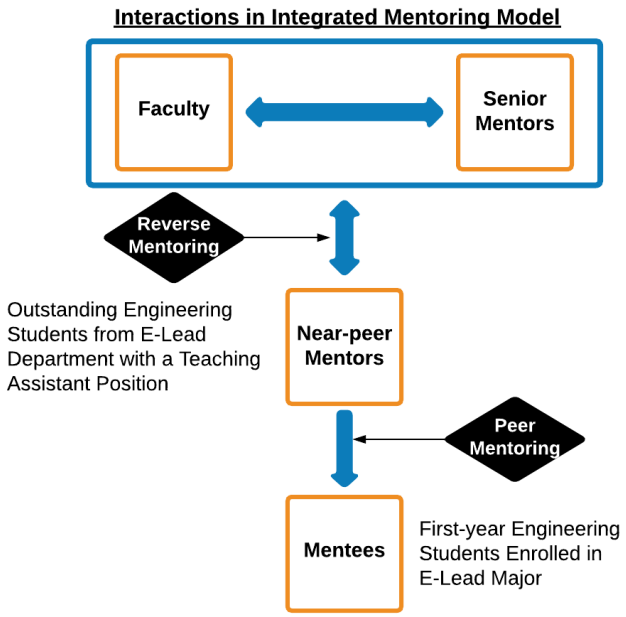


Figure 1 - Integrated Mentoring Model for First-Year Engineering Students.

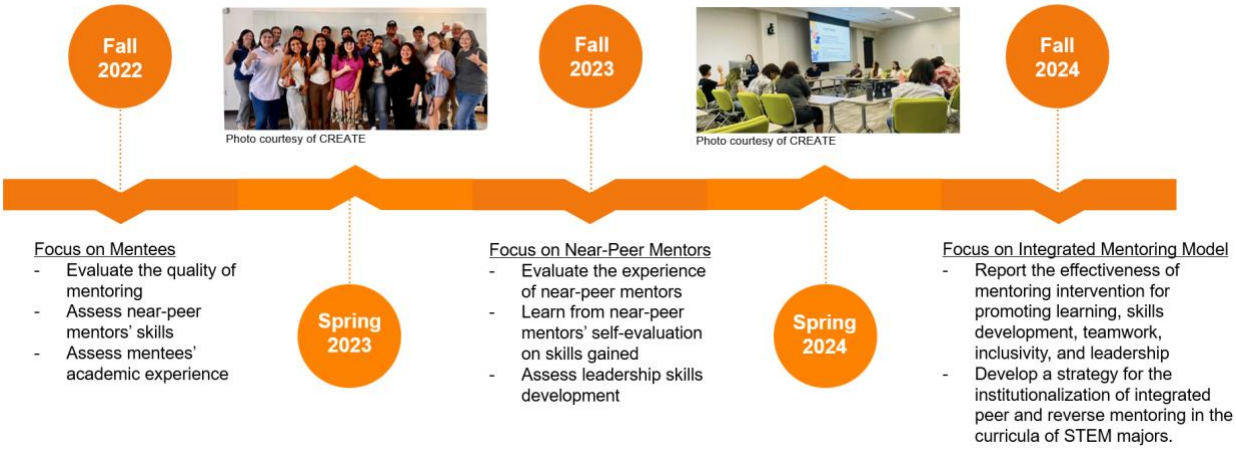


Figure 2 – Implementation Timeline of Mentoring Program.

The integrated mentoring program required preparatory meetings for near-peer mentors before the semester, beginning with development workshops on teaching strategies, troubleshooting difficult situations with students, and refreshing basic course curriculum. Afterward, weekly instructor-led mentoring sessions took place with the near-peer mentors during the semester. These sessions addressed the previous week's class successes, challenges, and experiences. The weekly sessions with near-peer mentors also allowed the team to plan the upcoming course material and project assignments. During these sessions, near-peer mentors were invited to share personal concerns, difficulties, and successes with the mentoring team.

To support near-peer mentors' mental health and well-being, the integrated mentoring model included four mandatory workshops throughout the semester, which senior mentors provided. Senior mentors consisted of graduate students and CREaTE professional personnel. The workshops included engineering mentorship training, personal enrichment, personal and career fulfillment, and cognitive distortions. In addition, these workshops focused on academic enrichment, professional relationships, and career choices. Alternative activities were also available for the near-peer mentors, which included art, nature, and e-sports.

