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Students' Lived Experiences with the Integrated STEM Activities

Maram H Alaqra

Bugrahan Yalvac (Associate Professor)

Michael Johnson (Professor)

Dr. Michael D. Johnson is a professor in the Department of Engineering Technology and Industrial Distribution at Texas A&M University. He also serves as the Associate Dean for Inclusion and Faculty Success in the College of Engineering. Prior to joining the faculty at Texas A&M, he was a senior product development engineer at the 3M Corporate Research Laboratory in St. Paul, Minnesota. He received his B.S. in mechanical engineering from Michigan State University. Dr. Johnson received his S.M. and Ph.D. from the Massachusetts Institute of Technology. Dr. Johnson's research focuses on engineering education, production economics, and design tools. Dr. Johnson has over 80 peer reviewed publications and several patents. His research has been funded by the National Science Foundation, the Department of Energy, and industry. Dr. Johnson is a member of the American Society for Engineering Education, the American Society of Mechanical Engineers, SME, and a senior member of IEEE. He served as the president of the Tau Alpha Pi Engineering Technology Honor Society national board from 2014-2018. He is past chair of the Mechanical Engineering Technology Leadership Committee. He is also a member of the Engineering Technology Accreditation Commission of ABET. Dr. Johnson has won several departmental and college-level awards for teaching, research, and service. He is also an ASEE National Engineering Technology Teaching Award and Fredrick J. Berger Award winner.

Jennifer Whitfield (Instructional Associate Professor)

Jay R Porter (Professor and Associate Dean)

Dr. Jay Porter received his BS in Electrical Engineering in 1987, his MS in Physics in 1989, and his Ph.D. in Electrical Engineering in 1993, all from Texas A&M University. He has been on faculty in the Department of Engineering Technology and Industrial Distribution at Texas A&M University since 1998 and teaches in the areas of circuits, electronics, and applied electromagnetics. Dr. Porter currently serves as the Associate Dean for Engineering at Texas A&M-Galveston. His applied research interests include STEM education and the design of application-specific instrumentation solutions.

Mathew Kuttolamadom (Associate Professor)

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Abstract

Engineering has been rarely taught in K-12 schools in US. Integrated STEM education can be a means to teach engineering and engineering related concepts. Students who learn about engineering in K-12 will be more interested in choosing STEM careers.

The overall goal of the present study was to explore the impact a Professional Development (PD) program designed for teachers on students' lived experiences as they completed integrated STEM activities. The STEM activities involved cutting edge technologies and their implementation in daily life. These activities were then embedded in their science and mathematics courses.

Researchers at Texas A&M University received a National Science Foundation (NSF) engineering education grant in 2016. The overarching goal of the grant was to increase the STEM pipeline by providing engineering focused PD activities to in-service science and mathematics teachers. The teachers were trained and guided to develop lesson plans for the purpose to implement them in their classrooms. Throughout the year, the teachers taught their students the cutting-edge technologies and their implementations.

In this paper, we report the findings from one classroom where the teacher of the classroom participated in the project activities. The design of the research was a case study. The case under investigation was one of the teacher participants' classrooms and their students. We visited the teacher's classroom and collected firsthand data from the student participants. We purposively selected six students and interviewed them one on one. In the interviews we asked questions to explore the students' lived experiences with the integrated STEM activities. We also interviewed the teacher at another session. We attended one of the class meetings and took field notes along with images of the projects students completed. The interview data collected were transcribed. The textual data were analyzed using the constant comparative method. Analyses reveal the student's lived experiences with the newly implemented engineering focused integrated STEM activities.

Introduction

Increasing K-12 students' interest in Science, Technology, Engineering, and Mathematics (STEM) fields has been a mutual goal of educators and stakeholders [1]-[3]. There is a growing interest among the education researchers to design and implement integrated STEM education [4]-[8]. Researchers have emphasized the role of Project Based Learning (PBL) in teaching integrated STEM [9],[10]. Many science and mathematics teachers in middle and high schools utilize PBL and ask their students to complete projects that integrate different disciplines of STEM [9], [11].

