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## Students Becoming Supervisors: Student Transformation during a Cross-National, Collaborative Community Engineering Project

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# STUDENTS BECOMING SUPERVISORS:

Student Transformation during a Cross-National,  
Collaborative Community Engineering Project

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## STUDENT AUTHOR BIO SKETCHES

**Alessandra Napoli** is a senior in Mechanical Engineering at Purdue University. She has been working in the DeBoer Lab for one year as an undergraduate research assistant; her work has been with the engineering courses and community gym project at the Tumaini Innovation Center in Eldoret, Kenya. She plans to pursue her master's and PhD in the field of mechanical engineering.

**Kevin Nyaga** completed his primary school education at Tumaini Innovation Center in 2017. He is currently a form two (Grade 10) student at Kapsoya Secondary School. Kevin resides at Tumaini, and during his time at Tumaini continues to learn engineering and practices it through hands-on projects. Kevin aspires to go to university and eventually return to Tumaini Innovation Center as the director.

**Dhinesh Radhakrishnan** is a research assistant at DeBoer Lab, School of Engineering Education at Purdue University. Dhinesh studies capacity building on engineering knowledge and skills in marginalized communities through participatory methods. He leads the "Localized Engineering in Displacement" project at the center for street children in Western Kenya and assists the team on the same project in a refugee camp in Northern Kenya.

**Dr. Jennifer DeBoer** is currently Associate Professor of Engineering Education and Mechanical Engineering (by courtesy) at Purdue University. Dr. DeBoer studies and supports diverse students around the world as they learn, develop, and meaningfully apply engineering in their own communities. She has received multiple awards including NSF's prestigious Early CAREER Award and the Mara Wasburn Women in Engineering Early Engineering Educator Award.

## INTRODUCTION

UNICEF estimated there were 100 million "Street Youth" in the world in 1989 (UNICEF, 1994), and since then the number is said to have increased (Ennew & Swart-kruger, 2003; Glauser, 2015). The purposefully problematized term "street youth" (SY) is defined by UNICEF (2001)

to refer to children who work and/or sleep on the streets. Various factors can push or pull youth onto the street, including poverty, violence, abuse, familial conflicts, peer pressure, and more (Glauser, 2015). SY include both children "on the street" who work and live on the street during the day but return home at night, and children "of the street" who live on the street both day and night and

often have limited contact with their families (Sorber et al., 2014; Steffen, 2012).

Kenya is home to an estimated 250,000–300,000 street youth (Steffen, 2012). Eldoret, the fifth largest city in Kenya with a population of about 250,000 people, has approximately 3,000 youth living on the street (Kilbride et al., 2000; Kipyegon et al., 2015). A “Street Youth Cycle of Poverty” (Fischer, 2014) has been identified that, once entered, can be very difficult to escape. This includes high-level obstacles such as a weak economy, lack of gainful employment opportunities, poverty preventing access to higher education, an education system that does not teach students skills matched to job market demands, and societal perceptions that diminish the input of youth in the community (World Bank, 2005). Physical and sexual abuse is not uncommon, with 21% of youth aged 10 to 24 having been sexually abused (World Bank, 2005). On the street, abuse is one of the means by which youth are initiated into and kept from leaving gangs. Sniffing glue and engaging in other forms of substance abuse, another common practice in a gang initiation, can make it harder to leave the street due to addiction (Wachira et al., 2015).

Purdue University (PU) is a large, midwestern academic institution, and Tumaini Innovation Center (TIC) is an alternative school in Western Kenya. TIC was founded in 2009 to help break the “Street Youth Cycle of Poverty.” The center worked to repatriate street youth into their families and reintegrate them into the traditional education system. While they were able to provide services to more than 1,000 youth, approximately 80% returned to the street because of a lack of support to face the other additional challenges described above (Fischer, 2014).

To better react to and overcome these obstacles, and, further, to recognize and build on the assets that SY themselves have, TIC adapted by revising their program model in 2015. The priorities shifted from reintegration with families and schools to rehabilitation, counseling, education, and critical health services. In class, students learn basic literacy and numeracy to embed “practical information instead of traditional concepts” (Fischer, 2014). Following the establishment of this foundation in basic education, instructors teach skills and subjects that relate directly to the surrounding community and guide students to interact with their community. The innovative, hands-on curriculum structured around engineering concepts allows the youth to directly apply the lessons learned in the classroom to fixing real-world problems around them. The skills learned by the youth prepare them for jobs in the market, while also empowering

them as entrepreneurs. This model differs from the traditional formal education model by focusing on growing the strengths of students, recognizing their assets, and preparing them for employment (Fischer, 2014).