Instructors met bi-weekly to discuss progress and insight from near-peer mentors' participation and student engagement in the mentorship application. Additionally, instructors began identifying positive elements of the near-peer mentors and sharing reverse mentoring gains.

With the assistance of the University's Research and Evaluation and Assessment Services, an end-of-semester pre- and post-course survey was developed and distributed to near-peer mentors and mentees. Some of the elements rated the course objectives, including communication skills, time management, mental health, and well-being. The survey included an independent section addressing the near-peer mentorship approach, which evaluated the following elements: trust, communication styles, role model identity, assistance with coursework, confidence building, and overall attitude toward near-peer relationships.

Student Population

Table 1 summarizes the demographic information of the student population who participated as mentees during the Fall of 2022. A total of 72 students participated in this semester.

Table 1. Mentees' Demographic Information (Total of 72 students)

Demographic Information	**Fall 2022**
Gender	**Percent of total students**
Man	66.2%
Woman	31.1%
Other	2.7%
Age Group	
17 to 20	87.7%
21 to 25	9.6%
31 to 35	1.4%
36 to 40	1.4%
Race/Ethnicity	
Hispanic or Latino	79.5%
Two or more races	9.6%
White	8.2%
Black or African American	1.4%
Other	1.4%

Table 2 reports the demographic information collected for the near-peer mentor students. Most near-peer mentors had already been mentors for first-year engineering students. From the six near-peer mentors, five near-peer mentors participated during the Fall 2022 semester, two near-peer mentors were part of the Spring 2022 semester, two near-peer mentors also mentored first-year engineering students during the Fall 2021 semester, and one near-peer mentor was involved in mentoring students since the Spring 2021 semester. It must be clarified that the integrated mentoring model was first incorporated during the Fall 2022, but mentoring was part of the introductory engineering course before then.

All near-peer mentors, except for one, indicated that they did not have experience mentoring before they started participating as near-peer mentors for the introductory engineering course evaluated in this study. In addition, three students indicated that they did not receive any formal form of mentorship before participating in the introductory engineering course, while three students indicated they were mentored by other college professors, high school advisors, high school teachers, and family members before participating in the introductory engineering course.

Table 2. Peer Mentors' Demographic Information (Total of 6 students)

Demographic Information	Fall 2023
Gender	**Number of students**
Man	2
Woman	2
Other	1
No Response	1
Age Group	
17 to 25	4
Older than 40	1
No Response	1
Race/Ethnicity	
Hispanic or Latino	3
Asian American	1
Alaska Native	1
Other	1

Discussion of Results

Feedback from Mentees

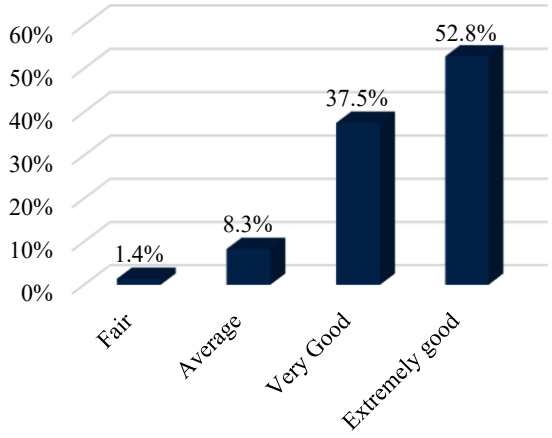
Mentees were asked to indicate the overall quality of the mentoring they received during their introductory E-lead engineering course. Figure 3a shows the responses of the mentees on the overall quality of mentoring. For Fall 2022, approximately 90.3% of mentees rated the quality of the mentoring as very good or extremely good. A small percentage of remaining mentees rated the quality of the mentoring as fair (1.4%) or average (8.3%). The qualifier "Poor" was not provided as an option to respond to the survey.

Mentees were asked to indicate their level of agreement with the mentoring support provided by their E-Lead mentors (see Figure 3b). Around 90.3% of mentees agreed positively with the mentoring support from E-Lead mentors. The remaining mentees indicated that they had a neutral (6.9%) opinion, disagreed (1.4%), or strongly disagreed (1.4%).

