The Future of Engineering Education
2024 Annual Conference & Exposition
Oregon Convention Center
Portland, OR . June 23 - 26, 2024
ASEE
Paper ID #42965

Reflections of Undergraduate Engineering Students Completing a Cross-Disciplinary Robotics Project with Preservice Teachers and Fifth Graders in an Electromechanical Systems Course

Dr. Krishnanand Kaipa, Old Dominion University

Dr. Krishnanand Kaipa is an Associate Professor and director of the Collaborative Robotics and Adaptive Machines (CRAM) Laboratory in the Department of Mechanical and Aerospace Engineering at the Old Dominion University. Dr. Kaipa received his BE (Hons.)

Dr. Jennifer Jill Kidd, Old Dominion University

Dr. Jennifer Kidd is a Master Lecturer in the Department of Teaching and Learning at Old Dominion University. Her research interests include engineering education and educational technology.

Isaac Koduah Kumi, Old Dominion University

Isaac K. Kumi is a Mechanical Engineering Ph.D. student at Old Dominion University. He has a B.Sc in Biomedical Engineering and an M.E. in Mechanical Engineering. His research interests are in biomechanics and biomechanical modeling and simulation.

Dr. Stacie I Ringleb, Old Dominion University

Stacie Ringleb is a professor in the Department of Mechanical and Aerospace Engineering at Old Dominion University and a fellow of the American Society of Biomechanics. Dr. Ringleb received a B.S. in biomedical engineering from Case Western Reserve Univer

Dr. Orlando M Ayala, Old Dominion University

Dr. Ayala received his BS in Mechanical Engineering with honors (Cum Laude) from Universidad de Oriente (Venezuela) in 1995, MS in Mechanical Engineering in 2001 and Ph.D. in Mechanical Engineering in 2005, both from University of Delaware (USA). Dr. Ayala is currently serving as Associate Professor of Mechanical Engineering Technology Department, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA.

Prior to joining ODU in 2013, Dr. Ayala spent three years as a Postdoctoral Researcher at the University of Delaware where he expanded his knowledge on simulation of multiphase flows while acquiring skills in high-performance parallel computing and scientific computation. Before that, Dr. Ayala held a faculty position at Universidad de Oriente at Mechanical Engineering Department where he taught and developed graduate and undergraduate courses for a number of subjects such as Fluid Mechanics, Heat Transfer, Thermodynamics, Multiphase Flows, Fluid Mechanics and Hydraulic Machinery, as well as Mechanical Engineering Laboratory courses.

In addition, Dr. Ayala has had the opportunity to work for a number of engineering consulting companies, which have given him an important perspective and exposure to the industry. He has been directly involved in at least 20 different engineering projects related to a wide range of industries from the petroleum and natural gas industry to brewing and newspaper industries. Dr. Ayala has provided service to professional organizations such as ASME. Since 2008 he has been a member of the Committee of Spanish Translation of ASME Codes and the ASME Subcommittee on Piping and Pipelines in Spanish. Under both memberships, the following Codes have been translated: ASME B31.3, ASME B31.8S, ASME B31Q and ASME BPV Sections I.

While maintaining his industrial work active, his research activities have also been very active; Dr. Ayala has published 90 journal and peer-reviewed conference papers. His work has been presented in several international forums in Austria, the USA, Venezuela, Japan, France, Mexico, and Argentina. Dr. Ayala has an average citation per year of all his published work of 44.78.

Dr. Kristie Gutierrez, Old Dominion University

Dr. Gutierrez received her B.S. in Biology from the University of North Carolina at Chapel Hill in 2001, M.Ed. in Secondary Science Education in 2005 from the University of North Carolina at Wilmington, and Ph.D. in Science Education in 2016 from North Ca

Dr. Pilar Pazos, Old Dominion University

Pilar Pazos is a Professor in the Department of Engineering Management and Systems Engineering at Old Dominion University, Norfolk, VA, USA. Her main areas of research interest in Engineering Education include team learning, virtual teams, and team decision-making.

