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Educational Enrichment: The Benefits of Near-Peer Mentoring for Undergraduate Engineering Students

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Abstract

Near-peer mentoring is a common teaching practice where a senior learner guides a junior learner. The proximity of skills and experiences of near-peer mentors generate a deep level of relation and understanding of mentee needs, allowing mentors to provide effective learning strategies. This connection between mentor and mentee enhances mentee learning, confidence, and motivation. However, the benefits of near-peer mentoring for the mentors are less clear. To understand the benefits of near-peer mentoring for mentors, we collected data from near-peer mentors who participated in a Science Technology Engineering Art and Mathematics summer camp.

The summer camp was a weeklong remote paper mechatronics camp designed for incoming seventh, eighth, and ninth grade students. Mechatronics is an interdisciplinary field that combines electronics, computation, and mechanics and thus provides a high ceiling for creative design. In contrast, paper mechatronics focuses on inexpensive paper components and craft parts to create a low barrier for student entry. The camp was grounded in culturally sustaining pedagogy to promote learning, identity development, and sense of belonging to STEM. It consisted of two key components: near-peer mentors and storytelling. Near-peer mentors were the primary facilitators for the students. The mentors were two undergraduate engineering students responsible for designing the project curriculum, testing, developing student support, and facilitating most of the sessions throughout the summer camp, with supervision from faculty members. The students created two machines, the Walking Jansen and the Up-and-Down Crank. Furthermore, students were encouraged to use their personal experiences and identities to tell stories through their projects.

To assess the benefits of near-peer mentoring, we asked *What did near-peer mentors gain from creating and facilitating the summer camp?* We collected two forms of data to address the research question 1. Daily journals kept by the mentors during the camp, and 2. Semi-structured interviews. The analysis reveals considerable benefits for the mentors: Mentors developed essential teaching skills, their belonging to STEM improved, and mentors practiced consolidation. The results highlight the extensive benefits of near-peer mentoring. Near-peer mentoring is a valuable enrichment opportunity to supplement undergraduate core engineering education.

Introduction

Near-peer mentoring is when a senior student with a more advanced skill set teaches a junior student [1], [2]. Near-peer teaching creates a more conducive environment to learning than the traditional teaching models because mentors share cognitive and social congruencies with the mentees [3]. The mentor's recent encounter with the learning material and their understanding of mentees' social perspectives [4] provide mentors with effective learning strategies that create a positive relationship and learning experience for the mentor-mentee pair [3].

Near-peer mentoring belongs to a greater category of Peer Assisted Learning (PAL) techniques, officially introduced to the United States higher education in 1980 [5]. PAL consists of various cooperative learning techniques, including peer teaching, learning, and leadership [6]. PAL methods are thought to be effective because of cognitive congruence, that is, the similarity in knowledge and thought processes due to proximity in age [3] instead of typical faculty members who are likely beyond the cognitive capabilities of most of their students.

A common PAL technique is the Peer Educator Model, which is a broad term used to describe when those of similar societal status train to teach other members of their group on a specific issue [7]. These programs are standard in health education, especially on higher education campuses, because the topics covered are typically sensitive subjects (e.g., sexual health), and students best receive information from a similar background [8]. However, the difficulty with the peer educator model is that it is difficult to accurately evaluate the effectiveness of their programs due to the lack of structure and clarity of the peer educator model [7]. The Peer-Led Team Learning Model, which is related to the Peer Education Model, involves collaborations and problem-solving among a small group of students, led by a student who has previously taken the course [9]. This model was developed for an undergraduate chemistry course, but since, has been applied to other science fields including computer science, nursing, and biology [6]. Studies have shown that using a Peer-Led Team Learning model can improve reasoning skills [10], [11], and academic performance [12], [13].

A technique that is becoming more popular in higher education is peer coaching, though it was first introduced to develop and support new teachers [14], [15]. In higher education, peer coaching is often in the form of academic coaching, a relationship where two peers or near-peers provide work together to support the peer through goal setting, self-learning, and behavioral development seeking coaching [16]. The benefit of coaching for college students includes improved persistence [14], metacognition [17], retention, and academic performance [18].There are various other PAL techniques such as reciprocal peer-tutoring [5], peer teaching [19], and collaborative learning [20], all of which promote positive learning. However, what makes near-peer mentoring unique from the other strategies is that near-peer mentoring promotes a positive sense of belonging development for the near-peer mentees through working with mentors whom the mentees can identify with and see as role models [21].