Science and mathematics teachers often take several mathematics and science courses during their undergraduate education, and they are well prepared to teach science and mathematics. However, most of the in-service science and mathematics teachers did not receive formal education in engineering and/or in technology. To be certified to teach science and mathematics,

teachers are not assessed about their knowledge and skills in engineering and technology. Most in-service teachers are not ready to teach integrated STEM topics in their classrooms because of their lack of expertise in engineering and technology. There is a need for the in-service science and mathematics teachers to learn how to effectively integrate engineering and technology in teaching STEM topics. Programs and training designed to educate in-service teachers on engineering design principles and effective use of cutting-edge technologies are instrumental to attract students' interests in STEM fields [4], [9], [12]-[16].

Study Context

Recognizing the need to train and educate in-service teachers about engineering and technology, a team of researchers and faculty members secured a National Science Foundation (NSF) funded grant. The project team designed and delivered a professional development (PD) program to a selected group of teachers who have been interested in teaching integrated STEM. The teachers applied to the program. A cohort comprising 11 teachers were identified. These teachers were trained over a two-week period during the summer to use the connected devices [17] that are also known as the Internet of Things (IoT). IoT connects multiple devices at once over a network. It incorporates computer processing capability, sensors, and communications capabilities, which are currently being used in many industries [18]. Teachers also learned about additive manufacturing and computer-aided design (CAD) tools. Teachers received training on engineering design principles and the use of cutting-edge technologies in education [12], [13].

We provided continuous guidance over the academic year to the teachers who completed the summer PD activities. Teachers were asked to design lesson plans utilizing the new knowledge they learned in the PD activities and then implement the lessons in their own classrooms in the upcoming academic term. Teachers who implemented their instructional design collected data from their students about the effect of the newly designed instruction.

Purpose

In this study we explored and documented a purposively selected teacher's STEM classroom and their students' lived experiences as they completed integrated STEM activities. The teacher had participated in the STEM PD and integrated the use of some cutting-edge technologies and their implications in their STEM classroom. In the present study, our purpose has been to document the effect of these newly implemented instructions on the students' and the teacher's lived experiences in the classroom.

Methods

Study Design

In the present study, we conducted an instrumental and singular case study [19] to explore the impact of the PD activities on one teacher and their students in the classroom. The case under investigation was one of the teacher participant's classroom and their students.

Case studies are often conducted because of their unique characteristics [19] - [21]. The participants are asked to provide information about the case from multiple perspectives. Providing rich data about the case under investigation explains the case in more detail. Case studies can be instrumental in nature and they can be representative of similar cases.

Research Question

We asked the following research question that guided our investigation:

– *What are the lived experiences of the teacher and the students in a classroom where an integrated STEM instruction with cutting edge technologies were implemented?*

Participants

In the PD activities delivered in this study, there were several other teachers who completed the activities each year. We purposely selected one of the teachers, Kevin (a pseudonym), and his classroom to further explore the lived experiences of the students with the implemented activities. We aimed to capture the essence of the experience the teacher and the students went through and what their views, opinions, and perspectives were about the activities.

The participant teacher, Kevin, had attended the engineering-focused PD provided by the project, and he executed the project activities in his class. After the PD, Kevin interacted with some of the project team members who had expertise in learning science, engineering, and technology at the monthly meetings and received additional support to implement the project activities into the school curriculum. We purposely selected Kevin and his students [20], [21]. Selecting one case (the teacher and his classroom) provided us opportunities to conduct in depth investigations.

We purposely selected four students in Kevin's classroom and invited them to participate in one-on-one interviews [20], [21]. We secured consent both from the students and their parents because at the time of the data collection, the students were younger than 18 years old. Among the four students, three of them were male and one of them were female. All students were in the 4th grade.

Data Collection

We used an ethnographic data collection and analyses method to define procedures and circumstances that contributed to the lived experiences of the students and their teacher [20], [21]. We visited the teacher's classroom and collected firsthand data from the student participants. We interviewed the four students and Kevin one-on-one [20]. During the interviews, we asked questions to explore the students' lived experiences with the integrated STEM activities. We also interviewed the teacher, Kevin, at two different sessions [21]. We attended one of the class meetings and took field notes along with the images of the projects' students completed. The interview conversations were recorded and then transcribed.

Analyses

All interview conversations were transcribed verbatim. During the analysis process, we employed the constant comparative method [22]. We read the transcriptions several times and employed open and axial coding followed by selective coding [20] – [22]. The occurrences Kevin and his four students described in the interviews were used to develop themes. Teams were coded and categorized [22]. Analyses revealed the four students' and Kevin's lived experiences with the newly implemented engineering focused integrated STEM activities.

