2022

# Can We Make Our Robot Play Soccer? Influence of Collaborating with Preservice Teachers and Fifth Graders on Undergraduate Engineering Students' Learning During a Robotic Design Process (Work in Progress)

Krishnanand Kaipa
*Old Dominion University*

Jennifer Kidd
*Old Dominion University*

Julia Noginova
*Old Dominion University*

Francisco Cima
*Old Dominion University*

Stacie Ringleb
*Old Dominion University*

*See next page for additional authors*



Original Publication Citation
Kaipa, K., Kidd, J., Noginova, J., Cima, F., Ringleb, S., Ayala, O., Pazos, P., Gutierrez, K., & Lee, M. J. (2022). *Can we make our robot play soccer? Influence of collaborating with preservice teachers and fifth graders on undergraduate engineering students' learning during a robotic design process (work in progress).* Paper presented at 2022 ASEE Annual Conference & Exposition, Minneapolis, Minnesota. https://peer.asee.org/41343

## Authors

Krishnanand Kaipa, Jennifer Kidd, Julia Noginova, Francisco Cima, Stacie Ringleb, Orlando Ayala, Pilar Pazos, Kristie Gutierrez, and Min Jung Lee

ASEE 2022 ANNUAL CONFERENCE
Excellence Through Diversity
MINNEAPOLIS, MINNESOTA, JUNE 26TH-29TH, 2022 ASEE

Paper ID #37525

# Can We Make Our Robot Play Soccer? Influence of Collaborating with Preservice Teachers and Fifth Graders on Undergraduate Engineering Students' Learning during a Robotic Design Process (Work in Progress)


## Krishnanand Kaipa (Assistant Professor)

To be filled

## Jennifer Jill Kidd (Dr.) (Old Dominion University)

Master Lecturer at Old Dominion University

## Julia Noginova

## Francisco Cima

## Stacie I Ringleb (Professor)

Stacie Ringleb is a professor in the department of Mechanical and Aerospace Engineering at Old Dominion University.

## Orlando M Ayala (Associate Professor)

Dr. Ayala received his BS in Mechanical Engineering with honors (Cum Laude) from Universidad de Oriente (Venezuela) in 1995, MS in 2001 and PhD in 2005, both from University of Delaware (USA). Dr. Ayala is currently serving as Associate Professor in the Engineering Technology Department at Old Dominion University. Prior to joining ODU in 2013, Dr. Ayala spent 3 years as a Postdoc 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 where he taught and developed courses for a number of subjects such as Fluid Mechanics, Heat Transfer, Thermodynamics, Multiphase Flows, Hydraulic Machinery, as well as different Laboratory courses. Additionally, 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. 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. Dr. Ayala has published over one hundred 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 42.80.

## Pilar Pazos (Associate Professor)

## Kristie Gutierrez (Assistant Professor of Science Education)

## Min Jung Lee

Min Jung Lee is a postdoctoral fellow at Old Dominion University. She received her B.S. in chemistry in South Korea and M.S. and Ph.D. in Science Education from Teachers College, Columbia University. Her research interests include formal and informal STEM education and teacher education, specific to their knowledge, belief, and self-efficacy.

# Can We Make Our Robot Play Soccer? Influence of Collaborating with Preservice Teachers and Fifth Graders on Undergraduate Engineering Students' Learning during a Robotic Design Process