In general, the positive feedback and high ratings received showed that the mentoring program was well regarded by mentees. In addition, mentees were asked to rate the ability of near-peer mentors on specific skills. Figure 4 summarizes the evaluation of near-peer mentors' skills. From Fall 2022, near-peer mentors were considered highly skilled (considering the percentage given to rates "6" and "7") on employing strategies to enhance mentees' knowledge and abilities, acknowledging mentees' successes, and helping mentees to develop strategies to meet goals. Mentees were also effective in helping mentees to acquire on-campus resources, providing constructive feedback, and identifying and accommodating the mentees' communication style.

Although more than 50% of mentees gave a high rate, the lowest percentage of rates "6" and "7" was given to aligning expectations.

a) Overall Mentoring Quality



b) E-Lead Mentor Rating

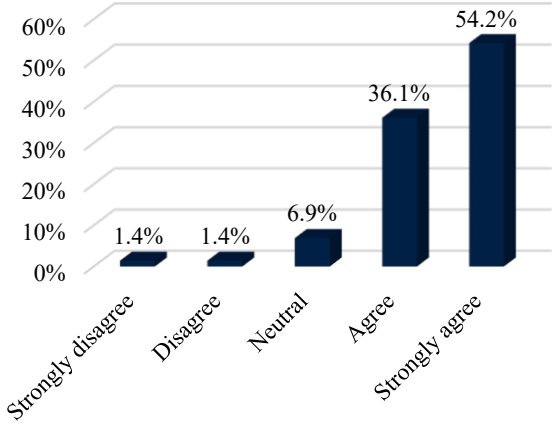


Figure 3 – Mentee's Feedback on Quality of Integrated Mentoring Program.

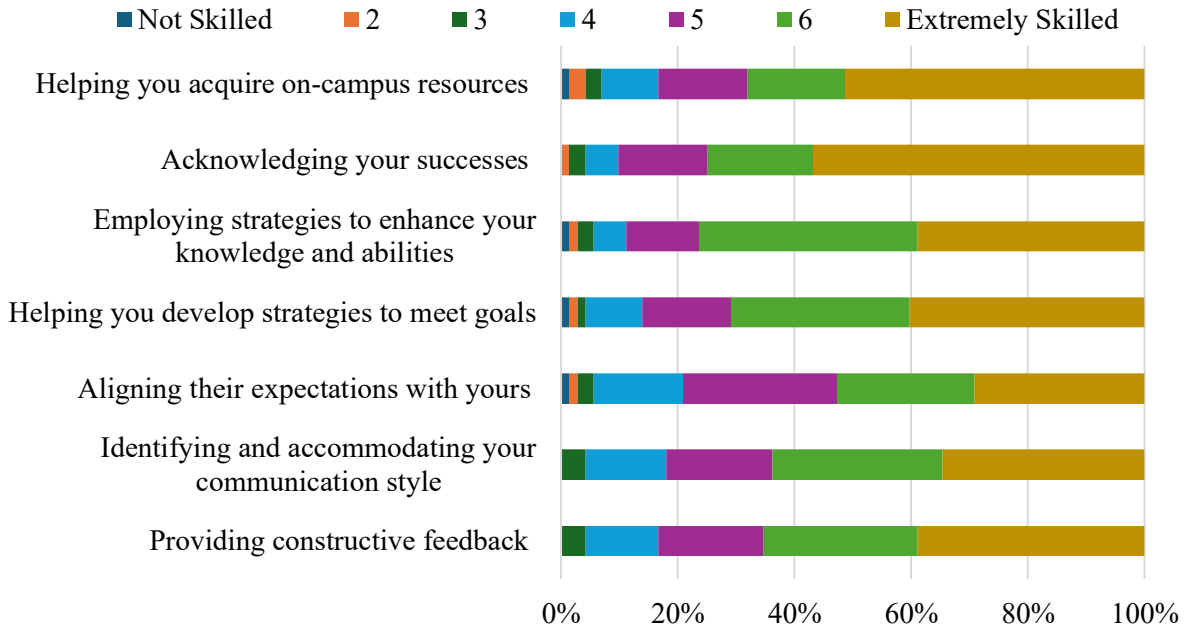


Figure 4 – Mentees' Evaluation of Near-peer Mentors' Skills.

Mentees also provided their level of confidence gained in several specific capacities and skills such as communication, time management, financial literacy, connectedness, and sense of belonging. The mentees' feedback was considered a surrogate indicator of the impact of the integrated mentoring program, but more specifically, to the mentoring interaction with near-peer mentors. As summarized in Table 3, mentees provided their perspective before and after the semester. The survey questions consisted of a 5-point rating system with a rate of 1 representing

"Not Confident at All" and a rate of 5 representing "Extremely Confident." The average and standard deviation of the mentees' ratings were calculated to describe overall trends.

