Paper ID #35689

A Pilot Interdisciplinary Robotic Mentorship Project to Study Engineering Soft Skill Development

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Abstract

As the complexity and diversity of general engineering practices continues to increase, it is becoming apparent that simply providing technical knowledge within the chosen discipline is insufficient to prepare our engineering students for related employment opportunities. The engineering workforce today is expected to perform effectively in a multi-disciplinary environment, underlining the importance of soft skills that include interdisciplinary communication, teamwork and leadership. Despite the increasing awareness, the gap between graduates' soft skills prepared by academics and those required in the job force stays significant, if not continues to widen. In collaboration between the engineering and education departments at the State University of New York (SUNY) at New Paltz, a robotics mentorship program was designed as a platform to foster soft skill development of engineering students. The program entails participation from three groups: mechanical and electrical engineering students, adolescence mathematics teacher candidates, and high school students in an after-school robotics club. A two-semester pilot project was conducted for feasibility study, comprising weekly planning and training between engineering students and adolescence mathematics teacher candidates. Furthermore, a resulting workshop series to mentor the robotics club at John Jay High School in Wappingers Central School District was developed to cover topics ranging from CAD and microcontrollers to the competition engineering notebook and general advice based on the mentors' previous experience in robotics. Even though the execution was abruptly interrupted by the COVID-19 pandemic in the first semester and completely moved to online in the second semester, survey and interview data was collected on five undergraduate engineering students and three mathematics teacher candidates, which offer encouraging qualitative evidence of their soft skills development, particularly for the engineering mentors. In this paper, we will introduce the collaborative mentorship program and the differentiating design considerations, then discuss the results with focus on 1) the journey of these engineering students as they collaborate with mathematics teacher candidates and serve as mentors in the afterschool program, and 2) the impact of the interdisciplinary model on fostering their soft skills.

1. Introduction

There is an increasing awareness that equipping students with technical knowledge in their chosen disciplines is insufficient. Researchers, educators, and industries are beginning to recognize the importance of communication, teamwork, leadership, critical thinking, and many other skills that enable an individual to perform more effectively and harmoniously in real-world working situations [1]. These social-relation interpersonal skills, or soft skills, are increasingly demanded in today's competitive global market [2]. For instance, Klaus [3] found 2010). The importance of soft skills has been well documented by the literature [4].

The development of soft skills is imparted through applications and experience of social interactions, which relies on the reflective thinking that occurs in communication and collaboration with others [5]. This is an organic learning process of observation and guided practices with an experienced individual who acts as a mentor. Thus, it is incumbent upon us as educators and researchers to investigate the role of mentoring in the development of soft skills.

This paper introduces an interdisciplinary model in a two-semester afterschool program, where the undergraduate engineering students and mathematics teacher candidates teamed up to serve as mentors for a group of high school students in an after-school robotics club. We will explain the pedagogical rationale of the mentorship approach and that the design of our interdisciplinary model is a particularly effective option to foster engineering mentors' soft skills development.

2. Theoretical Rationale & The Design of the Interdisciplinary Model

The interdisciplinary model brings together undergraduate engineering students and mathematics pre-service teacher candidates in a public university on the east coast to work directly with students in a high school robotics club. The overall framework of this model is shown in Figure 1, involving three interacting parties for a community of practice that promotes unique learning opportunities for all the participants. The project began by a joint meeting between the university team and the coach of the robotics club, where the participants shared resources, background, scope, and vision, and then jointly identified topics and approaches that are appropriate for the robotics learning workshop. Based on these selected topics, the college team, consisting of interdisciplinary members, collaboratively designed engineering-related hands-on robotics workshops during the internal meetings. Revisions were made based on peer feedback; the team then implemented the designed workshop with high school robotics club students in an after-school extracurricular setting. Faculty from the School of Education and the Division of Engineering Programs oversaw the collaborations and provided necessary assistance from the respective expertise to ensure quality designs and effective implementation.