K. Kaipa, J. Kidd, J. Noginova, F. Cima, S. Ringleb, O. Ayala, P. Pazos, K. Gutierrez, and M. J. Lee

## Abstract.

This work-in-progress 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. This project aims to address an apparent gap between what is taught in academia and industry's expectations of engineers to integrate perspectives from outside their field to solve modern societal problems requiring a multidisciplinary approach. Working in small teams over Zoom, participating engineering, education, and fifth grade students designed, built, and coded bio-inspired COVID companion robots. The goal for the engineering students was to build new interprofessional skills, while reinforcing technical skills. The collaborative activities included: (1) training with Hummingbird Bit™ hardware (e.g. sensors, servo motors) and coding platform, (2) preparing robotics lessons for fifth graders that explained the engineering design process (EDP), and (3) guiding the fifth graders in the design of their robots. Additionally, each undergraduate engineering student designed a robot following the theme developed with their preservice teacher and fifth grade partners. The intervention took place in Spring 2021 amidst the COVID-19 pandemic, necessitating the investigators to make critical decisions to address challenges of implementing the intervention in an online setting. This paper describes those decisions as it investigates how the cross-disciplinary, mixed-aged collaboration with preservice teachers and fifth graders impacted undergraduate engineering students' learning and investment during the design process of their robots. Preliminary results of a regression analysis revealed a relationship between the engineering students' robot rankings and post-scores on the design process knowledge survey ($r = 0.92$). Consistencies and a few anomalies in this pattern were explained using qualitative reflections which were analyzed to determine students' level of investment in the project, overall perceptions, and the extent to which they focused on the fifth graders' ideas in their designs. In general, robot quality was linked to both undergraduate engineering students' level of investment and whether they focused on the fifth graders' ideas in their designs. Engineering students' overall perceptions of the project were generally positive, appreciating the role of cross-disciplinary and mixed-aged collaborations in their learning to brainstorm innovative solutions and interact effectively with professionals outside of engineering as they embark on tackling societal problems in the real world.

### Introduction

Emerging trends in engineering suggest a need to train engineering students in interprofessional skills that allow them to appreciate, understand, and integrate perspectives from outside their field to solve modern societal problems requiring a multidisciplinary approach (Carrico et al. 2020; Shuman et al. 2005; Nagel et al. 2017; Ricther & Paretti 2009; Almeida 2019). Students lacking such an ability to relate an interdisciplinary subject to their own field of expertise and failing 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). Whereas engineering teams can be interdisciplinary (e.g., structural engineer collaborating with a geotechnical engineer) or multidisciplinary (e.g., structural engineer working with an economist) (Tomek 2011), diversity can also arise due to variation in ages in the team setting, which has also significantly increased in recent years (Kearney & Gerbert, 2009). 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 (Burton 2019; Almeida 2021). Contrasting ideas/views owing to age differences can hinder progress, but when used creatively, these differences can positively affect team performance (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 work-in-progress 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 over Zoom, students designed, built, and coded bio-inspired COVID companion robots. The goal for the engineering students was to build new interprofessional skills, while reinforcing technical skills.

The overall project focused on evaluation of both engineering students and pre-service teachers. Owing to the nationwide calls to integrate engineering and coding into PreK-6 education, schools need teachers who have not only the knowledge and skills to integrate these topics into mainstream subjects, but also the intention to do so. However, research suggests that preservice teachers do not feel academically prepared and confident enough to teach engineering-related topics. To address some of these challenges, the investigators of this project are exploring how education students' interactions with their engineering student and fifth grade partners influenced their teaching self-efficacy for engineering and coding and their intention to integrate these subjects into their teaching. 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). The work presented in this paper is confined to the research question and evaluation 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).

The intervention took place in Spring 2021 amidst the COVID-19 pandemic, necessitating the investigators to make critical decisions to address challenges of implementing the intervention in an online setting. Each engineering student designed a robot following the theme developed with their preservice teacher and fifth grader partners. The conceptual designs and final robots produced by the engineering students were influenced by their cross-disciplinary interactions (e.g., brainstorming with preservice teachers and fifth graders, motivation derived from the level of fifth graders' engagement, etc.) as well as logistical and structural elements (e.g., working remotely required every member in the team to build an individual robot, use of an educational robotics kit, complexity scaling, etc). This study aims to study the following research question:

> *How did the cross-disciplinary, mixed-aged collaboration with preservice teachers and fifth graders impact undergraduate engineering students' robot quality, interprofessional skills, and project investment during the design process of their robots?*

