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Robotics Mentorship as a Cross-Disciplinary Platform to Foster Engineering Soft Skills

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Abstract

An interdisciplinary robotics mentorship program was initiated in the Fall of 2019 to study soft skill development in undergraduate engineering students. The primary objective of this program is to design and implement an effective learning model to foster engineering students' development of soft skills through collaboration with students in education major. Results of the study demonstrated that cross-disciplinary collaboration and interaction effectively enhance engineering soft skill development, particularly in *Presentation*, *Teamwork*, and *Leadership*. Based on the challenge and findings from the pilot study, the program structure has evolved each year for the ensuing two academic years to further strengthen the interaction among the mentors. For example, the second phase of the mentorship program was redesigned to accommodate the team project approach for the high school robotics club where mentors had more opportunities to guide and support the high school students. In this paper, we describe the approach to our program revision beyond the pilot study and identify the issues and success unique to this cross-disciplinary robotics mentorship program in fostering engineering soft skill development as it entered the third phase in Fall 2022. Results of survey and interview data from participating mentors are reported regarding the soft skill development outcomes over the first two years, along with opportunities for broader impact in the future.

1. Introduction

It has been recognized that the acquisition of only technical knowledge and engineering judgment by graduating engineering students is oftentimes insufficient. In the workplace, interpersonal relations and soft skills are also necessary to work between disciplines and between functional groups in today's competitive global market [1, 2]. Despite the increasing awareness of soft skills in the educational community and effort by policymakers [3], the soft skills gap continues to occur for the engineering graduates [4]. Students and faculties devote more attention to academic success due to the orientation of school curriculum and assessment [5], lacking opportunity for students to learn the necessary soft skills in a traditional class setting.

Mentoring has been one of the most effective pedagogical approaches and has been widely adopted in education and related fields [6]. In addition, social interaction plays a critical role in how learners construct knowledge and skills through the social constructivism lens [7]. Thus, we designed an interdisciplinary robotics mentorship model, where the undergraduate engineering students collaborate with preservice mathematics teachers as mentors to support students in a high school robotics club. We aim to examine the effectiveness of this model in supporting engineering students' soft skills development. This paper describes and rationalizes the design consideration and approach to our program revision beyond the pilot study [8], reports on the analysis results for assessment, and provides recommendations for future revision.

2. Conceptual Framework of the Cross-Disciplinary Program

The conceptual framework of this cross-disciplinary program, shown in Figure 1, is aimed to promote thoughtful interaction between three parties: university undergraduate engineering students and education teacher candidates as mentors, and members of a high school robotics club. Each functional group has both needs that can be satisfied by the others and the experience to support the others from their respective competency areas. The program was initiated after a joint conversation between a faculty group from the university and the coach of the robotics club, where it was recognized that interactions between each group would be mutually beneficial and could be best implemented through the after-school robotics club activities. A collaborative and iterative approach allows those involved mentors to share interdisciplinary resources in the context of STEM education by jointly providing robotics learning workshops. Specifically, this paper aims to document how the program has evolved over the past two implementations since Fall 2019 to accommodate the growth of the robotics club, focusing on the soft-skill development of engineering students in their role as mentors in an extracurricular environment.