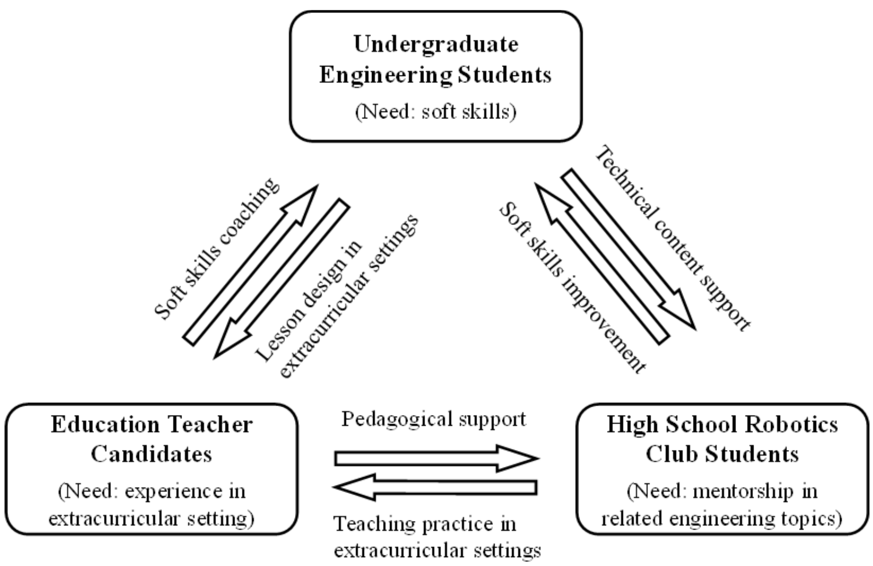

Figure 1. Conceptual framework of the interdisciplinary robotics mentorship model.

The designed concept of this model is framed in a sociocultural perspective of learning to promote student-centered and active learning of soft skills [6]. Social constructivism can be described as a process of acquiring skill and knowledge, which takes place with the individual's reflective thinking as well as the interaction with others [7]. While we predict this model offers the potential to generate positive outcomes for all the three groups, such as the high school students gaining engineering experience and becoming interested in STEM fields, and the teacher candidates' growth in designing and implementing activities outside of a traditional mathematics classroom, this paper will focus on the engineering students' soft skills development through the program experience. Specifically, we will study how the program facilitated the engineering students to develop soft skills via collaborating and learning from the pedagogy experts (teacher candidates) and serving as the mentors of the high school students.

3. Methods

In this research, we designed and executed a two-semester robotics mentorship program, consisting of a series of workshops designed and developed jointly by undergraduate engineering majors and mathematics teacher candidates for students in the high school robotics club. The impact of this interdisciplinary model was then evaluated through post-program surveys and interviews to address the following research questions:

- In what ways does the mentorship program affect undergraduate engineering mentors' self-development through the lens of soft skills? Also, are there observable changes in education mentors' soft skills self-development as well?
- In what ways do the mentors from their respective disciplines benefit from each other?

3.1 Context

Two sets of weekly activities were planned for the program, comprising development meetings and robotics workshops. Development meetings were exclusive to undergraduate students and faculty and would take place at SUNY New Paltz, where students would dedicate an hour to plan for the upcoming workshops and evaluate the effectiveness of the previous workshop. The engineering students would suggest relevant topics to present in a workshop and have materials prepared for discussion during the meetings, while the education students would provide feedback on how the materials could be delivered effectively and provide advice for improving soft skills. Robotics workshops involved all parties and would take place at John Jay High School, where the engineering students would spend an hour to run through the workshops for the high school students while the education students would observe improvement opportunities for future workshops. During each workshop, breakout sessions led by assigned college students were held for specific topics including general robotics, CAD design, coding, electrical control, fundraising, outreach and engineering notebook.

This program was initially implemented in-person in the first few months of 2020 before it was abruptly interrupted by the COVID-19 pandemic. Subsequently, all the activities had to take place remotely. Although the implementation features were modified for the remote format, the core goals of the model and the research questions remained the same.

3.2 Participants

- <u>High school robotics club</u>: John Jay High School of Wappingers Central School District in New York is a local high school with relatively limited experience in robotics. The club consisted of 15 active members with different interests and responsibilities related to the competition. Although the club coach offers extensive related experience in robotics competition from previous teaching positions, the majority of the club members had little, if any, experience in robotics or related engineering disciplines.