Findings

We report the findings from the students participants in one section and findings from the teacher, Kevin, in another section.

Student Participants' Lived-Experiences (N=4)

Findings from the analyses of the transcribed verbatim showed that students learned new things related to engineering and technology. Students stated that participating in the program helped them remediate their misconceptions about engineering and engineers. Students participating in real-life and authentic engineering tasks allowed them to understand the Nature of Engineering and its characteristics. Because of those authentic engineering experiences, students became more aware of the engineering practice and developed a deeper understanding of engineering in general.

We report the findings from the student interviews under six themes that are used as sub-titles next: (1) understanding the nature of engineering, (2) gaining engineering awareness, (3) changes in students' conceptions towards engineering, (4) interests towards engineering, (5) gaining knowledge and learning new things; (6) authentic engineering experiences.

Theme 1: Understanding the Nature of Engineering

The four students we interviewed reported that their understanding of engineering and its practice were improved. Students often think about engineering as constructing buildings or fixing engines [23]. One of the students commented: "We learned how engineering works."

Students reported that participating in an engineering project and interacting with engineers helped them gain a better understanding of the engineering field. They gained a better understanding of the types of tasks that engineers actually perform in their daily lives. One student reported: "Before we did the STEM project, I knew basically nothing about engineering. And then over the year, we learned about engineering and how engineers work and what engineers do." Another student stated "they help us figure out how to build things and how to build things so we can learn how engineering works."

Theme 2: Gaining engineering awareness

According to the students, participating in the integrated STEM activities increased their knowledge of the various branches of engineering. Students talked about conducting work in the fields of architecture and other engineering types.

One student reported:

> "I learned that it's not all done in a lab. You can also do it at just a regular desktop every day. Like how we work at our desk with a Chromebook. I also learned that engineering isn't just construction work, which was what I always thought it was. There's more to engineering than just working on a building or designing a new type of car"

Another student told us in the interview session that what "I learned is that engineering can be a really fun job to do because there's all these different types of engineering tasks to do."

Theme 3: Changes in students' conceptions towards engineering

Students discussed that before participating in the project, they had an incorrect impression about engineering. They used to think that engineering is a boring career, and it is just about building where there is no room for imagination. Students that participated in this initiative said that it had a positive impact on their perspectives on engineering. Students' attitudes toward engineers have shifted, and they now have a positive attitude towards engineers. Students reported that they adopted a positive attitude toward engineering because of the authentic engineering experience they had in the project. For example, one student reported "It was enjoyable when we can create things."

Another student reported:

> "We're making objects of our own kind, such as a log cabin. At first I thought it was more math and just building cars and mechanics. But now it has so many different points of view, and you could do so much with it. So I find there's more opportunities with engineering that I could get into. Before I had thought that engineering was just one thing and that was just one thing."

Another student discussed their attitude shift:

> "I was thinking maybe I wanted to go into that field; maybe I don't. I'm not sure yet. And it might be boring 'because I thought it was just only you design a building or you design this thing. But I really think engineers are people who can solve problems now."

Theme 4: Interests towards engineering

Students reported that they have developed an interest toward the engineering field after participating in the project.

A student said in the interview: "The project is getting people interested in engineering."

Theme 5: Gaining knowledge and learning new things

Students reported that they gained new knowledge and learned new things because of their participation in the integrated STEM instruction.

A student reported “I very much feel like I learned a lotta new stuff.” Another student told us: “I learned about how to design. Kind of how a 3D printer works. And how you can use your parts in your life.”

One student commented: “I learned how to use codes in a building to create something new and use it.” Another student said: “I didn't really know much about coding and building before. So I feel like I learned a lot on how to do both.”

Theme 6: Authentic engineering experience

Students reported that they had authentic engineering experiences in this project. Students participated in hands-on engineering activities where they had to do the work. Students reported that the work that they did in the project was student-centered.

Teacher’s (Kevin’s) Lived Experiences

Findings from the analyses of the transcribed data with Kevin showed that Kevin was able to implement in his class what he learned and what he did in the PD. Kevin found himself developing more confidence in teaching STEM in general and science in particular.