Mr. Francisco Cima

Francisco Cima is a PhD student of Engineering Management and Systems Engineering at Old Dominion University. He obtained his Masters in Business Planning and Regional Development from the Technological Institute of Merida. His areas of interest are innov

Danielle Marie Rhemer, Old Dominion University

Reflections of Undergraduate Engineering Students Completing a Cross-Disciplinary Robotics Project with Pre-Service Teachers and Fifth Graders in an Electromechanical Systems Course

Abstract. Engineering is becoming increasingly cross-disciplinary, requiring students to develop skills in multiple engineering disciplines (e.g., mechanical engineering students having to learn the basics of electronics, instrumentation, and coding) and interprofessional skills to integrate perspectives from people outside their field. In the workplace, engineering teams are frequently multidisciplinary, and often, people from outside of engineering are part of the team that brings a product to market. Additionally, teams are often diverse in age, race, gender, and in other areas. Teams that creatively utilize the contrasting perspectives and ideas arising from these differences can positively affect team performance and generate solutions effective for a broader range of users. These trends suggest that engineering education can benefit from having engineering students work on team projects that involve a blend of cross-disciplinary and mixed-aged collaborations. An NSF-funded project set out to explore this idea by partnering undergraduate engineering students enrolled in a 300-level electromechanical systems course with preservice teachers enrolled in a 400-level educational technology course to plan and deliver robotics lessons to fifth graders at a local school. Working in small teams, students designed, built, and coded bio-inspired robots. The collaborative activities included: (1) training with Hummingbird Bit hardware (Birdbrain Technologies, Pittsburgh, PA) (e.g. sensors, servo motors) and coding platform, (2) preparing robotics lessons for fifth graders that explained the engineering design process, and (3) guiding the fifth graders in the design of their robots. Additionally, each engineering student designed a robot following the theme developed with their education student and fifth-grade partners.

This paper reports on the reflections of the engineering students after completing a cross-disciplinary robotics project with preservice teachers and fifth graders with the goals of (1) assessing the suitability of the project to the specific course, (2) analyzing the nature of the balance between course and project workload/objectives, (3) benefits and challenges of participating in the project, and (4) evaluating the overall effectiveness of the intervention. Student reflections collected at the conclusion of the semester from implementations in Spring 2022 and Spring 2023 were analyzed for this study. Findings from a thematic qualitative analysis of the reflections revealed benefits such as students' perceived gains in coding skills, reinforcement of engineering concepts learned in class, acquisition of interprofessional skills (e.g., communication with technical and non-technical audiences, cross-disciplinary collaboration), and engineering-pedagogical skills such as lesson planning and classroom management. Students also reflected on opportunities to incorporate creative design insights when brainstorming with non-engineers. Students' perceived challenges were mainly related to workload, time management, course organization, and teaching/interacting with the fifth graders.

These findings provide insightful suggestions for future interventions in undergraduate engineering courses.

Introduction

Recent trends in engineering suggest a need to train engineering students in cross-disciplinary skills (e.g., mechanical engineering students having to learn the basics of electronics, instrumentation, and coding) and interprofessional skills to integrate perspectives from people outside their field to solve societal problems of the modern world (Carrico et al. 2020; Shuman et al. 2005; Nagel et al. 2017; Ricther & Paretti 2009; Almeida 2019). Students' inability to connect an interdisciplinary subject to their own field and their failure to value contributions of multiple technical and non-technical fields to an interdisciplinary problem have been identified as the key learning barriers to interdisciplinarity in engineering classrooms (Ricther & Paretti 2009). In the workplace, engineering teams are frequently interdisciplinary (e.g., structural engineer collaborating with a geotechnical engineer) and/or multidisciplinary, and often, people from outside of engineering (e.g., structural engineer working with an economist) are part of the team that brings a product to market (Tomek 2011). Additionally, teams are often diverse in age, race, gender, and in other areas. In particular, the issue of generational differences as they apply to teams is becoming a common phenomenon in many industries ranging from healthcare to education, engineering, corporate, and academia (Kearney & Gerbert, 2009; Burton 2019; Almeida 2021). Teams that creatively utilize the contrasting perspectives and ideas arising from these differences can positively affect team performance and generate solutions effective for a broader range of users (Tomek 2011). For example, in a study investigating mixed-aged collaborations, it was found that younger teachers valued the high level of knowledge possessed by more experienced teachers, while older teachers valued the creative and innovative methods used by younger teaching professionals (Geeraerts et al. 2016). In a recent documentary study carried out by Diana Leon (2020), it was shown that mixed-aged teams are a viable solution for encouraging intergenerational learning. These trends suggest that engineering education can benefit from having engineering students work in team projects that involve a blend of multidisciplinary and mixed-aged collaborations.