- Engineering students: Five undergraduate engineering students (including four mechanical engineering majors and one electrical engineering major, all male) at different years of their degree were selected with varying experience in robotics (ranging from no experience to 4+ years) and with different levels of teaching/mentoring experience (ranging from no experience to multiple semesters of teaching assistant work). The accreditation requires these engineering students to be exposed to different engineering disciplines such as electrical, computer and mechanical engineering, and to establish interdisciplinary knowledge for effective collaboration and communication [8].
- Mathematics teacher candidates: There were four teacher-candidates (two male and two female) who had completed the majority of their required courses in the secondary mathematics education program and were in the final stage of the student-teaching semester. These teacher-candidates lack engineering and robotics background.

3.3 Data Collection & Analysis

A self-reported survey instrument was administered at the end of the project year to measure the mentors' project experience in collaborating with the cross-disciplinary colleagues and mentoring the high school students. Given a list of defined skills listed by [9] as the options, participants were asked to self-evaluate their soft skills development based on the project experience.

Next, post-project individual interviews were conducted with all mentors (five engineering students and three teacher candidates) to further explore the mentors' perspectives and growth related to soft skills. The following interview protocol questions were asked to all of the mentors.

- Can you describe your mentoring experience with the high school students?
    - What did you enjoy about the experience? What did you struggle with the experience?
- What would you change your approach if you were to lead the workshops again next year?
- Can you describe your collaboration experience with experts outside of your disciplines?
    - What did you enjoy about the experience? What did you struggle with the experience?
- What did you learn from participating in this project?
    - Was there any surprise on your self-development? Please explain.

The interviewees were reminded of their choices of developed soft skills from the survey results and asked for an elaboration. The interview data was transcribed and analyzed through an open-coded approach using the constant comparison analysis method described by Strauss [10]. Next, the three co-authors independently reviewed the interview data and identified evidence related to each of the soft skills. The results from the independent analyses were then merged to seek patterns across participants by recursively identifying, revising, and combining the emerged categories. These categories will be named, defined, and further clarified with specific examples of interview data.

4. Results

4.1 Survey Result

One of the survey questions asked to the student mentors was their motives for participation. It was assumed that these students would want to volunteer because of the interest in getting back into robotics. When asked why they wanted to volunteer for the project, it was revealed that these students had motives and goals prior to joining. The mentors identified the social interaction opportunity of working with the robotic club students as the main motivation behind their involvement in the program. Most of the mentors participated in the program because they were encouraged by, benefited from or victimized by their own robotics experience in the past as a high school student. They wanted to provide meaningful advice to the high school students based on their previous experiences in various areas that include robotics, engineering, women in STEM, and advising for future career aspirations. As for the teacher candidates, many participated in preparation for becoming a robotic club coach themselves in the future.

Overall, all responded mentors reported that they had a positive experience throughout the program, and half of the mentors (50%) strongly agreed that the program helped in developing their confidence in the ability to help others. Most mentors also agreed (33%) or strongly agreed (50%) that the program was effective in helping the high school students learn knowledge related to STEM topics. In addition, the impact of the program on the mentors' soft skills was measured by a survey question "In this project, I developed skills related to…" with a four-level scale of *None* (0)*, A few* (1)*, Some* (2)*,* and *A lot* (3).

Figure 2 shows the stacked plot of individual mentor's development of soft skills based on self-evaluation from the project experience. Overall, *Presentation*, *Teamwork*, *Leadership* and *Communication* are the four top ranked skills with at least *Some* (2) from all mentors.