Near-peer mentoring and its positive outcomes for mentees are well documented in the medical and health fields. When learning from a near-peer, learners experience a less threatening environment and feel that teachings are more relevant and better aligned with their interests [2], [22]. Additionally, learners are more comfortable asking questions [1], [23], which improves their learning and understanding. Beyond academics, learners also exhibit lower anxiety levels when performing clinical skills in front of their near-peer mentors than when compared to performing in front of a typical instructor [24].

The advantage of the near-peer relationship is that it is mutually beneficial; the near-peer mentor can be both a learner and a teacher. Mentors report improved skills in public speaking ability, communication skills, basic teaching skills and report the experience as more rewarding than anticipated [7]–[10]. Mentors in medical courses often report greater understanding and insight of the course material due to reviewing, reorganizing, and explaining the students' information [5]. Mentoring is so beneficial that in one study, those who mentored near-peers achieved higher course grades than their peers who were not mentoring [25].

Although there are many studies about the topic, there seems to be little knowledge of the near-peer model outside the medical and health postsecondary spaces. Few papers examine near-peer mentoring relationships outside the medical field [23], [26], [27] and mentoring outside of the undergraduate-undergraduate mentor-mentee relationship. Moreover, few papers look at mentor relationships between undergraduate and middle/high school students [26], [28], [29]. This paper aims to add to the conversation of near-peer mentoring via a pilot study that examines the experiences of two undergraduate students who were near-peer mentors of middle school students in a summer engineering camp. Specifically, we asked, *What did near-peer mentors gain from creating and facilitating the summer camp?*

Description of the Summer Program

When the pandemic required families to isolate themselves at home, families took a greater interest in at-home informal learning STEM kits, but these experiences occurred in isolation and without access to STEM expertise. Without these resources, the depth of learning potential decreases. Adding near-peer mentors with content-area expertise to these informal learning contexts increases the learning potential through social interaction. By first implementing within a week-long virtual summer camp context, the mentors were freed of many of the logistical tasks, providing the ability to focus on the curriculum and facilitation. The Renaissance Engineering Summer camp was one of ten camp sessions coordinated through the University of Illinois' Grainger College of Engineering's Worldwide Youth in Science & Engineering program (WYSE) and one of three sessions specifically for middle school students. The WYSE program provided the session infrastructure, including camp promotions and registration, risk management, a learning management system, and distance communication tools and accounts. The program kicked-off with opening ceremonies on Sunday afternoon with introductions to camp staff and the technology tools. Monday through Friday sessions occurred synchronously daily using the Zoom web-conference platform and a Moodle learning management system for sharing resources and collecting artifacts. The camp session concluded on Friday afternoon with a closing ceremony to showcase the activities and products created throughout the week. The camp served twenty-two, diverse 7^{th}, 8^{th}, and 9^{th} graders from four states (36% identified as female, 32% identified as white, 41% as Black, and 23% as Asian).

Curriculum

Paper mechatronics is an interdisciplinary field that integrates mechatronics with papercrafts and focuses on art and creativity [30]. The accessibility of the paper material and the creative aspects makes paper mechatronics a great introduction to engineering for younger students, as demonstrated in prior studies [31]. Each day students participated in introduction lectures followed by building sessions led by the mentors. The mentors were responsible for developing the builds the students would design. Using their personal experience and trial and error in the design lab, they determined two builds for the students: the walking Janssen and the up-and-down crank.