This paper describes engineering students' experiences in an NSF-funded project that partnered undergraduate engineering students with pre-service teachers to plan and deliver robotics lessons to fifth graders at a local school. Working in small teams, students designed, built, and coded bio-inspired companion robots. The goal for the engineering students was to build new interprofessional skills, while reinforcing technical skills. The paper reports on the reflections of the engineering students after completing the cross-disciplinary robotics project with preservice teachers and fifth graders with the goals of (1) assessing the suitability of the project to the specific course, (2) analyzing the nature of the balance between course and project workload/objectives, (3) benefits and challenges of participating in the project, and (4) evaluating the overall effectiveness of the intervention.

Earlier work of the project investigators focused on evaluation of both engineering students and pre-service teachers. Previous results focusing on pre-service teachers participating in this project and results evidencing meaningful learning and engagement of the fifth grade students have been reported in other recent works by the same authors (Kidd et al. 2020, Kidd et al. 2020a). However, the work presented in this paper is confined to the evaluation of results pertaining to engineering students.

Prior studies have shown benefits from partnering engineering students with preservice teachers. In the *Paired Peer Mentors* project (Fogg-Rogers, Lewis, & Edmonds, 2017), pairs of preservice teachers and engineering students presented engineering design challenges to primary school children. Both groups of college students showed sizable gains in teaching engineering self-efficacy and subject knowledge confidence after the project. Working with their cross-disciplinary partner was rated as one of the most rewarding aspects of the project and the engineering students reported learning from the organization and communication skills of the teachers. In a study exploring a similar partnership model, preservice teachers and engineering students collaboratively planned robotics activities for early childhood students using LEGO WeDo robots (Bers & Portsmore, 2005). The engineering students helped the preservice teachers use robotics to explore concepts in math and science. The engineering students indicated how much they liked engaging in an authentic design process where they truly were the experts. Although these studies have begun to explore the potential of partnering preservice teachers with engineering students, there is much to learn about the benefits of this approach and its impact on engineering students' engineering and interprofessional skills. The aspect of mixed-aged collaborative activities where engineering students and fifth graders collectively brainstorm and build companion robots bears some similarity to recent works in social robotics where children are treated as robot designers (Alves-Oliveira et al. 2021). Honoring human-centered design practices, this approach lets children participate in the robot's design process by incorporating their views about its appearance, physical attributes, and emotional characteristics, thereby increasing the usability and value of the robot (Woods et al. 2004, Obaid et al. 2018).

Methods

Participants & Context

Undergraduate engineering students enrolled in a 300-level electromechanical systems course were partnered with preservice teachers (undergraduate students aspiring to become teachers) enrolled in a 400-level educational technology to plan, prepare, and deliver robotics lessons to fifth graders at a local school. The meeting times for the two courses were scheduled to overlap for 75 minutes a week, allowing the engineering and education students to work collaboratively during multiple class sessions. Each team comprised one or two engineering student(s), one preservice teacher, and one or two fifth grader(s). The teams engaged in the following collaborative activities over the course of the semester:

- *Training phase.* The first two collaborative sessions involved engineering students and preservice teachers meeting in a classroom on campus and partnering in teams to:
    - train with the Hummingbird Bit™ hardware (e.g. sensors, servo motors) and coding platform
    - prepare robotics lessons for fifth graders that explained and incorporated the engineering design process
- *Teaching phase.* The final three collaborative sessions took place in an after-school technology club for fifth graders at a local elementary school (Figure 1). The club activities included:
    - introducing fifth graders to bio-inspired robots used to address global challenges and working with Hummingbird™ robotics kits
    - collective brainstorming with fifth graders on ideas for COVID companion robots
    - guiding the fifth graders in the design, building, and testing of their robots
    - each engineering student designed a robot following the theme developed with their education student and fifth-grade partners