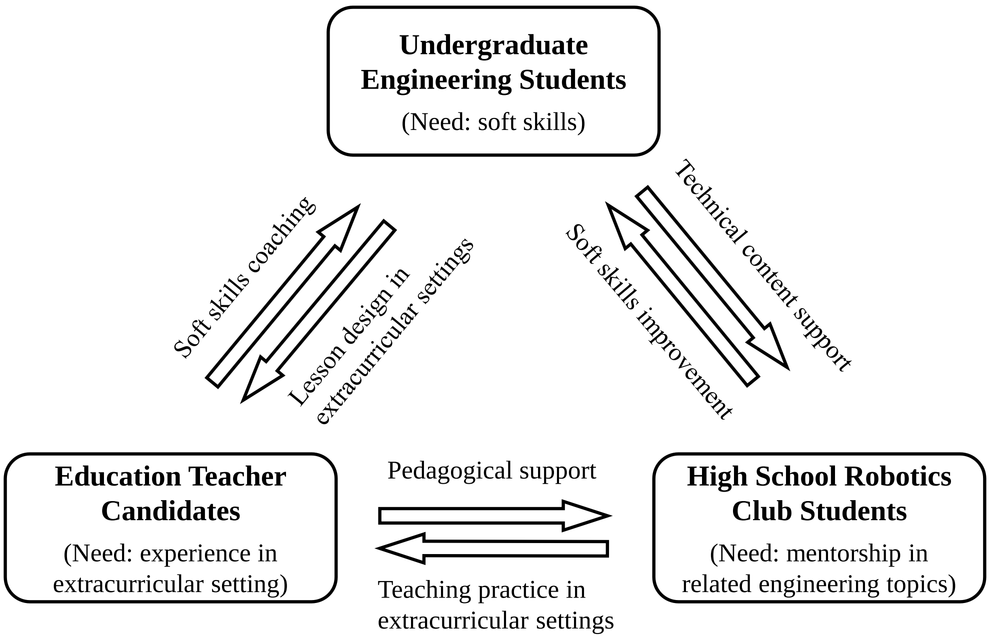

Figure 1. Conceptual framework of the interdisciplinary robotics mentorship model (adapted from [8] with permission)

3. Methodology

3.1. Contexts

Initiated in Fall 2019, the primary goal of this interdisciplinary robotics mentorship program is to leverage cross-disciplinary expertise to enhance the development of engineering soft skills through collaboratively designing and executing the mentoring activities between the engineering and education mentors. The design considerations, methodology and results for the pilot project (the first implementation) have been reported previously [8].

3.2. Participants

In alignment with our pilot study, the participants of the second implementation consisted of three parties, including members of the high school robotics club, engineering mentors, and education mentors.

High school robotics club members: Founded in 2018, the robotics club at John Jay High School of Wappingers Central School District in New York was a new after-school program seeking technical guidance, thus prompting the development of our robotics mentorship program in 2019. With the success in the 2020/2021 competition seasons during the first implementation of the program, the club attracted a large influx of new members in the beginning of Fall 2021, increasing its size from 15 to about 55 members. Since only a small fraction of the more experienced members could be involved in building the competition robot, most of the new members were not actively participating and lacked the basic skills necessary to make meaningful contributions. Also, based on past experience, inexperienced members had been left out of the core tasks of robot development, resulting in a vicious cycle that could lead to widening of skill gap in the club. To accommodate its tremendous growth while keeping all members engaged and on the track of acquiring relevant skills, the club initiated the Dream-Think-Create (DTC) Challenge as an experiment of engineering pedagogy based around guided self-driven exploration, where new members were provided opportunity to learn engineering principles through hands-on experience. Teams of three new club members proposed DTC projects in a variety of engineering fields, and their proposals and budgetary plan were reviewed by the senior club members for revision and final approval. Accordingly, as will be discussed later, the second implementation of the mentorship program was modified to provide effective support and to leverage for enhancing mentoring experience.

Engineering and education mentors: Voluntary student mentors from both the engineering and education departments in the State University of New York (SUNY) at New Paltz were selected to participate in the mentorship program. Engineering students, majoring in electrical, computer, or mechanical engineering, were at different years of their 4-year degree with varying experience in robotics. As an ABET-accredited organization [3], the Division of Engineering Programs actively explores opportunities to promote interdisciplinary collaboration and communication. Education students were mathematics teacher candidates in either the undergraduate or graduate level who had completed most of their required coursework and were in their last semester prior to student-teaching. The numbers of active mentors over the previous two implementation phases (Cohorts 1 and 2) and the third implementation currently undergoing (Cohort 3) are summarized in Table 1.