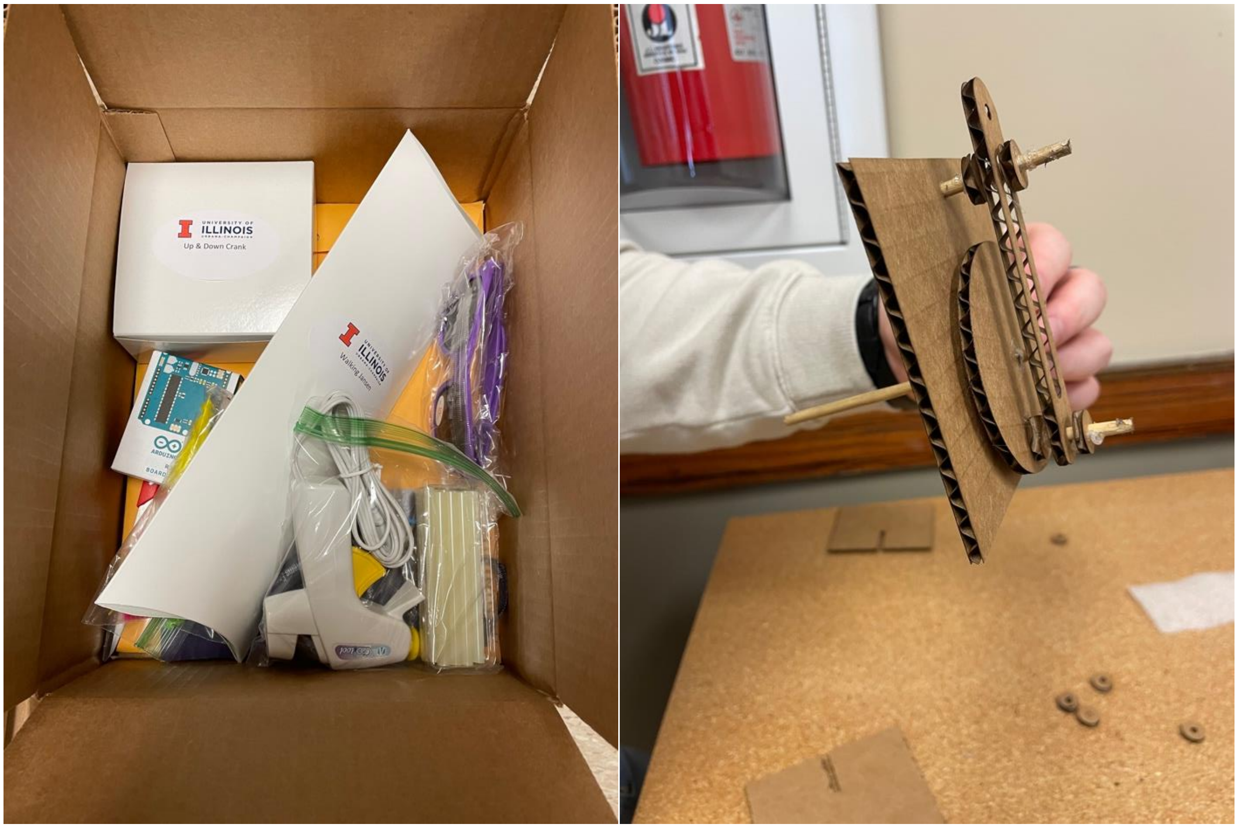

Figure 1a. Boxed kit; Figure 2b. Video demo of up-and-down crank

Design Story Approach

The camp was grounded in culturally sustaining pedagogy, where educators connect learning with the cultural and lived experiences of the students [32]. The curriculum emphasizes the design story of the builds, focusing on a character or scenario. The design story approach offers an example of the importance of student cultural knowledge to project success. The near-peer mentors encouraged the mentees to be creative and use their personal stories when designing the builds and when participating in group discussions.