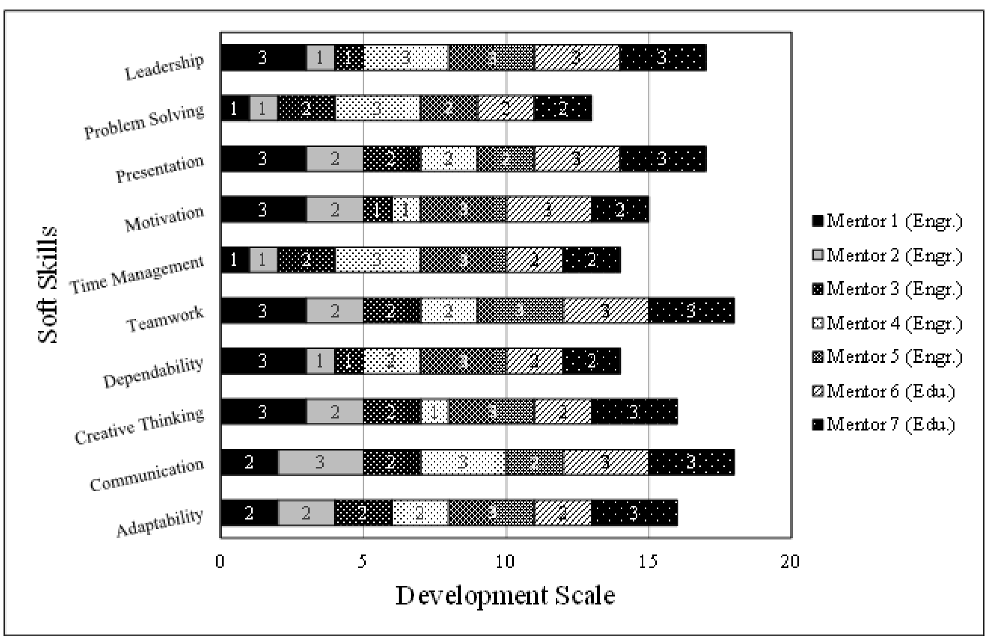

Figure 2. Results of the survey question "In this project, I developed skills related to..." in a four-level scale for each category: *None* (0)*, A few* (1)*, Some* (2)*,* and *A lot* (3).

4.2 Interview Result

In this section, we will present the recurring and shared themes for each of the four top soft skills identified by the mentors and the corresponding quotes that represent the mentors' soft skills developments. It is important to note that, while *Communication* is the top-rated soft skills developed in this study based on the survey results, the mentors devoted limited attention to it during the interview, despite related follow up questions. Therefore, this paper will focus on the evidence of the other top-rated soft skills, including *Presentation*, *Teamwork* and *Leadership*.

4.2.1 Presentation Skill

In this study, *Presentation* was coded as the mentors described their experience in leading a formal workshop, with a specific focus on their interaction with the mentees. This involves making sure the slideshow can draw and retain attention from the audience, while not having excessive information. This is coded differently from *Communication* which is a separate code for the exchanges of information in a non-workshop setting.

<u>Presentation – Theme 1: Engineering mentor's realization of the lack of instruction skills</u>

A recurring theme expressed by the mentors was an improvement in presentation skills. A fourth-year engineering mentor expressed how he learned to not overwhelm his presentation content with information. More specifically, the mentors acknowledged the challenge to convey materials to the high school students regardless of their strength in technical background.

> *"The engineers are always just like so now focused on like the core of the material, not so much being able to expand on or how to present it or how to teach it..."*

> *"I learned a lot about how you know students learn at different pof aces, and you know at certain levels. That's one thing I definitely learned and I've never even really thought of that before... by kind of like simplifying the approach to the students rather than saying stuff to him for just saying stuff..."*

Mentors described a sense of realization that they tend to overcomplicate the teaching material, with one second-year engineering mentor explaining how he worked on not overwhelming the high school students with material.

> *"...Trying to really, not try to overcomplicate things and really try to teach at their learning level. I always found myself like making these presentations with you know, hours like prepping for him [them] and there would be like way too much. It was just too high of a level I was thinking at. So it's kinda hard to simplify."*

<u>Presentation – Theme 2: Development of teaching and presentation skills</u>

A second-year engineering mentor shared his learning of pedagogical moves for presentation or teaching throughout the program, including differentiation and reinforcing positive behavior.

> *"I was able to bring it down a little bit in a way that it be easy to for the students to digest and breaking it down so they're not overwhelmed with everything."*

A fourth-year engineering mentor shared that the mentorship experience prepared him to construct concise and informative presentation slides, acknowledging an improvement from when he first started leading workshops.