Table 1. Number of active mentors for the three implementations of the mentorship program.

	Cohort 1	**Cohort 2**	**Cohort 3**	**Total**
Engineering Mentors	5	4	3	**12**
Education Mentors	4	5	4	**13**
Total	**9**	**9**	**7**	**25**

3.3. Data Collection and Analysis

To measure the mentors’ experience in collaborating with cross-disciplinary colleagues and delivering the co-designed STEM activities to the high school club members, we administered a self-reported survey at the end of the implementation year. In particular, we asked the mentors to evaluate their soft skills development from the project experience, using a list of defined soft skills by Willmot and Colman as a reference [5]. We received an 83% response rate from our post-year surveys, with a total of 15 surveys (4 engineering & 3 education mentors in Cohort 1, and 4 engineering & 4 education mentors in Cohort 2) out of the 18 mentors who actively participated across the two cohort years. In addition, we were also able to collect interview data from all the mentors and are in the process of extracting conclusive findings to summarize in a forthcoming report.

4. Implementations

4.1. First Implementation – pilot project (2020 Spring ~ 2021 Spring)

In the first implementation of this program, the two groups of university student mentors collaboratively developed and delivered technical tutorials and workshops to equip the high school robotics club members with basic skills to design and build a robot to participate in the FIRST® Tech Challenge, an international high school robotics competition. To execute, the mentors engaged in alternating weekly activities throughout the semesters, comprising (1) internal development meetings where they gathered to brainstorm on subjects that include basic technical skills (CAD, 3D-printing, microcontroller, coding), additional topics relevant to the competition (engineering notebook, fundraising, outreach), as well as to reflect on the lessons learned from the previous workshop at the high school, and (2) workshop series where they visited the high school robotics club to deliver the workshops. At the end of the first implementation, the outcome of soft skill development for the mentors was evaluated through surveys and interviews. Among the ten soft skills assessed, four were identified as the top skills benefited from the project: *Presentation*, *Teamwork*, *Leadership*, and *Communication*.

It is noteworthy that this pilot project was originally designed to be a two-semester program. However, the implementation was abruptly interrupted by the COVID-19 pandemic halfway through the Spring 2020 semester until it was resumed in Spring 2021 in a remote synchronous mode. It can be surmised that the lack of continuity (about 10-month gap during the pilot project) and the subsequent remote setting may have an influence on the outcome. Also, all the tutorial materials and presentations in the pilot project were originated by the engineering mentors and finalized with feedback from the education mentors. Though the cross-disciplinary learning and communication took place mainly during the biweekly internal development meetings, engaging both parties throughout the presentation development could have further promoted mutual learning.

4.2. Second Implementation – revision for DTC projects (2021 Fall ~ 2022 Spring)

As schools opened up for activities after in-person learning resumed in Fall 2021, the robotics mentorship program returned to in-person mode where the second cohort of engineering and education mentors participated in the bi-weekly internal development meetings and hosted workshop tutorials. While the results of the pilot study demonstrated that our cross-disciplinary collaboration model effectively enhances engineering soft skill development [8], it also revealed limitations in our initial design and opportunities for improvement. Thus, the research team revised the model in the second implementation to strengthen the shortcomings identified from the valuable pilot experience, using mentors' feedback and accommodating foreseen challenges in the upcoming academic year that include the in-person workshop delivery and a significantly increased club size. Next, we will detail the changes occurred in four main aspects of the second implementation.