We organized our findings from Kevin’s transcribed interview data under five sub-sections, or the themes: (1) implementation and integration, (2) inquiry learning, (3) drawing as education, (4) STEM self-efficacy, and (5) challenges faced during the implementation phase.

Theme 1: Implementation and Integration

Kevin stated that he was able to implement the knowledge he learned and the messages conveyed in the PD activities with his student in class. Kevin talked about the interaction between him and his students. He emphasized how his students interacted with him and how much they were engaged in using technology. Kevin explained to us how he integrated technology with mathematics in a way that it made things relevant and meaningful to the students. Kevin mentioned that his Pedagogical Content Knowledge (PCK) helped him implement and integrate the content he had learned.

Kevin told us in the interview: “I introduced 3D printing at the beginning of the year with the embedded geometry concepts so that when it comes at the end of the year, April, they [students] already know it."

Kevin mentioned that he incorporated geometry in what he taught throughout the entire academic year: “To be able to do it in the beginning and not save geometry all the way to the end. So it's like, hey, we're studying geometry all year and not just in a span of three weeks So that was really good.”.

Theme 2: Inquiry Learning

Kevin told us that the way he implemented the content he learned in the PD was student-centered and he acted like a facilitator for his students. Kevin said: “It's more facilitating. So let them learn: "How does this thing work?" And let them be the troubleshooter for the other kids.”

Kevin explained how he used a questioning method to make students think about what they have been learning and helped them connect things in a more meaningful way as well as making room to reflect on their own learning. Kevin reported:

> “On the problem-solving side, looking at how, from a teacher, from the role of a teacher, getting students to struggle, to understand what it means to create something that was not what they intended, and to really look at, OK, I'm not gonna settle for that. And just really learning how not to give them the answers. So I think as an educator I grew in that area. Because as a math teacher: Okay, we gotta move on [and I will provide the answer].”

Kevin continued:

> “But so when I asked them [students] questions about what wasn't working, I would pose the questions in a way: What if you did this? What do you think will happen? And really getting them to reflect on the process of what's happening as they change the dimension of something or they extrude something.”

Theme 3: Growing as an Educator

Kevin discussed how implementing the principles of the PD allowed him to grow as an educator. Kevin explained that his perspective about problem solving and giving students the opportunity to learn were enhanced because of going through the implementation experience.

Kevin said “As an educator I grew in” the area of not giving the correct answer to the students but letting them discover this. Because as a math teacher: Okay, we gotta move on.”

Theme 4: STEM Self-efficacy

Kevin expressed in the interviews that while he took the integration approach to STEM, he found himself more confident in teaching STEM and felt that it is something he can do. Kevin reported:

> “So definitely more about the engineering design process and really how it relates to something as simple as 3D printing. I think I always looked at engineering as this field of mathematics and science that I could never be a part of. Because I always struggled with science. And I don't know if it was just the teacher or the concepts. But I just knew and had this built in my mind that I'm not good at science. And so as engineering and with the advancement of technology and computer programming, and just seeing how companies and organizations are bringing it into the school setting, I think that really opened up these opportunities for me as a teacher to say, OK, these kids need to learn this.”

Kevin added:

> "And the experience that I had where: I can't do science because I'm not good at it. But showing them [students] that it's not just science concepts and isolated math concepts, but you're looking at the connectedness of everything, and just finding something that they're passionate about. So definitely taking all that and just hopefully getting our students at our school excited about it"

Theme 5: Challenges faced during the implementation phase

Kevin reported that he faced several challenges when he started implementing the content. He discussed some challenges that he phased in the school such as students coming in and out and needing more support from school.

Discussion & Conclusion

There are similar studies conducted elsewhere to help improve teachers' capabilities to teach integrated STEM education [24]-[27]. However, it is rare that the researchers focus on one classroom and select the teacher and students' lived experiences with the integrated STEM activities as the unit of analyses. In this study, we collected interview data from one teacher and four selected students.

Students' lived experiences with the activities signaled that students participated in authentic engineering activities. Students on multiple occasions reported that they had had limited knowledge about engineering, what engineers do, and what the nature of engineering was before the project. After the project was completed, students became more aware of the authentic engineering activities, and they increased their knowledge of engineering and what engineering do. Students' lived experiences focused on the new knowledge they had learned and how conscientious they have become about engineering. Students' interest in STEM fields might have been improved because of their enhanced understanding of the Nature of Engineering and what engineers do in general.