## Methods

### Participants & Context

Twenty-two undergraduate engineering students enrolled in a 300-level electromechanical systems course and sixteen preservice teachers (undergraduate students studying to become teachers) enrolled in a 400-level educational technology course partnered to plan and deliver robotics lessons to fifth graders at a local school. The meeting times for the two courses overlapped for 75 minutes a week, enabling the engineering and education students to work collaboratively during several 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 five collaborative activities over the course of the semester. The first two collaborative sessions involved engineering students and preservice teachers partnering over Zoom to (1) train with the Hummingbird Bit™ hardware (e.g. sensors, servo motors) and coding platform, and (2) prepare robotics lessons for fifth graders that explained and utilized the engineering design process. The final three collaborative sessions took place over Zoom during an after-school technology club for fifth graders (Figure 1). The club activities included (1) introducing fifth graders to bio-inspired robots used to address global challenges and working with Hummingbird™ robotics kits, (2) collective brainstorming with fifth graders on ideas for COVID companion robots, and (3) guiding the fifth graders in the design, building, and testing of their robots. The design instructions were to have the robot take inspiration from an animal and use light, movement, and sound to interact with a human in multiple ways. Teams were encouraged to select the animal inspiration and functions of their robot based on the fifth graders' interests. 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 aspects of physical separation between team members due to Zoom-based interactions and 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 over Zoom when they needed it. Teams developed diverse robot designs ranging from parrot-inspired robots to rabbit-inspired, and cat-inspired robots (Figure 2).

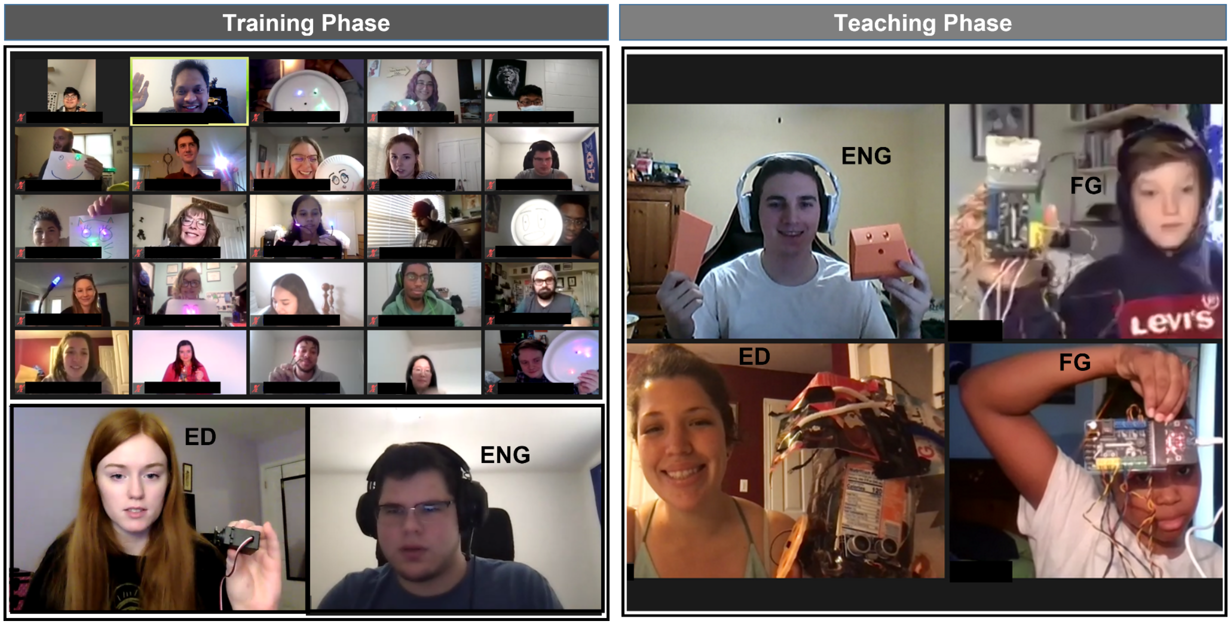



*Figure 1: Collaboration between engineering students, education students, and fifth graders in Spring 2021. Each Zoom session started out with an introductory session where the instructors briefed about the activities and later students split into their individual team breakout rooms to conduct their activities.*