> *"I definitely got better at my PowerPoints and in terms of creating them so that they are not too busy. Keeping it minimal, introducing things slowly and like all the formatting... I know [my] first presentation probably had a lot of words, a lot of technical pictures or various things, and to throw out the students that may have intimidated them... I was able to bring it down a little bit in*

a way that it be easy to for the students to digest and breaking it down so they're not overwhelmed with everything."

The mentorship experience also reinforced education mentors, who were responsible for providing pedagogical feedback post-workshops, to become more cognitive on others' teaching practices as well as be reflective of their own. A teacher-candidate shared,

> *"I feel like I've developed more as a teacher and being able to teach others how to teach. In a way I feel like that sounds so condescending, but I don't know any other words to say. It's allowed me to be more reflective and even become more confident as an educator."*

4.2.2 Teamwork and Collaboration Skills

Teamwork was coded for the moments when multiple people worked together to achieve a common goal and to collectively complete the project. The design model of this program tasks mentors to meet and co-design workshops on a weekly basis, which naturally promotes collaboration within as well as across disciplines. A community was formed in the mentor team as the mentors learned to rely on the expertise of each other. Thus, it was not surprising to find that mentors frequently refer to the unique opportunity of teamwork and collaboration experience with different disciplines.

<u>Teamwork and Collaboration – Theme 1: Impact of teamwork</u>

A second-year engineering mentor expressed his initial worries about the lack of pedagogical knowledge or teaching skills, and then shared the benefit of collaboration with the teacher candidates.

> *"As the engineer, you're like, 'oh yeah, we can do this topic', but you are thinking at the level that you are learning [as a college student with the content background] rather than a high school student that hasn't learned anything. We can really talk more with the education students 'cause they know more about what levels they [students] can understand. When I did the coding presentation, how high of a level should I go or how low."*

A third-year engineering mentor further shared his perspective on the collaboration model, and the experience to co-design the workshops with the teacher candidates in ways that are appropriate at the high school level.

> *"I like that we had kind of a system where, like we decide what the presentation be and then get that done early in that we try to send out for revisions…I think it worked out probably as it should have because while the engineering students ran probably the majority of the actual workshop, it's a robotics club so we are the ones with the knowledge. But, the teaching students [teacher candidates] were able to support us to make a better experience for the kids."*

<u>Teamwork and Collaboration – Theme 2: Changes in reputation</u>

Similarly, the teacher candidates also shared positive experiences working with the engineering mentors. They shared that the opportunity to collaborate with engineering mentors in this program altered their view on the stereotype of an engineer. For example,

> *"I always thought they [engineers] were logic driven and very… almost… robotic. I thought that they would think they were the smartest in the room and flaunt any point they could. I was*

pleasantly surprise[d] when they all seemed to listen to me and my presentations. Working with them humanized them in a way."

4.2.3 Leadership Skill

In this study, *Leadership* was coded with the focus on the non-technical soft skills as previously described. Since the development of leadership skills may lead to the unique transformation of how one views him/herself, or the formation of self-identity and values [11], the code also includes moments where the mentors construct, evaluate or transform their identity as a result of the leadership progression. The analysis result reveals that although all mentors provided evidence of leadership, the degree and context of the development varied. Instead of shared themes, we will present the story of two mentors, one engineering student and one teacher candidate, as they shift their identities while developing their leadership skills throughout the program.

<u>Leadership – Case Study: Joanna</u>

Similar to many education mentors, Joanna joined the program in a passive role with mixed emotions of excitement, hesitation, and timidness. As she participated mostly as an observer, Joanna acknowledged the difficulty engineering mentors encountered due to the lack of pedagogical knowledge, particularly in the early stage of the program. She stated,

> *"I was very quiet in the beginning. I know myself as the education major, and I was kind of intimidated by them [engineering mentors]. Because, you know, I think they're smarter than me and they know their content more, so who am I to judge?"*

Midway through her participation in the program, multiple education mentors began to take an active role during the design workshop to provide feedback with their pedagogical expertise. Joanna explained her motivation was inspired by observing the struggle of the high school students due to the lack of pedagogical approaches by the engineering mentors. She stated,