Kevin's lived experiences with the activities conveyed that he was able to understand and then implement the newly learned knowledge in his classroom. Implementation was not difficult for Kevin. However, during the implementation, Kevin acted differently than he was acting before. By observing students and his own reactions, he concluded that after the PD, he was more reluctant to tell the correct answer to the students even though they needed it to move forward. He was also going to ask more challenging questions and not easily answer a question if students could not answer it. He became more aware of the role of scientific inquiry in teaching integrated STEM.

Kevin improved his confidence and capabilities to teach integrated STEM. He had a higher STEM self-efficacy after he completed the PD and implemented the newly introduced instruction in school.

This study was conducted in one classroom with one teacher and four purposively selected students. The case under investigation was the classroom and the classroom participants' lived experiences. The teacher's (Kevin's) and the four students' demographic differences might have affected the outcome of this study. If the same study was conducted with a different teacher and different classrooms, findings would differ.

Learning to implement integrated STEM education helped the teacher develop confidence in STEM education. Being an expert in engineering and technology is a time-consuming task and not always feasible for the in-service teachers. Specifically designed PD programs that have rich engineering and technology emphases can provide a means to train in-service teachers on these two important but mostly neglected disciplines of studies in middle and high school education.

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References

[1] T.J. Moore, K.M. Tank, A.W. Glancy, and J.A. Kersten, "NGSS and the landscape of engineering in K-12 state science standards," *Journal of Research in Science Teaching,* vol. 52, no. 3, Jan, pp. 296-318, 2015.

[2] National Academy of Engineering and National Research Council, *Engineering in K-12 Education: Understanding the Status and Improving the Prospects*, The National Academies Press, Washington, DC, 2009.

[3] S. Pruitt, "The Next Generation Science Standards: The Features and Challenges," *J Sci Teacher Educ,* vol. 25. no. 2., March, pp. 145-156, 2014.

[4] B. Yalvac, O. A. Bewaji, M. E. Spier, G. M. Elizondo, C. T. Umah, T. Sherron, J, T. Lightfoot, C. L. Cannon, and R. S. Fuchs-Young, "Promoting the STEM pipeline and enhancing STEM career awareness through participation in authentic research activities (RTP, Diversity)," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Salt Lake City, UT, 2018. Available: https://peer.asee.org/30908.

[5] M. D. Johnson, E. Ozturk, L. Valverde, B. Yalvac, and X. Peng, "Examining the role of contextual exercises and adaptive expertise on CAD model creation procedures," in Human-Computer Interaction Part II vol. 8005 LNCS, M. Kurosu, Ed., ed. Berlin: Springer-Verlag, pp. 408-417, 2013.

[6] E. Ozturk, B. Yalvac, X. Peng, L. M. Valverde, P. McGary, and M. D. Johnson, "Analysis of Contextual Computer-Aided Design Exercises," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Atlanta, GA, 2013. Available: https://peer.asee.org/19204.

[7] X. Peng, P. McGary, E. Ozturk, B. Yalvac, M. Johnson, and L. M. Valverde, "Analyzing Adaptive Expertise and Contextual Exercise in Computer-Aided Design," Computer-Aided Design and Applications, vol. 11, no. 5, pp. 597-607, 2014.

[8] W. Zhan, B. Hur, Y. Wang, S. Cui, and B. Yalvac**,** "Creating Maker Culture in an Engineering Technology Program," *International Journal of Engineering Education*, vol. 37, no.3, 712-720. 2021.

[9] S. Y. Han, B. Yalvac, M. M. Capraro, and R. M. Capraro, "In-service teachers' implementation and understanding of project based learning in science, technology, engineering, and mathematics fields," *Eurasia Journal of Mathematics, Science, & Technology*, vol. 11, no.1, 63-76. 2015.

[10] W. Zhan, W. B. Hur, Y. Y. Wang, S. Cui, and B. Yalvac, "Actively engaging project-based learning through a mini maker faire in an engineering technology program," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Online Virtual, 2020. Available: https://peer.asee.org/34090.