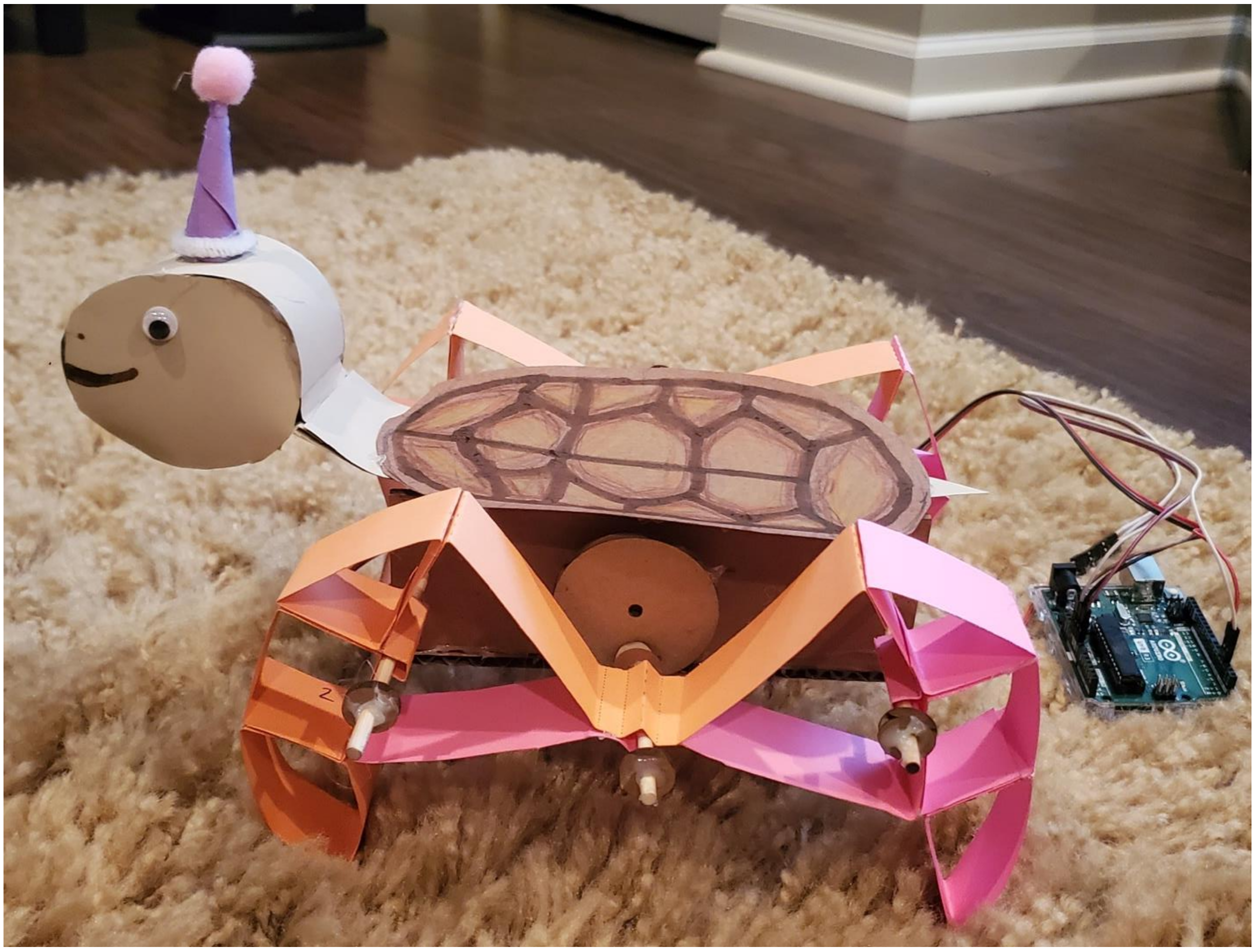

Figure 2. Student final artifact "turtle out of her shell" walking Jansen

Near-Peer Mentors

There were two near-peer mentors for the duration of the camp, both of whom were rising seniors at the time of the program. They studied Industrial & Enterprising systems, and both identified as Latino and first-generation college students. Two data sources were analyzed for the study. The first source consists of near-peer mentor journals. These journals were used daily and included prompts: "What did your mentees excel at or enjoy today?", "What did your mentees struggle with or disengage from today?" and "Did anything surprising or unexpected happen? If so, briefly describe the situation." The average journal length was about a half-page. At the end of the week, the near-peer mentors were asked to "Reflect on your experiences as a mentor." After the program's conclusion, the second source was a group interview with both near-peer mentors. The second source consisted of a 30-minute semi-structured interview (Appendix A) where the interviewer asked the mentors to talk about their experiences designing and implementing the program and any benefits they gained from their near-peer mentoring experience.

A near-peer mentor is a senior learner who supports other junior learners by providing support to other learners instead of faculty providing the support[1]. Near-peer has various interpretations, such as having a single-year difference between the mentor and mentee [33], middle school students mentored by high school students [29] to pre-college students mentored by undergraduate students [34]. Since mechatronics is an advanced area of engineering, the team determined that the near-peer mentors were required to have advanced technical knowledge and thus selected undergraduate students as the near-peer mentors.