First, during the pre-workshop internal development meeting, we continued the initiative by the education mentors at the end of the pilot year and hosted pedagogic-related seminars at the beginning of the second implementation year. Seminar topics included *Effective PowerPoint*, *Collaborative Learning,* and *Formative Assessments*. Engineering mentors found these seminars exposed them to different teaching techniques, including ways to grab student attention, provide positive reinforcement, and be mindful of students' ownership. They felt that the experience effectively improved their ability to deliver a presentation and to engage the audience, as well as grew their confidence in public speaking. For example, one engineering mentor shared that, "*Learning different teaching strategies is definitely beneficial.*" Another engineering mentor provided a specific example, that "*I remember I brought up the idea of why don't we just call on students? But then I believe one of the other education students reminded me that some students won't accept that. They mentioned the idea, think-pair-share [strategy]. I never heard that before, so I am learning.*" We also reinforced cross-disciplinary collaboration by allocating meeting time for all mentors to co-design the structure and approach of the workshop, as opposed to an asynchronous model during the pilot year, where engineering mentors took the primary responsibility of the workshop material and delivery while the education mentors played a supporting role. When time permits, we also encourage rehearsals of the presentation during our internal meetings.

Second, the mentorship program was revised to leverage the club's new DTC Challenge to enhance engineering soft skill development, entailing DTC project advising and judging, as depicted in Figure 2. It is important to note the difference in the target audience and mission of the mentorship program between the first and second implementations. While the first cohort of mentors worked with the more experienced club members to perform in the robotics competition, the second cohort of mentors helped new members to develop their basic skills and retain their interest in the STEM fields. Therefore, the workshops developed for the second implementation only covered the basic technical skills to facilitate the execution of the DTC projects, excluding other non-engineering topics for the competition. Meanwhile, DTC teams worked on their projects during club meeting hours with support from mentors and senior club members, which continued after all the workshops in Fall 2021 and through the Spring 2022 semester.

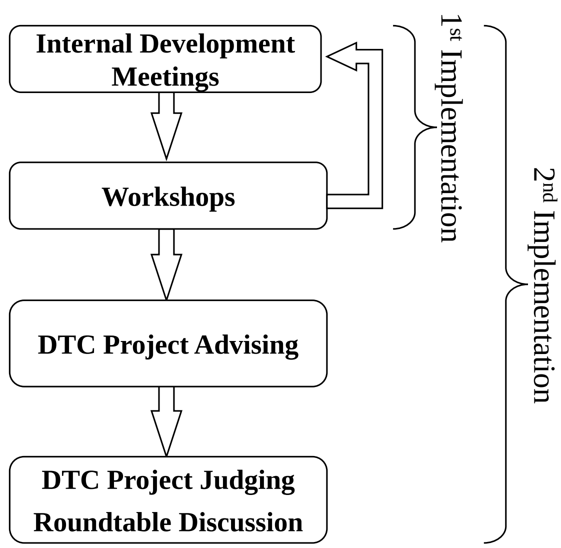

Figure 2. Mentorship activities for the two implementation phases.

Third, and to end the mentorship program for the year, the DTC Challenge teams and other club members were invited to SUNY New Paltz to showcase their projects and demonstrate the club's competition robots to the university community. Out of the initial 13 DTC projects, three teams applied for the final presentation to compete for the newly installed SUNY New Paltz *Engineering Education Innovation Award*. Student judges, comprising mentors and other voluntary engineering students, were provided a rubric to evaluate based on delivery, content, and enthusiasm of the presentation [9]. Afterwards, the high school club members demonstrated the robot built from the previous competition season and participated in a roundtable discussion with the judges. The purpose of arranging these activities is based on the hypothesis that the judges would benefit from the experience of interacting with and offering advice to the high school club members about their engagements in the STEM fields. The engineering judges were asked to reflect on their experience of the activities afterwards. Based on the response from four of the five engineering judges, the feedback was unanimously positive as the interaction provided them with an opportunity to give back and make some difference in the engineering community. For example, one engineering judge shared that, "*I felt this was impactful…seemed to resonate with the high school students in a way that hopefully showed them the benefits of taking such a path.*" Another stated that, "*I think the most rewarding part was offering insight into what they might run into in the future.*" Additionally, it is evident that such interaction reinforced their motivation. As an example, one judge mentioned that, "*I am driven to do further research in this field as to learn how these robots are created and developed into the wonderful machines that they are.*"