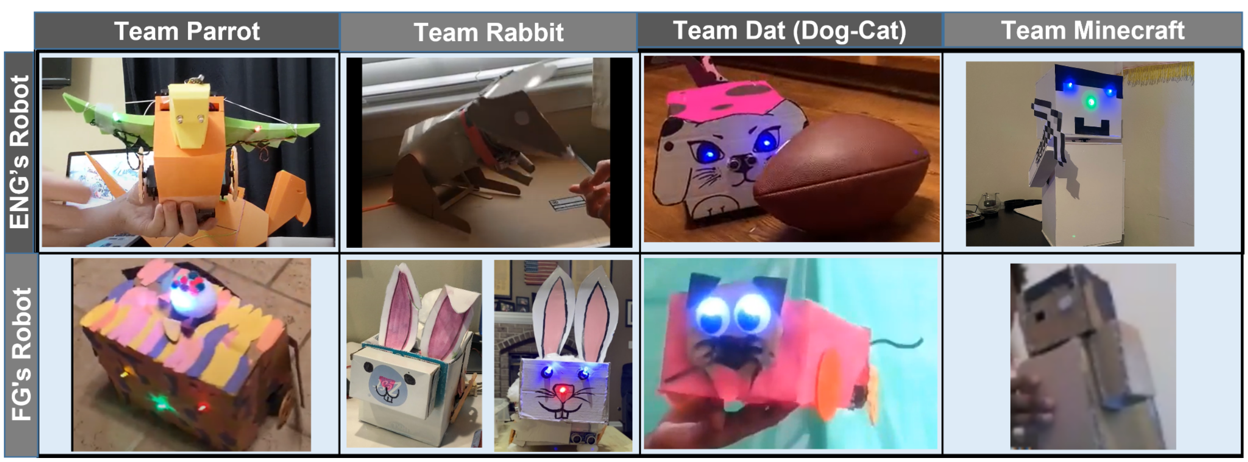



*Figure 2: Samples of bio-inspired COVID companion robots built by engineering (ENG) students and their fifth grade (FG) partners during the Spring 2021 semester.*

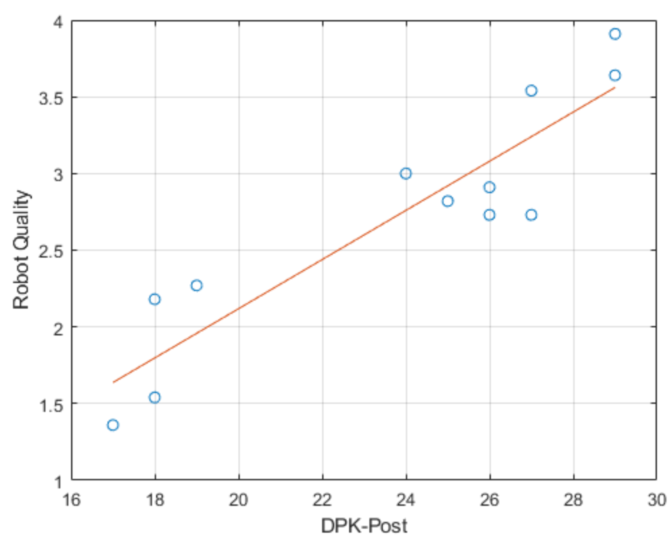
**Measures**

Three sources of data were used to address the research question. First, a robot evaluation rubric was developed to rank the quality of robot prototypes produced by engineering students. The rubric used the following metrics: 1) prototyping effectiveness of a brainstormed idea (e.g., a soccer playing robot executing an intended task of sensing and hitting a ball effectively), 2) robot complexity in terms of factors like mechanical structure (e.g., body frame, transmission mechanisms), devices used (e.g., number of sensors, motors, etc), robot features (e.g., body part movements, mobility, and ability to physically interact with environment), 3) coding complexity, and 4) sensing-actuation coupling effectiveness (e.g., how well the rotation motors used for mobility responded to a trigger from a distance sensor?). As an example, a robot that was built using a rugged mechanical structure, demonstrated features of mobility, responded to external sensing stimuli and executed an intended task effectively scored very high on the rubric. In contrast, a robot that had a simple boxy appearance, was immobile, could not sense, and had only one body part moving scored very low on the rubric.