Table 3. Summary of Impacts on Mentees' Academic Preparation

Capacity	Perspective	Fall 2022	
		Mean	Change
Communicating in group and team projects	Before	3.2	31%
	After	4.2	
Communicating with individual near-peers and classmates	Before	3.4	21%
	After	4.1	
Communicating with faculty and senior mentors	Before	3.2	31%
	After	4.2	
Balancing your time between school, work, family, leisure, etc.	Before	2.6	38%
	After	3.6	
Prioritizing tasks/to do lists	Before	2.9	28%
	After	3.7	
Managing your income	Before	2.9	34%
	After	3.9	
Saving your money	Before	3.1	32%
	After	4.1	
I feel a sense of belonging to my university	Before	3.0	37%
	After	4.1	
I feel comfortable talking about a problem with faculty	Before	1.9	37%
	After	2.6	
I feel comfortable contributing to class discussions	Before	2.1	43%
	After	3.0	
I have developed personal relationships with other students in class	Before	2.1	48%
	After	3.1	
I feel comfortable asking a question in class	Before	2.0	55%
	After	3.1	

Mentees indicated that their communication skills improved in a group setting (change of 31%) and with individual students (change of 21%). Their communication with faculty and senior mentors increased by 31%. In terms of time management, mentees' feedback resulted in an increase in confidence of approximately 38% and 28% for balancing time between school, work, and family, and prioritizing tasks, respectively. Mentees also indicated a positive change in their skills in managing their income (34%) and saving money (32%). In terms of connectedness, and sense of belonging, mentees were asked about how they relate to (1) feeling a sense of belonging to their university, (2) feeling comfortable talking about a problem with faculty, (3) feeling comfortable contributing to class discussions, (4) developing personal relationships with other students in class, and (5) feeling comfortable asking a question in class. The improvement or positive change in their confidence or feelings in these capacities was between 37% and 55%.

Near-peer Mentors' Feedback

Table 4 reports the results from the survey questions provided to the near-peer mentors. The first set of questions were related to the personal growth of the near-peer mentors and consisted of a 5-point scale survey question ranging from strongly disagree (1) to strongly agree (5). Near-peer mentors exhibited the greatest growth in learning how to navigate conversation with students about potentially sensitive topics and active listening with changes of 31% and 50%, respectively. For the other capacities (i.e., *develop leadership skills*, *develop my confidence*, and *become a better communicator*), the near-peer mentors gave a considerably initial high rate meaning they felt already highly confident about these capacities. This could be attributed to their previous experience mentoring undergraduate students as well as their interest in becoming effective leaders in engineering.

Table 4 – Summary of Self Evaluation for Near-peer Mentors' Skills

Capacity	Perspective	Fall 2023	
		Mean	Change
Navigate conversations with students about potentially sensitive topics[A]	Before	3.25	31%
	After	4.25	
Develop leadership skills[A]	Before	4.25	6%
	After	4.5	
Develop my confidence[A]	Before	4	6%
	After	4.25	
Become a better communicator[A]	Before	4	6%
	After	4.25	
Active listening[A]	Before	3	50%
	After	4.5	
Helping your mentees acquire on-campus resources[B]	Before	4.75	16%
	After	5.5	
Acknowledging your mentees' successes[B]	Before	4.5	11%
	After	5	
Employing strategies to enhance your mentees' knowledge and abilities[B]	Before	4.75	11%
	After	5.25	
Helping mentees develop strategies to meet goals[B]	Before	4.5	28%
	After	5.75	
Aligning your expectations with your mentees'[B]	Before	4.25	24%
	After	5.25	
Identifying and accommodating your mentees' communication styles[B]	Before	3.5	71%
	After	6	
Providing constructive feedback[B]	Before	4.5	22%
	After	5.5	

Footnotes: [A] 5-point scale rating question, [B]7-point scale rating question

The second set of questions were related to the mentoring service provided to the mentees. Thus, near-peer mentors were asked to reflect on their quality of mentoring in seven capacities. These survey questions consisted of a 7-point scale rating questions (i.e., 1 = not skilled and 7 = extremely skilled). On average, near-peer mentors gave initial ratings between 4 and 5 for most capacities, except for the capacity *"Identifying and accommodating your mentees' communication styles"*

which received a 3.5 rating. Based on the rating given after the semester, near-peer mentors indicated a greater growth in identifying and accommodating your mentees' communication styles. Near-peer mentors indicated a growth of 22% and 28% for capacities such as *"helping mentees develop strategies to meet goals"*, *"aligning your expectations with your mentees"*, and *"providing constructive feedback."* Lastly, they did not express a significant skill improvement in terms of *"employing strategies to enhance your mentees' knowledge and abilities", "acknowledging your mentees' successes", and "helping your mentees acquire on-campus resources".* The latter capacities yielded percent changes of 6%.