We used a general inductive approach [35] to analyze the qualitative data. The group interview was recorded and transcribed using Zoom video conference software. The mentor journals were kept in the original format in Microsoft Word. Before analyzing the data, the evaluator read the texts multiple times to understand the data. Once there was an understanding of the text, the evaluator developed codes from pieces of text. Once each data source was coded, codes were compared and combined to develop themes. Three themes were highlighted as the benefits of near-peer mentoring. Mentors developed their teaching skills, their sense of belonging to STEM improved, and they practiced learning and consolidating STEM topics.

Trustworthiness

Trustworthiness focuses on the quality and validity of a qualitative study [36]. The mentors were asked to review the results and conclusions and verify whether they accurately depict the mentoring experience as a form of member-checking. Both mentors agreed that the results did well at capturing and explaining their feelings and experiences. Additionally, direct text from the interviews and notebooks were used below to provide understanding and context for the conclusions.

Results and Discussion

The analyses highlighted three key benefits of near-peer mentoring: Mentors developed essential teaching skills, improved belonging to STEM, and practiced learning and consolidation, which align with previous studies on near-peer mentoring [13], [29].

Teaching Skills

Both mentors had previous experience teaching and mentoring students within the engineering field. However, they faced novel challenges with designing the curriculum and teaching virtually. Although the two mentors had experience working with students, neither had designed a curriculum. Designing a curriculum required them to think like a teacher, assessing the skill set required to complete the builds and anticipating students' difficulties when designing their builds. For example, Mentor 2 mentioned that: *"We tried to keep the students in mind….to consider time constraints and difficulty….testing multiple material for how structurally sound...we were also considering materials we were giving and the difficulties that it might bring."*

Beyond designing the curriculum, mentors developed additional skills during the weeklong program. They were the primary teachers during the building lab sessions, and as such, had to practice quick problem solving and adaptability while tackling the additional challenge of not being able to help students physically. Mentor 1 speaks on the difficulty of troubleshooting student projects virtually:

> *We had to split them up into breakout rooms. Literally worked one-on-one with them. That's how difficult it was. We really needed like one-on-one because each*

student had a different issue and a different error popping up on their Arduino….It was the most tough part of the week for sure.

While they tried to mitigate challenges during the curriculum design, it is impossible to foresee all students' challenges. They had to adapt as the challenges arose. Although challenging, the mentors did grow from this experience. They understood the importance of adaptability for student learning. Mentor 1 expressed that:

> *…it is collecting data from the students and just like feedback and I think in interpreting that and then finding ways to better improve….Understanding the feedback and seeing how the students are relating to the things or not relating to them….if they get bored or distracted during a certain portion how we could fix portions of the problems.*

Sense of Belonging to STEM

Both mentors identify as Latino, an underrepresented and minoritized identity in STEM. Students of color are more likely to report low levels of belonging in STEM [38], and Mentor 1 talks about how she struggles with her sense of belonging to STEM, inspiring her to be a near-peer mentor; she wants to represent what she lacked as a young student.

> *I think my sense of belonging for sure was the reason I wanted to pursue this research and kind of get myself out there with students like that because I know for sure if I was introduced to STEM in any way, maybe even in elementary school, that would have impacted me and my interest in engineering positively like earlier on. I really didn't start getting into engineering until high school….so my sense of belonging now that why I like doing these programs and running them just to expose minority students specifically…so they can see themselves doing this later….*

The mentors discussed how their sense of belonging to STEM is affected by the lack of representation in engineering courses:

> *Coming into the university there definingly was a question within a sense of belonging. We started in a little bit simpler classes within engineering and progressed up the ladder. So seeing students who don't look like us in a little bit more advanced classes and one we get to those advanced classes there still mixed with a ton of kids who don't necessarily look like us….*

The lack of ethnic/racial diversity in advanced courses hindered their sense of belonging STEM. It is difficult to feel like you belong when the environment signals that you do not [39]. However, participating as near-peers positively affected their sense of belonging to STEM. Working with faculty and adding to the program conversation positively affected their sense of belonging to STEM. For example, Mentor 1 notes that:

> *I think with the research and working with the professor, she respects us and really takes our opinion into account, and that's really rewarding…I think that it adds to the sense of belonging. Just to feel like our opinion matters and what we're doing matters.*

By working with faculty, their voices were heard and valued and thus affirmed that they belong in STEM. The literature identifies the importance of STEM belonging to career interests in STEM [40].