One of the course modules at TIC, created in collaboration with the DeBoer Lab at PU, is Localized Engineering in Displacement (LED). The engineering program, recently completing its second iteration, aims at developing skills in engineering design and technical and professional competency. The lessons teach students about the engineering design process, teamwork, electrical circuits, 3D modeling, prototyping, engineering drawing, and other engineering knowledge required to solve locally identified problems. The structure of these classes encourages teamwork and allows the students to take the lead on projects like designing and installing a solar panel system for the school, which was completed by students in March 2018. They are able to try different ideas, observe and evaluate the results of prototypes, and make decisions about future iterations of the design based on those results.

In 2018, the TIC received a grant from the Ambassador’s Fund of the United States Embassy in Kenya for the construction of an outdoor community gym. Due to the close connection between TIC and the DeBoer Lab, a team of graduate and undergraduate students from PU began working on the design for the gym in close collaboration with the management and students at TIC. They received supplemental funding through a service-learning grant to implement 3D modeling to support the design and implementation. During the stages of idea generation, initial designs to 3D printed prototypes, and final part drawings, the first author, a PU undergraduate student, worked on her first real-world engineering project. During the initial stages of project implementation, the second author, one of the 18 students at TIC at the time, observed and helped the artisans constructing the gym, including when he noticed errors in the process. The second author, as an engineering student, reported the mistakes in construction and offered advice to correct them. The second author was later appointed as the supervisor of the project by TIC’s management team. In this paper, we will examine the first author’s and second author’s experiences with this engineering project to investigate how integrating community projects with classroom learning affects an engineering student’s development.

## METHODOLOGY

In this research, we use a qualitative approach to investigate and develop an understanding of how engineering

students take on leadership roles, what gives them the confidence to step into these higher responsibility roles, and how combining community projects with classroom learning affects their development.

The data for this research include written reflections from both authors, a 45-minute interview of the second author, and project notes from the first author. The qualitative analysis was performed by taking the following steps: (1) compiling the data, (2) reading the texts multiple times for understanding and interpretation, (3) developing codes using “open coding” (Saldaña, 2015), and (4) synthesizing the codes into themes.

The codes were synthesized using narrative analysis, which is summarized in the following sections. Analysis of narrative was then used to identify similarities in experiences and potential explanations for the authors’ actions.

## PARTICIPANTS

### Reflections by First Author: Student Impact

I am a student at PU and started my bachelor’s in Mechanical Engineering in 2015. In 2018, I joined the research lab as an undergraduate project assistant to create some of the engineering lessons being taught at TIC and to design a 3D model of the community gym.

I had initially approached it like a school project. This approach did not fit the situation, caused me confusion and anxiety, and made me lose confidence. I was able to gain confidence in my contributions and complete my tasks after my team and mentors showed confidence in me and created a space in which I could experiment and not be afraid of failure. In addition, they reframed my view of my role in the project to accurately reflect it. Later in the project, when I helped incorporate the gym model into a learning module at TIC, I went into the task with more confidence and less hesitation.

When I began the project, my role was to create a CAD model of the gym, including various types of workout structures (Figure 1). Even though I had a few years of experience designing models in CAD, I was not confident in my work because I did not know the exact measurement requirements, available material, and any information that I needed, based on my training at PU, to determine prior to working on a problem. To me, it seemed that there were too many things that I did not know for sure to even start this project.

After I expressed these concerns, I was reassured that my work was meant to be a starting point for a design. I was guided to do research on outdoor gyms and create a model to visually describe the gym layout and equipment. Then, I would rely on the other people in this global team to determine what material could be