Students were provided with design instructions to create the robot by borrowing inspiration from an animal and using light, movement, and sound to interact with a human in multiple ways. Teams were encouraged to choose the animal inspiration and their robot's functions based on the interests of the fifth graders. Each team member was expected to build their own robot based on their team's chosen theme. To facilitate this, the Hummingbird™ robotics kits were distributed to each fifth grader, preservice teacher, and engineering student in all teams. These kits are very student- and teacher- friendly, and come with abundant online resources on its hardware and sample projects. They are simple enough for fifth graders to manipulate, utilize web-based block coding that is relatively easy for beginners to master, and include a variety of components enabling users to scale up complexity as desired. The fifth graders could not afford to remain passive during the robot building activities, owing to the requirement for each participant to build their own robot. Instead, the fifth graders actively engaged in building and coding their robots, while seeking guidance from the education and engineering students when they needed it. Teams developed diverse robot designs ranging from squid-inspired robots to panda-inspired, and dragonbird-inspired robots (Figure 1).

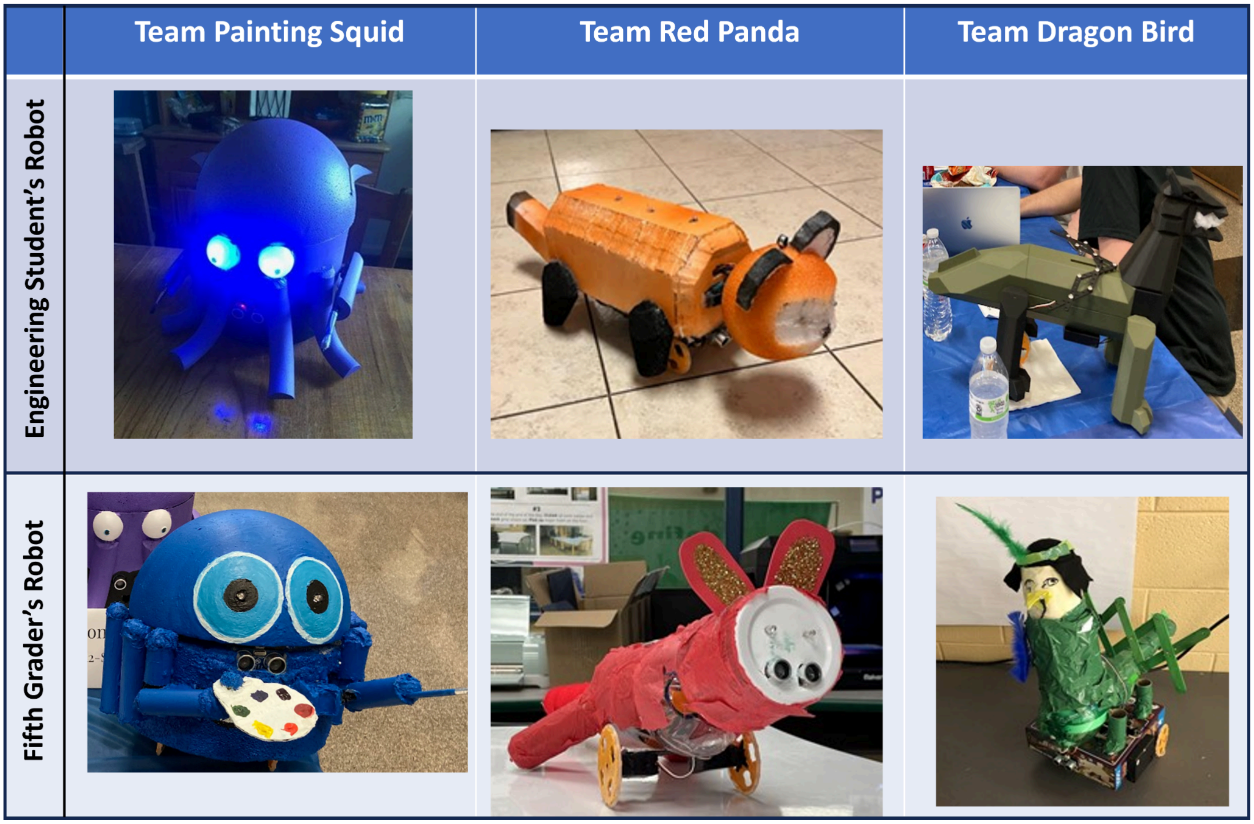

Figure 1: Samples of bio-inspired companion robots built by engineering students and their fifth grade partners during the collaborative activities at the after-school technology club