Fourth, the efficacy of the mentorship program on the high school robotic club members was evaluated. Due to the constraints of collecting data directly from the club members, we instead interviewed the club coach who was able to provide insight from the students' perspective of their design and development of the DTC projects: "*The majority of the students claimed that their experiences with the New Paltz mentorship increased their interest in STEM fields*" and "*the response from the students was unanimous that the on-campus experience was positive and enriching, and most cited the mentors involvement in the DTC Showcase at the end as a major reason why.*"

4.3. Third Implementation – work in progress (2022 Fall ~ 2023 Spring)

We are currently in the third implementation and collecting data from Cohort 3 of engineering and education mentors shown in Table 1. Based on the lessons learned from the previous two implementations, minor revision was made which will be described in Future Work.

5. Survey Response

Overall, consistent with the results from the pilot studies [8], all mentors agreed (36%) or strongly agreed (64%) that they had a positive experience in the program. In addition, all mentors also agreed (40%) or strongly agree (60%) that the experience reinforced their decision to become an engineering or education major.

To further measure the impact of the program on the mentors' soft skills, we included 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). When comparing between the two implementations without considering the specific soft skills or the mentors' major, Cohort 2 reported an average of 2.31 (out of 3), a slight 2.2% increase relative to 2.26 from Cohort 1. To further quantify the survey results for analysis, each evaluation area is scored by taking the sum of the population's responses (0-3) and dividing them by the highest possible score (score of 3 for all responses). Hence, each soft skill area is scored on a percentage scale. Figure 3 shows a bar chart of total scores with both majors combined, comparing the two cohorts (implementations) with evident similarities. For example, when comparing ranked percentages between the two cohorts, *Communication* (86% & 92%), *Teamwork* (86% & 88%), and *Leadership* (81% & 83%) led the three top-ranked skills for both years.