[11] B. Yalvac, H. D. Smith, P. Hirsch, and J. Troy, "Promoting advanced writing skills in an upper-level engineering class" *Journal of Engineering Education*, vol. 96, no.2, 117-128, 2007

[12] E. Cevik, B. Yalvac, M. Johnson, M. Kuttolamadom, J. R. Porter, and J. G. Whitfield, "Improving in-service science and mathematics teachers' engineering and technology content and pedagogical knowledge (Evaluation)," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Online Virtual, 2021. Available: https://peer.asee.org/37306.

[13] E. Cevik, M. Johnson, B. Yalvac, J. G. Whitfield,. M. Kuttolamadom, J. R. Porter, and J. A. Morgan, "Professional development activities for secondary STEM teachers and students' engineering content knowledge and attitudes," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Online Virtual, 2020. Available: https://peer.asee.org/35089.

[14] E. Cevik, M. Johnson, B. Yalvac, J. G. Whitfield,. M. Kuttolamadom, J. R. Porter, and J. A. Morgan, "A Study of Secondary Teachers' Perceptions of Engineers and Conceptions of Engineering," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Virtual Conference, 2020, Conference Paper. [Online]. Available: https://peer.asee.org/34058.

[15] E. Cevik, M. Johnson, B. Yalvac, J. G. Whitfield,. M. Kuttolamadom, J. R. Porter, and J. A. Morgan, "Exploring Parents' Knowledge and Awareness of Engineering through Middle School Students' Summer Camps," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Tampa, FL, 2019. [Online]. Available: https://www.asee.org/public/conferences/140/papers/25241/view.

[16] E. Cevik, M. Johnson, B. Yalvac, J. G. Whitfield,. M. Kuttolamadom, J. R. Porter,

and J. A. Morgan, "Assessing the effects of authentic experiential learning activities on teacher confidence with engineering concepts," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Salt Lake City, UT, 2018. Available: https://peer.asee.org/29827.

[17] M.E. Porter, and J.E. Heppelmann, "How smart, connected products are transforming companies," *Harvard Business Review,* vol. 93, no. 10, pp. 96-114, 2015.

[18] G.B. Cotet, B.A. Balgiu, and V.C.Z. Negrea, "Assessment procedure for the soft skills requested by Industry 4.0," *MATEC Web of Conferences,* vol. 121, August, pp. 1-8, 2017.

[19] R. E. Stake, "Qualitative case studies." In Denzin N. K., & Lincoln, Y.S. (Eds.) *The sage handbook of qualitative research* (3rd ed.) pp. 443-466, Thousand Oaks, CA: Sage Publication, 2015.

[20] J. W. Creswell. *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.) Thousand Oaks, CA: Sage Publication, 2012.

[21] N. K. Denzin and Y.S. Lincoln, *The sage handbook of qualitative research* (3rd ed.) Thousand Oaks, CA: Sage Publication, 2005.
11
[22] B. G. Glaser and A. L. Strauss, *Discovery of grounded theory: Strategies for qualitative research*, Chicago, IL: Aldine Publishing Company, 1967.

[23] M. Knight and C.M. Cunningham, "Draw an engineer test (DAET): development of a tool to investigate students' ideas about engineers and engineering," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Salt Lake City, UT, 2004.

[24] S. Y. Yoon, H. Diefes-Dux, and J. Strobel, "First-Year Effects of an Engineering Professional Development Program on Elementary Teachers," *American Journal of Engineering Education*, vol. 4, no. 1, pp. 67-84, 2013.

[25] M.-C. Hsu, M. Cardella, and S. Purzer, "Assessing Elementary Teachers' Design Knowledge Before And After Introduction Of A Design Process Model," In Proc. of American Society for Engineering Education (ASEE) Annual Conference and Exposition, Louisville, KY, 2010.

[26] K. M. Tank, D. R. Raman, M. H. Lamm, S. Sundararajan, and A. Estapa, "Engineering Encounters: Teaching Educators About Engineering Preservice elementary teachers learn engineering principles from engineers," *Science and Children,* vol. 55, no.1, pp. 74-79, 2017. [Online]. Available: www.jstor.org/stable/26387037.

[27] A. T. Jeffers, A. G. Safferman, and S. I. Safferman, "Understanding K–12 Engineering Outreach Programs," *Journal of Professional Issues in Engineering Education & Practice,* vol. 130, no. 2, pp. 95-108, 04// 2004, doi: 10.1061/(ASCE)1052-3928(2004)130:2(95).