Near-peer mentors were asked to describe their mentoring experience in a couple of sentences. One student said, "My teaching team is very communicative, either by a message or a meeting," interpreted as the near-peer mentor was able to communicate with the faculty, senior mentors, and other near-peer mentors. Another student indicated, "My students are engaged in the class content and ready to learn," exposing a positive experience when interacting with mentees. Three students commented " I have had the opportunity to enhance my presentation skills," "I feel confident that I know what I am presenting to the class," and "I feel I am knowledgeable enough to know how to provide the proper instruction across mentees in a way they can understand" revealing their growth on mentoring, particularly interacting and communicating with mentees, and mastering public speaking. Near-peer mentors were also asked for specific skills they considered to have strengthened during their mentoring experience. Four near-peer mentors indicated "public speaking", three near-peer mentors responded, "organizational skills" and "time management," and two near-peer mentors mentioned "listening to others." Other skills mentioned by individual near-peer mentors were connecting to students, leadership, stress management, and task prioritization.

Lessons Learned

The mentoring team (including instructors, senior mentors, CREaTE professionals, and near-peer mentors) embraced this new approach with an open mindset to acquire new viewpoints and perspectives from each other. This open mindset helped significantly to implement the integrated mentoring model for the introductory engineering course. The lessons learned from this mentoring implementation were derived from different perspectives and are shared here.

Mentees showed a positive attitude towards being a part of the mentorship model. Apart from receiving adequate support to succeed academically, mentees recognized the benefits of having near-peer mentors to acclimate faster to college life and academic expectations, as well as fostering a close relationship with the instructors and senior mentors. Mentees constantly exercised their communication skills, which was a skill rated highly by mentees. In addition, mentees were taught about prioritization and balancing different aspects of their lives, including academic, personal, professional, and social. Through the mentorship activities, mentees expressed their interest in the use of new technology for educational purposes, for instance. During a mentoring session, mentees engaged in an educational activity involving a virtual reality space maker classroom. Thus, the mentee's feedback was actively used to modernize and improve the mentoring sessions with the ultimate objective of providing better mentoring support to them. Access to near-peer mentors revolutionized the integration and participation of mentees during the first-year engineering course.

From the near-peer mentors' experience, it was observed that the role of near-peer mentors helped these students to solidify their interest in teaching and mentoring. Several of the near-peer mentors expressed having a positive experience while mentoring and supporting younger students to achieve their academic goals. The inclusion of near-peer mentors helped our academic department to instill leadership skills in engineering students at an early stage in their degree plans. As the semester

progressed, near-peer mentors became more appreciative of working as a team with the instructor and senior mentors to improve the learning experiences of first-year engineering students. They also acknowledged that being a near-peer mentor was a challenge that left them with cemented learning lessons. Among these learning lessons, near-peer mentors experienced how to lead a group of engineers, communicate effectively to groups and individuals, provide constructive feedback to mentees, instructors, and senior mentors, and recognize the value of mentoring in academic settings.

Through the integrated mentorship model, senior mentors and instructors were able to connect with mentees and near-peer mentors and discern potential changes to current teaching and mentoring approaches that can help to enrich the academic experience of first-year engineering students. Similarly, the integrated mentorship model was a solid platform that allowed every participant to gain or improve leadership, communication, and soft skills.

Summary

The integrated mentoring model was considered an effective strategy for promoting learning, skill development, career advancement, and inclusivity among first-year engineering students and their mentors. By establishing reciprocal relationships between mentors and mentees, this integrated mentoring approach offered unique opportunities for knowledge exchange, networking, and personal and professional growth. After witnessing the gains in the students and mentors involved in the introductory engineering course, it is evident that the integrated mentoring model is working and should be continued with some modifications to account for the challenges identified and based on student survey data. Further exploration and implementation of these mentoring applications can contribute to students' overall positive development and advancement in higher education.

Acknowledgments

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