Measures

Student reflections collected at the conclusion of the semester from implementations in Spring 2022 and Spring 2023 were analyzed for this study. Data from a total of 36 engineering students (16 from Spring 2022 and 20 from Spring 2023) were used in this study. Open-ended prompts directed students to describe what they were teaching, the roles they played during the lesson, what they learned from their education partner, how collective brainstorming with fifth graders affected the design process of their own robot, what they felt most/least confident about, their impressions of the success of their lessons, their interactions with preservice teachers and fifth graders, and what they learned from the experience. A list of reflection questions that are relevant for this study context is shown in Table 1.

Table 1. Reflection questionnaire answered by students at the conclusion of the semester

Reflection Questions
1. What did you learn from your education partner?
2. To what extent did you benefit from working with them?
3. Were you satisfied with your partnership experience overall? Please explain your answer.
4. If you were to work on a multi-disciplinary partnership like this again, what would you do to ensure a successful collaboration? Or, what would you suggest the instructors should do to help ensure success?
5. What surprised you about working with your 5th grade partner(s)?
6. What challenges did you and your partners face in translating the team's ideas into a working robot? How did you solve them? What did you learn from these experiences?
7. How did designing, building, and coding the robots with the children affect the design process for your own robot?
8. How did designing, building, and coding your robot alongside your education and 5th grader partners affect your learning overall?
9. What did you learn about communicating with people outside the field of engineering?
10. How effective do you think you were in guiding your students through the engineering design process? Were your lesson activities effective in accomplishing the goal of each stage? For example, did your brainstorming strategy result in many different ideas? As you tested out various parts of the robot, did you help the children think through redesign ideas? Were you able to help your students think about how to communicate about their robots via their Shark Tank pitch?
11. How did participating in this project affect your understanding of coding and engineering?
12. What aspects of the lesson/project did you feel most confident about?
13. What aspects of the lesson/project did you feel least confident about?
14. What factors affected your motivation for this project over the course of the semester? For example, did your instructor impact your motivation, the topic itself, your relationship with your teammates, your interactions with the kids, the feedback you received, outside demands etc. Please consider factors that positively affected your motivation as well as factors that negatively affected it and consider how your motivation may have changed over time.
15. How valuable was building your own robot based on the 5th graders' ideas?
16. How valuable was working with the education students and the 5th graders to build the robots together?
17. How valuable was this project overall? Do you have any suggestions for improving the project in the future? If so, please share your thoughts.
18. If you had to sum up your experience with this project in a single word, what word would that be?

Results

Qualitative analysis of the engineering students' reflection data revealed the benefits and challenges of the cross-disciplinary robotics project involving preservice teachers and fifth graders for undergraduate engineering students (Table 2). Results show that engineering students expressed benefits in gaining engineering, robotics, and coding skills, reinforcement of engineering concepts, and acquiring interprofessional and engineering-pedagogical skills. Challenges perceived by engineering students in the project included workload, time management, organization of the course, and teaching/interacting with the fifth graders.

In terms of perceived gains, 21 instances (corresponding to reflections of 21 out of 36 students) were recorded for engineering students having a better understanding of coding, robotics, and engineering, and 22 instances were recorded for students becoming more confident in their coding and robot-building skills. Tables 3 - 7 show sample quotes from engineering students highlighting their perceived gains from the cross-disciplinary project. For the acquisition of interprofessional skills, most engineering students (31 instances) agreed that communication with non-engineers is different and often requires clarity and conciseness.