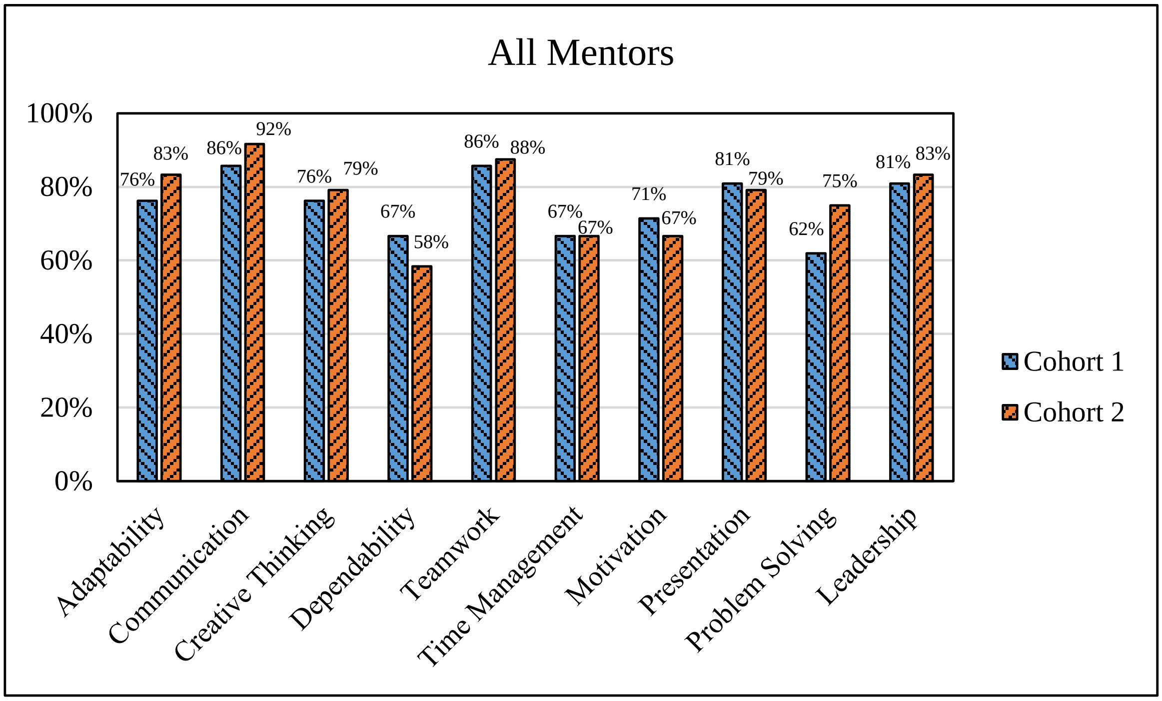

Figure 3. Overall scores from all the mentors in each soft skill area, comparing between the first and second cohorts.

There were noticeable changes observed in three soft skill areas between the two cohorts of mentors: *Problem Solving*, *Adaptability*, and *Dependability*, as shown in Figure 3. These changes can be rationalized as follows.

- *Problem Solving* (+13%): This may be attributed to the program's return to an in-person modality for Cohort 2, increasing the technicality of the workshops by allowing mentors to involve the use of technology like CAD software and microcontrollers. The addition of the DTC projects over a wide range of subjects may also have highlighted the importance of problem-solving skill for mentors in unfamiliar fields.
- *Adaptability* (+7%): We hypothesize the increase in recognition of adaptability was due to the modality change in delivering workshops and mentoring activities. As a result, mentors of Cohort 2 had to adapt promptly to challenges ranging from student reaction to equipment issues.
- *Dependability* (-9%): For Cohort 2, faculty emphasized a higher involvement in workshop preparation by all mentors during internal development sessions. While observing an increase in collaborative efforts between mentors, this shared responsibility and interdependence created less individual accountability.

To further analyze the self-evaluation scores to compare between the two mentor groups, the overall results in Figure 3 were separated into two score sets for engineering mentors and education mentors. Figure 4 shows the bar chart for the two cohorts of engineering mentors. Gauging the general outcome between the two cohorts of engineering mentors, the overall score (the average of all the assessed soft skill areas) increased by 9.1% from Cohort 1 to Cohort 2. This suggests that the revisions and modality change led to stronger outcomes for engineering mentors. In contrast, the overall score decreased by 7.6% for education mentors, as shown in Figure 5. It is evident that the experience in the soft skill development through the two implementations of the mentorship program is different between the engineering and education mentors. We will provide a brief analysis of the respective results.

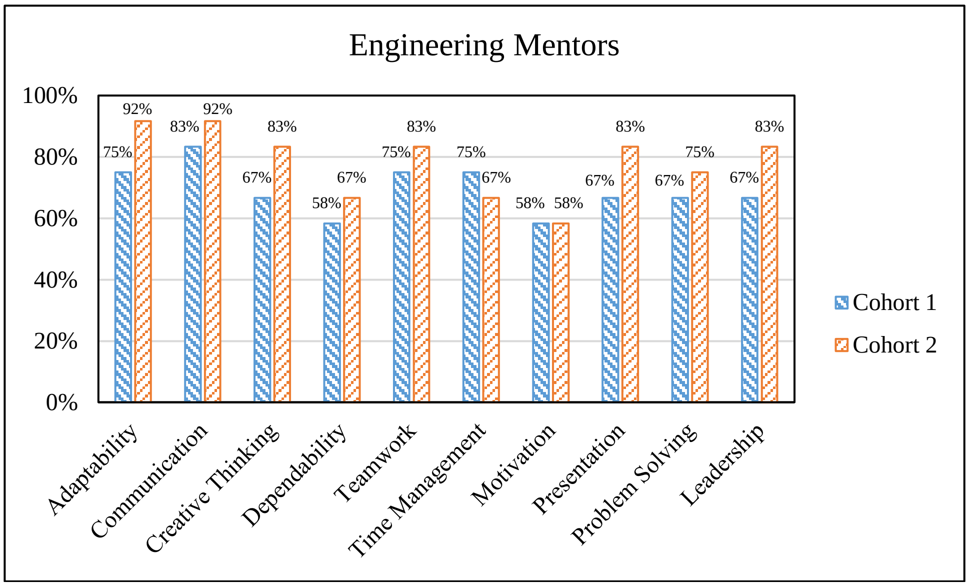

Figure 4. Scores from engineering mentors, comparing between the first and second cohorts.