A quantitative survey evaluating the engineering students' understanding of design process knowledge was used to study the relationship between the quality of robots produced and the engineering design concepts they learned during the course of the collaborative team project. Written reflections were collected from the engineering students at the end of the project to add a qualitative perspective to the study. Open-ended prompts directed students to describe what they were teaching, the roles they played during the lesson, 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.

**Results**

Preliminary results of a regression analysis revealed a relationship between the engineering students' robot rankings and post-scores on the design process knowledge survey ($r$ = 0.92). Consistencies and a few anomalies in this pattern were explained using qualitative reflections which were analyzed to determine students' level of investment in the project, overall perceptions, and the extent to which they focused on the fifth graders' ideas in their designs. In general, robot quality was linked to both engineering students' level of investment and whether they focused on the fifth graders' ideas in their designs. For example, in response to a reflection



question, "*How did brainstorming, designing, and building your robot alongside your education and 5th grader partners affect your design process?*" students who built good quality robots answered:

*(1) This process is what drove our project. Our 5th grade student basically laid out desirable traits that they wanted. These traits narrowed down our animal selection, then everyone came up with ideas from the traits.*
*(2) The fifth grader's ideas were the foundation of the project. I provided insight on our limitations and some alternatives.*
*(3) I think we all wanted to go off of what the 5th graders ideas were so we made a PowerPoint of some examples of bioinspired robots so they could come up with some ideas but it was ultimately their idea to make a cat dragon*

Engineering students' overall perceptions were generally positive, appreciating the role of cross-disciplinary and mixed-aged collaborations. Responding to a reflection question, "*What did you learn from your education partner*?" students answered:

*(1) I have learned that getting other views from other degrees really helps to better your design and makes it fun to learn from each other's failure.*
*(2) I learned that finding each other's strengths in the group can help make these projects more efficient and that collaboration is key to success.*
*(3) Good planning skills when instructing others*
*(4) I believe that my education partner helped me be more creative. This is a good skill to have as an engineer, especially when designing circuits. Just by talking to someone who isn't in my field and explaining to them technical concepts has helped with my communication skills. Which is also very beneficial to an engineer when pitching a product or idea.*
*(5) I learned about lesson plans and how best to present topics in a formal manner. This also included what kinds of communication tactics were most beneficial to the virtual environment we are in.*

Responding to a reflection question, "*What surprised you about working with your 5th grade partner(s)*" students answered:

*(1) They had a lot of imagination and ideas for what we wanted to accomplish with our robot and they were very motivated.*
*(2) I was surprised with how creative they were and how they took charge in helping design the robot.*
*(3) That they had a big interest in designing and build[ing] the robots. They wanted to learn more about what engineers do and how they do it.*
*(4) One of our 5th grader[s] were very enthusiastic and extremely quickly learning about the microbit.*

## Discussion & Conclusions

This study investigated the influence of an NSF-funded model of cross-disciplinary and mixed-aged collaborations on the robot quality, interprofessional skills, and investment level of undergraduate engineering students during a collaborative robot design process. Teams composed of engineering student(s), a preservice teacher, and fifth grader(s) collaborated over multiple Zoom sessions to design and build bio-inspired companion robots. Preliminary results revealed that the quality of robots built by the engineering students was linked to their engineering design process knowledge, and influenced by their level of investment and how they valued and integrated the fifth graders' ideas into their robot designs. The usage of Hummingbird™ robotics kits enabled the fifth graders to participate on par with college students and translate their designs into effective robot prototypes. This kept them motivated in the project, which further influenced the engagement level of the engineering students. Engineering students' overall perceptions were generally positive, appreciating the role of cross-disciplinary and mixed-aged collaborations in their learning to brainstorm innovative solutions and interact effectively with professionals outside of engineering as they embark on tackling societal problems in the real world. While initial findings seem promising, more research is planned to examine the impact of this model on the professional and interprofessional skills and investment levels of engineering students in the future.

## 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

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. 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.

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.

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. 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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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. 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.

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.

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.