Engineering students also mentioned that they learned how to communicate with nontechnical audiences and teach/relay information to kids. In other aspects, engineering students expressed gains in their ability to plan lessons and manage a classroom. These benefits are a result of their association with the preservice teachers. Although engineering students may have yet to use these pedagogical skills, they saw these skills as benefits that may come handy in their future careers. Table 6 provides quotes from engineering students in support of these views.

Undergraduate engineering students also expressed that they benefited from working with the non-engineers, especially with the fifth graders. Engineering students benefited from having to brainstorm with these non-engineers and having the opportunity to incorporate their creative and innovative ideas into their designs (Table 7).

On the other hand, engineering students expressed that the workload of the course and other classes became a challenge in putting in their best efforts. Other challenges included the time constraints for the project and the need for proper organization of the course. Students felt the professors could better communicate expectations and plan the course. Finally, although engineering students mentioned gains in communication with non-engineers and classroom management, they still mentioned that they felt least confident working and interacting with the fifth graders (10 instances). Table 8 provides sample quotes from students relating to their challenges encountered during the project.

Table 2. Results of qualitative thematic analysis showing number of instances and percentage occurrence of themes under categories of benefits and challenges

Category	Themes		Frequency of Occurrence	
			No. of Instances (out of 36)	%
Benefits	Perceived gains in engineering, robotics, and coding skills	Better understanding of coding, robotics and engineering	21	58%
		More confident in coding and building robot	22	61%
	Reinforcement of engineering concepts		2	6%
	Acquisition of interprofessional skills	Communication with non-engineers (agree that communication with non engineers is different and require clear and concise information)	31	86%
		Learnt communication skills from education students	20	56%
	Engineering-pedagogical skills such as lesson planning and classroom management	Lesson planning	3	8%
		Classroom management	14	39%
	Opportunities to incorporate creative design insights when brainstorming with non-engineers		4	11%
Challenges	Workload		1	3%
	Time management		10	28%
	Course organization		8	22%
	Teaching/interacting with the fifth graders		10	28%

Table 3. Sample quotes from participating students on perceived gains in content skills

Perceived Gains in Engineering, Robotics, and Coding Skills	
Better understanding of coding, robotics and engineering	*This project helped me understand the practical side of coding and engineering; we often only think about the numbers or technical things.* *I think it required a greater level [of] understanding to teach coding than it would have if we were just doing it ourselves.* *You had to understand the process of coding really well because it wasn't just you that needed to understand what you were doing but you then needed to teach it to someone who needed to understand it as well.* *This project allowed me to expand my knowledge of coding and engineering by letting me apply my knowledge to a physical application instead of just theoretical*
More confident in coding and building robot	*I felt most confident in the coding portion of the project* *I was confident in my ability to build whatever robots I had to build* *I felt most confident about the actions we covered in class/with our pseudo-code*

Table 4. Sample quotes from participating students on reinforcement of concepts

Reinforcement of Engineering Concepts
It made me actually reevaluate my understanding of engineering. Teaching people outside of the field of engineering made me review and relearn engineering concepts. *Gaining a new perspective, as well as reinforcing my own understanding of certain base subjects*

Table 5. Sample quotes from participating students on acquisition of interprofessional skills

Acquisition of Interprofessional Skills	
Communication with non-engineers	*I learned that there is a lot more engineering lingo than I realized.* *I learned that it is important to be clear and to have an understanding of what they know. You don't want to talk down to them but you need to communicate in a way they understand.* *I learned how to speak in simple terms and how to attempt to describe complex ideas/terms in a vocabulary that somebody outside of my major would understand.*
Learnt communication skills from education students	*I learned how to break down complicated concepts into a more simplified version for people who are unfamiliar with them.* *I think I gained a lot of interpersonal communication skills by working with the education students.*

Table 6. Sample quotes from participating students on engineering pedagogical skills

Engineering-Pedagogical Skills	
Lesson planning	*Sage helped walk us through the lesson planning process.* *Lesson planning, how to work with kids, how to break down difficult concepts, and how to ENGAGE students.*
Classroom management	*She was really good at handling the kids in all aspects, like when they would get off-topic. And it made it easier to apply what I watched her do.* *Learned a lot of different things about teaching, working/talking with kids, the like. Was great to work with her, without her those 5th graders would have eaten me alive.* *The importance of organization and prompt communication. She also set a good example for dealing with the kids.*