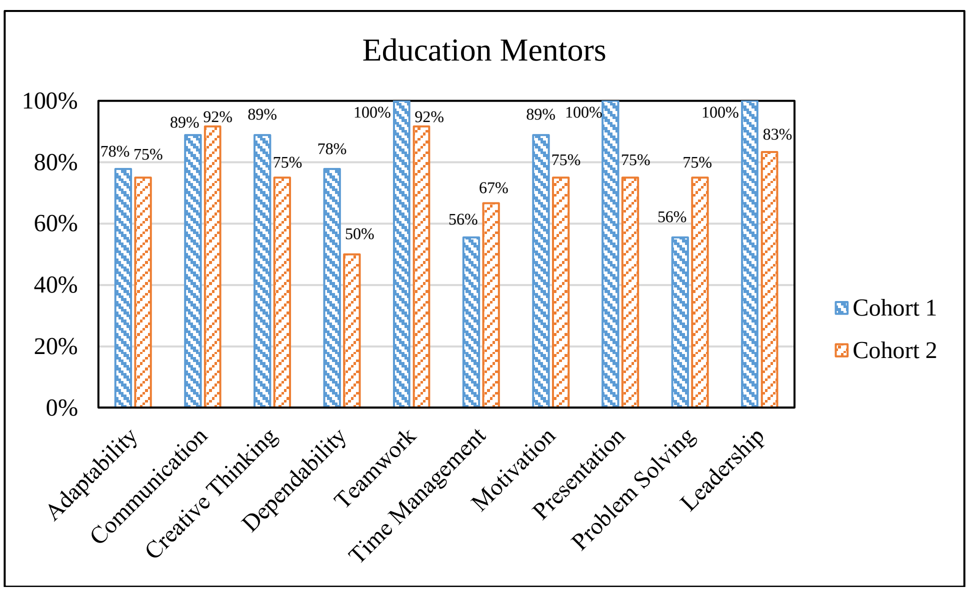

Figure 5. Scores from education mentors, comparing between the first and second cohorts.

For engineering mentors, as shown in Figure 4, the average score increased by 9.1%. Areas reporting the most growth between the two cohorts are: *Adaptability, Creative Thinking, Presentation*, and *Leadership*.

- *Creative Thinking* (+16%) and *Adaptability* (+17%): These inter-related soft skills may have been required in response to the introduction of the DTC project, which increased the variety of the club member's STEM-related interests and inquiries. Both an adaptable attitude and creative thinking are required in the increasingly versatile environment.
- *Presentation* (+16%) and *Leadership* (+16%): To provide effective support, the engineering mentors had the obligations to both prepare themselves and the education mentors to deliver technical content. Reciprocally, the education mentors prepared the engineering mentors with increased pedagogic support via their hosted workshops on topics pertaining to presentation and learning during the second implementation to better develop their presentation and classroom management skills.

For education mentors, as shown in Figure 5, the results exhibit similar patterns to the findings of our overall scores in Figure 3, except for the notable decrease in *Presentation* (-25%) and *Leadership* (-27%), which contributed to the 7.6% decrease in the overall score. We argue that by empowering the engineering mentors to increase the effectiveness of the workshop delivery while the size and scope of the program implementation increased, their direct effect on the delivery of the workshops declined. Additionally, during mentoring the DTC projects, resources were very limited for education mentors to familiarize themselves with the diverse range of engineering topics required to advise the club members on their project development. As a result, as observed, the second cohort of education mentors mainly played the supporting role to facilitate the leadership by the engineering mentors.