Learning and Consolidation

Designing the curriculum required trial-and-error, which encouraged students to pull from what they learned from other experiences and learn new material. Prior to the camp, neither mentor had much knowledge of paper mechatronics. Mentor 1 notes that: *"Paper mech was completely new to me and to the other mentor as well when it was introduced to us."* The act of teaching fosters in-depth learning and retainment [3], [28]. They engaged in readings and lectures surrounding the topic to ensure a solid foundation. However, as they began to read and build, they realized they had engaged with paper mechatronics, but they did not know. Mentor 2 states that: *"I guess I had done some activities that were paper mech[atronic] related but I never knew the name for it….We recognized some of the movements but never pinned a name to it."*

In addition to learning from readings and individual research, the mentors also learned from the students. Frequent interactions with the students provided new perspectives and a unique learning experience. Mentor 1 explained that:

> *They were using the machine's movement in ways I had never thought of and that was incredibly exciting to see. It allowed me to see the scale of "decorative adaptability" the machine had. It also got me thinking of ways to change the parts themselves to give the students more room to design.*

Finally, as mentioned previously, the mentors pulled knowledge from other courses and experiences as they developed the program builds. Mentor 2 stated that: *"We did end up implementing our own design specifications for the program and to make it easier for the students as well. Our experience doing any type of prototypes in our prior classes did help."* The development of the program encouraged the mentors to pull from their prior experiences to practice and share what they had learned.

Mentors' Final Thoughts

While teaching was not new to either mentor, they expressed how fulfilling and exciting it was to be a near-peer mentor. Below is a portion of their mentor journal final reflection about the program:

> Mentor 1: *Being a mentor to these campers is something I really enjoyed and I hope to do again in the future with more middle schoolers, or students even younger. Reflecting more, I realized how important it is for us as mentors, to understand how these students view themselves and how they relate to STEM. I also didn't realize, up until this camp, that young students and their motivations to pursue STEM, has a lot to do with influence from family or friends that are also in the STEM field.*

> Mentor 2: *This camp was really an amazing experience like no other. I had been a part of projects or camps before where I would have a hand in the build up, however, those experiences were provided through the guideful hand of past instruction. This was the first time I got the opportunity to formulate an entire*

educational production from the very beginning. It was an incredibly rewarding experience to see and hear the campers express their disbelief at what they had created . It was even more interesting to see the campers pull their own creativity together and express it through the creation of their characters.

Conclusion

This study examined the benefits of being a near-peer mentor for a summer engineering camp. The mentors gained valuable teaching skills, improved their sense of belonging to engineering STEM, and practiced learning and consolidation. The findings of this study provide a glance into possible benfits a near-peer mentoring.

Existing literature presents several benefits of near-peer mentoring, particularly in the medical field (e.g., universal skills that can be applied professionally, learning and consolidation, and a deeper understanding of knowledge). These early findings support those findings and find that mentoring can positively affect a sense of belonging to STEM. Data collected from two mentors provide valuable insight into the benefits of being a near-peer mentor. However, we recognize the sample size.

Our early findings suggest that near-peer mentoring can be rewarding and beneficial for undergraduate students. Providing near-peer mentoring opportunities seems to provide an opportunity for academic enrichment. Furthermore, his experience may be significant and affirming for students with underrepresented identities who struggle to develop a sense of belonging to STEM. Taken together, near-peer mentoring could be a great approach to enhancing the education of undergraduate students in engineering.

Future Work

Future work will involve continuing the current work of near-peer mentors. Additional data from more near-peers mentors will be collected and analyzed to develop significant findings on the benefits of near-peer mentoring. Future studies will continue to investigate possible disadvantages of mentoring and understand the typical qualities of mentors that make a good mentor.

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Appendix A: Interview Questions

1. Walk me through how you created the curriculum for the summer camp.
    a. How did they determine builds?
    b. How familiar were they with the subject before mentoring?
    c. Did you learn anything from this process?

2. What teaching experiences did you have coming into the camp?

3. What skills did you develop from this process, if any?

4. Has you sense of belonging to STEM been affected by participating in the camp? If so, how?
    a. Compare and contrast belonging before and after program.

5. Finally, reflect on your time mentoring, how was your experience?