Table 7. Sample quotes from participating students on brainstorming with non-engineers

Opportunities to Incorporate Creative Design Insights when Brainstorming with Non-Engineers
They are very interested to hear what you have to say. They are also very helpful and sometimes give an out of the box opinion on things. *Coding with the kids requirements was interesting as it brought some creative requirements to making the code work given their vision* *Allowing the 5th graders to decide the robot ideas allowed more creativity and excitement to begin the projects.*

Table 8. Sample quotes from participating students on perceived challenges

Workload
One thing that was a negative motivation for me was the workload in other classes as well as taking on a full time job. It is hard to get things to work perfectly with the workload I felt I had.
Time Management
The biggest stressor was the time constraint, along with all of the assignments that came with the lecture portion of the class and assignments/exams from other classes. *I feel least confident about the quality of the final product just because we did not have as much time as I would've liked to provide with the kids.*
Course Organization
Overall, better planning, better communication from professor to student, and a better plan would be to have engineers educate education students and then have the education students teach the children to hold the accountability of what's being taught and interpreted in class with this portion being held as a lab outside of the lecture. *The instructors need to be more COMMUNICATIVE in regards to assignments and expectations.* *My education partner was very helpful in keeping us on track on what we're supposed to do. My professor was very supportive and accommodating. Although, it would have been nice if the course was more structured and organized.*

Teaching/interacting with the Fifth Graders
[Least confident about] *Coding and my ability to teach it to 5th graders* [Least confident about] *Interacting and engaging 5th graders without their eyes glossing over in boredom.* [Least confident about] *Talking to 5th graders. I have no clue how much they know or what my expectations of them should've been.*

Discussion and Conclusions

This study reported on the reflections of undergraduate engineering students participating in an NSF-funded robotics project, involving a blend of cross-disciplinary collaborations with preservice teachers and mixed-aged collaborations with fifth graders. Participants composed of engineering students from an electromechanical systems course collaborating with preservice teachers from an educational technology course, and fifth graders from a local elementary school. Themes that were identified as a result of the qualitative analysis of reflections of the students shed light on their perceived benefits and challenges of participating in the project. The high percentages of students emphasizing the importance of communication with non-engineers (86 %) and reporting their learning of communication skills from education students (56%) were clear indicators of interprofessional skill acquisition as one of the primary benefits of the collaborative project. Another significant value of the project was evidenced in students' perceived gains in technical content skills in terms of a deeper understanding of engineering and robotics concepts (58%) and increased levels of confidence in hands-on skills involving building/programming of robots (61%). The intervention also helped engineering students gain engineering pedagogical skills which could help them engage in outreach in their future professional roles or enhance their ability to mentor younger colleagues in future team projects. The students were also able to explore opportunities of collaborative design thinking with non-engineers which could prepare them for human-centered design practices, such as social robotics where children participate in designing robots (Alves-Oliveira et al. 2021). The project may have helped the engineers learn to value contributions from non-technical stakeholders, demonstrating a model for removing barriers to interdisciplinarity in engineering education (Ricther & Paretti 2009). A good alignment of these perceived benefits with the expected course outcomes led the project investigators to the conclusion of a positive assessment of the suitability of the project to the specific engineering course chosen for the intervention. The challenges voiced out by students (workload, time management, organization of the course, and teaching/interacting with the fifth graders) provide useful insights into analyzing and adapting the balance between course and project workload/objectives and restructuring of the collaboration activities. In summary, the study findings point to the overall effectiveness of the intervention and offer insightful suggestions for future interventions in undergraduate engineering courses. By addressing the challenges identified in the study, educators can successfully implement cross-disciplinary projects in their classrooms and provide valuable learning experiences to their students.

Acknowledgement

This material is based upon work supported by the National Science Foundation under Grants #1821658 and #1908743. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

References

L. M. S. Almeida, K. Becker, and I. Villanueva, "Understanding Industry's Expectations of Engineering Communication Skills," in *Proceedings of the American Society for Engineering Education Annual Conference,* Tampa, FL, 2019.