While the survey results in this study indicated that our collaborative mentorship model positively influences mentors' soft skills development, our small sample size was inadequate to justify statistical significance. In addition, the survey results only provided a very broad picture of the mentor's self-reported perceptions; it did not reveal the characteristics of how a cross-disciplinary collative project benefits their development of soft skills. Thus, the interview data collected at the end of each cohort will be analyzed and reported in a follow-up paper to gain a deeper insight of the mentor's experience and impact of our design model.

6. Future Work & Conclusions

Overall, all the mentors surveyed from both Cohorts 1 and 2 agreed that they had positive experiences with the robotics mentorship program which reinforced their decision to become an engineering or education major, as well as the utility of such extracurricular experiences. With the new feedback and lessons learned from our second implementation of the robotics mentorship program, only minor revision was made for our third implementation in this academic year (Fall 2022 ~ Spring 2023). For example, we found that while the education mentors impacted the activity design during the internal development meeting, the lack of technical knowledge prevented them from being as effective in the field. One engineering mentor described, "*I guess at John Jay [High School]… I felt like I was doing my own thing… They [education mentors] would have to call upon the engineers to help fix things or explain things.*" The engineering mentors acknowledged that our previous focus was on supporting engineering mentors' pedagogical approach, or "*we never prepared it for the education students, so I feel that* *we kind of failed them.*" They asked to return the favor by emphasizing aiding education mentors' technical skills during our internal meeting. Thus, one of the remediations for the third implementation is for an engineering faculty to pre-record tutorial videos and explain the technical content, such as a step-by-step procedure for the CAD design workshop, for alignment in technical skills before the workshops.

In summary, this study is aimed to examine the impact and sustainability of the interdisciplinary mentorship model and understand its influence on supporting the mentors' soft skills development. We presented a revision of our project design since the pilot study, provided evidence of growth in *Communication*, *Teamwork*, and *Leadership* skills across the two-year duration, and discussed the relationship between this development and our revision. By reinforcing the social interaction among engineering and education majors to co-design and co-present a workshop, the mentors and high schoolers engaged in a process that allowed the opportunity to thrive and develop the necessary soft skills, in ways that would be difficult in a traditional class setting. As the structure and implementation of the robotics mentorship program matures, it can be entertained to integrate the program into introductory engineering courses to offer freshmen such opportunities early in their journey toward an engineering career.

Reference

[1] Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour economics*, *19*(4), 451-464.

[2] Klaus, P. (2010). Communication breakdown. *California Job Journal, 28*, 1-9.

[3] ABET Engineering Accreditation Commission, *Criteria for Accrediting Engineering Programs, 2020 - 2021*, Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2020-2021/ [Accessed Feb. 14, 2023].

[4] Wilkie, D. (2019). Employers say students aren't learning soft skills in college. The Society for Human Resources Management. Availiable: https://www.shrm.org/resourcesandtools/hr-topics/employee-relations/pages/employers-say-students-arent-learning-soft-skills-in-college.aspx [Accessed Feb. 7, 2023].

[5] Willmot, P., & Colman, B. (2016). Interpersonal skills in engineering education.

[6] McCann, T. M., Johannessen, L., & Ritter, J. (2009). Mentoring matters: Working with student teachers. *The English Journal*, *99*(1), 114-117.

[7] Vygotsky, L. S. (1978). Socio-cultural theory. *Mind in society, 6*, 52-58.

[8] Huang, W., Wang, P.-C., & Pearl, S. (2021, November). A Pilot Interdisciplinary Robotic Mentorship Project to Study Engineering Soft Skill Development. In *2021 Fall ASEE Middle Atlantic Section Meeting*.

[9] National Council of Teachers of English (2013). Read Write Think. Oral Presentation Rubric. Available: https://www.readwritethink.org/sites/default/files/resources/printouts/30700_rubric.pdf [Accessed Feb. 7, 2023].