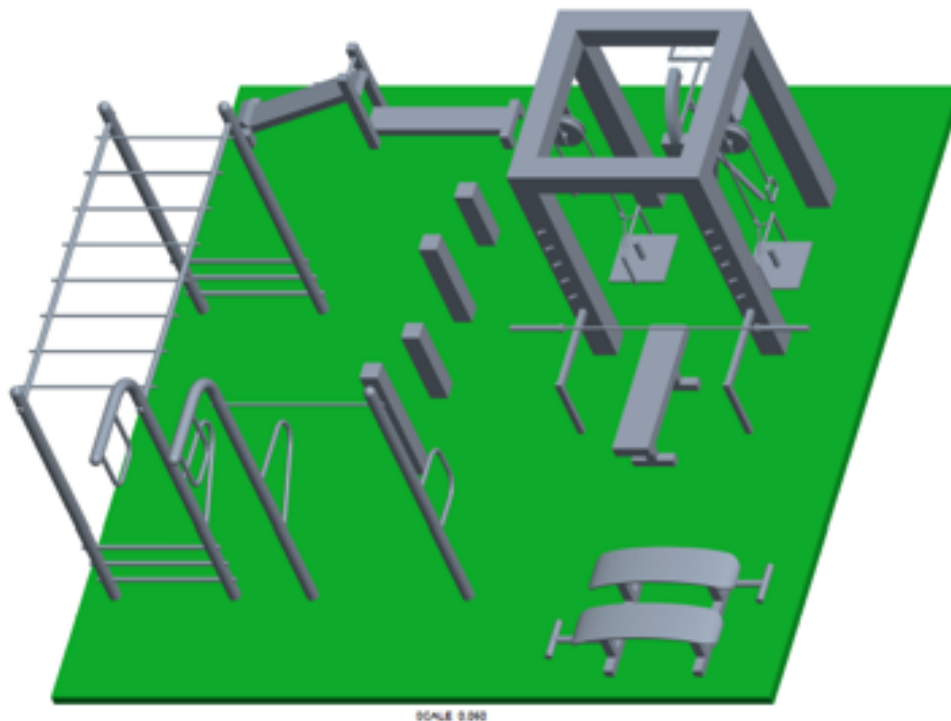


Figure 1. Outdoor gym concept design, scale 0.050.

sourced, what dimensions were needed, and how to manufacture it. The biggest obstacle that I had to face was a fear of not creating a finished design in the first iteration. Perhaps it was because the implementing team worked across the globe that it took some time to realize that I was working as part of a larger team and should rely on their expertise to validate my work; I could work through ideas with them as opposed to presenting finished solutions.

I was excited to work on this project to test my capabilities and apply classroom learning to real-world engineering problems, but I was initially so afraid to fail and, as a result, I held myself back from starting the project. Without the support of the team (second, third, and fourth authors), I would not have felt comfortable and confident in my decisions and contributions. They created a space where ideas would not be failures, but topics for discussion and improvement. In addition, they trusted that I could do the work that I was assigned, and they respected my opinions and comments on that work. The fact that I alone was not responsible for the design gave me confidence to continue.

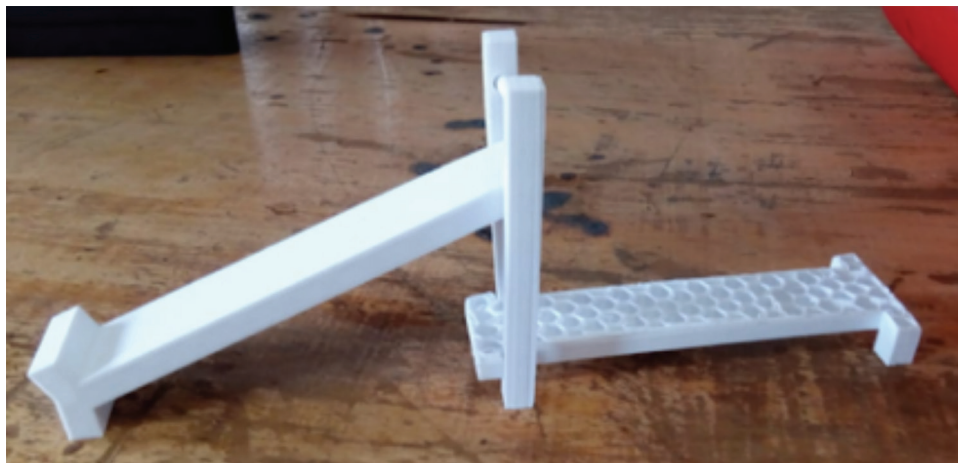
Later in the project, when part drawings and 3D printed prototypes were needed and the gym was being prepared for construction, the engineering course at TIC was reaching the point where students were to learn about 3D printing and prototyping. To include the students in the gym project, another undergraduate researcher and I created a lesson and tutorial on 3D modeling and printing that prepared the students to make a scaled 3D printed model of their future gym (Figure 2). I had fewer hesitations to start working on these steps because I knew the design and the software, but more importantly, because my team had reframed how I saw the project and my position in it.

### Reflections by Second Author: Community Impact

I joined TIC as a student in 2015 and have since held multiple leadership roles including school president, class prefect (representative), and team captain for soccer. At TIC, I took the localized engineering and welding fabrication courses. In these courses, I learned how to weld, differentiate between good and bad quality welds, manufacture parts according to their technical drawings, and how to engineer as part of a team.

The main objective of the first engineering course was to address the inconsistent and unreliable electrical power at TIC. In the engineering class, we (the students in the course) defined the problem, determined the requirements of a solution and how they would be measured, and made detailed technical drawings. In groups, we then made prototypes of the system. Based on what did not work, we redesigned the system and tested it again.