L. M. S. Almeida, K. H. Becker, and I. Villanueva, "Engineering communication in industry and cross-generational challenges: an exploratory study", *European Journal of Engineering Education*, 46:3, 389-401, 2021.

P. Alves-Oliveira, P. Arriaga, A. Paiva, and G. Hoffman, "Children as robot designers," In *Proceedings of the 2021 ACM/IEEE International Conference on Human-Robot Interaction*, pp. 399-408. 2021.

M. U. Bers and M. Portsmore, "Teaching partnerships: Early childhood and engineering students teaching math and science through robotics," *Journal of Science Education and Technology*, 14(1), 59–73, 2005.

C. M. Burton, C. Mayhall, J. Cross, P. Patterson, "Critical elements for multigenerational teams: a systematic review," *Team Performance Management*, vol. 25 No. 7/8, pp. 369-401, 2019.

J. D. Carrico, J. Anjum, and A. Anjum, "An interdisciplinary project-based service learning and action research project with mechanical engineering and speech-language pathology students," in *Proceedings of ASEE Virtual Annual Conference, June 22, 2020 - June 26, 2020.*

L. Fogg-Rogers, F. Lewis, and J. Edmonds, "Paired peer learning through engineering education outreach," *European Journal of Engineering Education*, 47(1), 75–90, 2017.

K. Geeraerts, J. Vanhoof, and P. Van den Bossche, "Teachers' perceptions of intergenerational knowledge flows," *Teaching and Teacher Education*, vol. 56, pp. 150-161, 2016.

E. Kearney and D. Gerbert, "Managing diversity and enhancing team outcomes: the promise of transformational leadership," *Journal of Applied Psychology*, vol. 94 No. 1, pp. 77-89, 2009.

J. Kidd, K. Kaipa, K. Gutierrez, P. Pazos, O. Ayala, and S. Ringleb, "Zooming In" on robotics during COVID-19: A preservice teacher, an engineering student, and a 5th grader engineer robotic flowers via Zoom. In E. Langran (Ed.), *Proceedings of SITE Interactive Online Conference*, pp. 503-512, 2020.

J. Kidd, K. Kaipa, S. Sacks, S. Ringleb, P. Pazos, K. Gutierrez, O. Ayala, and L. M. S. Almeida, "What do undergraduate engineering students and pre-service teachers learn by collaborating and teaching engineering and coding through robotics?" E. Langran (Ed.), *Proceedings of the ASEE Virtual Annual Conference*, June, 2020.

R. D. Leon, "Intergenerational learning - a topic of discussion or a reality? Taking a closer look at the academics." *Management Dynamics in the Knowledge Economy*. 8(2), pp. 111-123, 2020.

J. K. Nagel, P. M. Ludwig, and E. J. Lewis, "Community health innovation through an interprofessional course," in *Proceedings of ASEE Annual Conference & Exposition*, Columbus, Ohio, June 2017.

M. Obaid, G. E, Baykal, A. E. Yantaç, *et al.*, "Developing a prototyping method for involving children in the design of classroom robots. *International Journal of Social Robotics,* 10, 279–291, 2018.

D. M. Richter and M. C. Paretti, "Identifying barriers to and outcomes of interdisciplinarity in the engineering classroom," *European Journal of Engineering Education*, vol. 34, no.1, pp. 29-45, 2009.

L. J. Shuman, M. Besterfield-Sacre, and J. McGourty, "The abet "professional skills"—can they be taught? Can they be assessed?" *Journal of Engineering Education*, vol. 94, no. 1, pp. 41–55, 2005.

S. Tomek, "Developing a multicultural, cross-generational, and multidisciplinary team: An introduction for civil engineers," *Leadership and Management in Engineering*, vol. 11, no. 2, pp. 191-196, 2011.

S. Woods, K. Dautenhahn and J. Schulz, "The design space of robots: investigating children's views," in Proceedings of *IEEE International Workshop on Robot and Human Interactive Communication (IEEE Catalog No.04TH8759)*, pp. 47-52, 2004.