> *"It was kind of, you know, putting on my teacher hat and being like okay, I see that this isn't really working for the students and I care about the students. So let me offer suggestions so that they [engineering mentors] can connect more with their students."*

To further support the engineering mentors, Joanna then volunteered to create and lead pedagogical related presentations during the internal mentors meeting, with focuses on topics such as *How to make an effective PowerPoint?*, *What is collaborative learning?* and *What is assessment in a classroom?* For Joanna, such an experience not only developed her leadership skill, but also transformed her identity from a silent observer into an active contributor. She described,

> *"When I started doing the presentations, I feel like they [engineering mentors] started seeing me as one of their colleagues… I feel like because I was able to contribute, they felt they saw me more as a colleague because I was contributing in a way that was going to help them improve their contributions to the students. In a way, it's kind of a symbiotic relationship."*

Leadership – Case Study: Sean

In contrast to Joanna, Sean was a senior engineering student who started the project in an influential role by taking the lead in designing and implementing the first three workshops. He described,

> *"I viewed myself in this project so far as being the senior or the higher-level engineering students. That's what I'm going through like leading the workshops, taking the initiative to put everything together and deliver to students."*

As the project continued, Sean shared his deliberate action of stepping down in order to create space for his peers. He explained the intention was to better engage other mentors in this program, honoring peers' opportunity for having a voice in the team, and to allow himself the chance to learn from others. He explained,

> *"I did have that intent to take a step back to see what the others are doing, to let the others take over so that they could feel that they have a role…so getting to see what everyone else is able to bring to the table. I don't have a particularly strong electrical engineering background so seeing those who are early on showing everything with the wiring was helpful to me and also for the students to also hear like a different voice."*

Sean shared his reflection of his transformation shifting from an active leader into a silent participant, and explained,

> *"...I changed my role in the middle of the projects like starting off as a leader and then falling back to a role player… That was a really interesting dynamic perspective just being able to make that hard adjustment. I thought that was one of the biggest things that I gained was not just adaptability from project-to-projects but adaptability within the same project"*

The skill of leadership may be shaped or demonstrated in various forms. While Joanna and Sean shifted between the role of a passive observer and an active participant in reverse order, both mentors revealed qualities of leadership.

5. Discussion, Conclusions & Future Work

This paper introduces a collaborative model involving cross-disciplinary mentors of engineering majors and teacher candidates to work with high school robotics students in an afterschool mentorship program. We highlight the findings on the mentors' growth in soft skills, and using the mentor's quotes to illustrate the impact of this collaboration model on key theme emerged for *Presentation, Teamwork,* and *Leadership*.

Most of our mentors identified the collaboration and interaction with their cross-disciplinary colleagues as the key factors contributing to their soft skills development from this mentorship experience. This finding is apart from related studies [12], [13], which often describes soft skills growth by working with the mentees. We argue the social interaction structured in this model creates unique opportunities that naturally foster collaboration between engineering majors and teacher-candidate as they work towards a common goal - creating effective workshops for the high school robotics students. Such experience contributes to the mentors' ability and confidence in various soft skills. Also, it leads to a shift in identity for the mentor while participating in this project, particularly as described in the two leadership cases studies.

The goal of this study was to better understand the nature of a collaborative mentorship model and explore ways to support the development of the mentor's soft skills, particularly for engineering education. Limitation of the study includes the small sample size and the abrupt change of workshop modality due to the COVID-19 pandemic. Further data is needed to create a more comprehensive image of soft skills development supported by this collaboration model, particularly in ways beyond self-reported data. Based on our findings and constraints of the study, more questions arose:

- *What strategies reinforce the interaction across disciplines to help increase development across evaluated soft skills?*
- *How is the soft skills development influenced by the instructional methodology, if at all?*

More research is needed as we learn about ways to support mentors, particularly engineering majors, to develop the necessary soft skills in the 21st century learning communities.

6. Acknowledgement

The authors thank Coach James Amodio of John Jay High School and Director Adam Panzer of Wappingers Central School District for graciously allowing us to work with students of the robotics club in their high school. The material is based on work supported by the 2020-2021 Research and Creative Projects Awards at SUNY New Paltz.

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