Two years ago, we began a project at TIC to build a community weight gym. I had seen the design when making the 3D printed prototypes of the equipment in class. I liked the design, so I went to the worksite to see how it was being built and to offer help, even though I did not know how useful I could be. I wanted to become more involved in the project, because I wanted to learn more from the professionals in the field and gain more experience in welding, fabrication, and implementing design solutions. While there, I noticed that one of the structures in the gym looked incorrect and checked its dimensions against the part drawings. The artisans who were building the gym had made mistakes in their construction. I told them this, but they did nothing to fix it. Then, I told the TIC management what I had noticed, and the TIC manager told me that I had the engineering



**Figure 2.** 3D printed gym equipment prototype by TIC students.

skills necessary to work on this project and that I should use them. He made me the supervisor of the construction project. I was shocked. I am a student, but people trusted me more than the professionals building the gym. I was ecstatic and wanted to prove to the manager that I could do this job well. He tells me almost every day to “Take my role [as manager of TIC].” He really believes that I can lead well, and I thought, “If I do not supervise this project well, I cannot be a manager,” so I took the role very seriously.

In order to do my job well, I needed to be tough with the artisans. At first, they were shocked that I was telling them what to do; some were even angry. In the end, they did redo the structures that they had built incorrectly. I never felt nervous about correcting them because I knew that if I had been gentle, they would not have done their job. I was the one with responsibility over the project, so the results needed to be good.

As a supervisor, I watched over the project until the end and helped the artisans whenever they needed me. Through this, I learned a lot about how to be a good engineer and a leader. I was proud of the project and felt that it was mine. I worked on the project so much that other students around the school referred to it as my gym and would frequently ask about its progress.

Working on the gym and installing the solar panels have helped me a lot. In class, it can be difficult to understand everything, or even if it is understood, knowing how to apply what is learned in class happens best when I can be on a team working on an interesting project. That way, we can go through the whole engineering process and discuss anything that is not understood as a group. Also, learning through community projects like these is important because we would not have things like the community gym otherwise. This gym will be the only community gym in our area. I feel a very strong connection to this gym and have therefore put in a lot of work to ensure that it is exactly as it should be.

## RESEARCH RESULTS

### Research Question 1: What leads an engineering student to take on leadership roles?

For both the first author and second author, three factors influenced their decision to take on leadership roles: their desire to gain practical engineering experience, their desire to demonstrate the engineering skills that they already had and were developing, and the level of confidence they had in themselves paired with the

level of confidence and support shown to them by their team members and mentors.

### Gain Experience

First, they desired more practical experience in engineering. Both wanted to apply the knowledge they had learned in class to a real-world problem. One of the first reasons why the second author wanted to start going to the worksite was to see how the artisans did their job applying the skills he was learning. By being actively engaged in this activity and noticing the mistakes being made, he was able to gain first-hand experience, which would help him prepare for managing at a larger scale, such as being the manager of TIC one day. In addition, since it directly affected his community, the second author felt a close connection to the project and had a strong desire to become involved. The first author had also mentioned that this project was the largest engineering project that she had worked on to date; by working on the project, she knew that she would be able to better prepare herself for engineering and research work in the future, especially as part of a multinational team.

### Demonstrate Skills

Second, they wanted to prove their engineering and leadership skills, both to themselves and to their mentors. The second author has had numerous leadership roles within the student body at TIC, but his role as supervisor marked the first time that he led an engineering project. Through his work on the project and its outcome, he meant to prove that he was capable of leading. As her first large engineering project outside of a well-defined class setting and its well-structured problems, the first author wanted to prove to herself that she was capable in her chosen field of study. Workplace engineering problems are ill-structured, and the well-structured variety often taught in education courses do not sufficiently prepare students for real-world problems (Jonassen et al., 2006). Joining the DeBoer Lab for this ill-structured project offered the first author this opportunity to expand her workplace skills. In addition, as it was her first project as part of the DeBoer Lab, the first author wanted her work to show that she would be a useful team member.

### Self-Confidence

The third factor that affected their decisions to take on the leadership roles was their self-confidence in their ability to do the task and the support given to them by their mentors. The first author had previous experience

in CAD modeling and was therefore confident in her ability to use the necessary software. If this skill had not been previously known, the task given to her would have seemed significantly more daunting. The second author had previous leadership experience and also had taken classes in engineering and welding fabrication. Because of these classes, he knew the designs and how to differentiate between good and bad craftsmanship. Being sure in his previous knowledge gave him the confidence to speak up about the problems that he saw.

**Research Question 2: What gives engineering students the confidence to step into larger engineering roles with more responsibility?**

One of the main factors that determined how much each student worked on the project or how much of a leading role they took was their level of confidence in their own ability. This confidence was due to a number of factors, but the largest motivating factor was the support of their mentors and teachers. The first author stated that when she began the project, she was very unsure of herself and her actions. Her mentors reassured her that the scope of her work was within her current knowledge base, and anything that was not could be determined as part of a group. In addition to creating a helpful and open space for new ideas and discussion, the first author's mentors also reached out to her to check in and ask if any help could be provided. This continued to reinforce an atmosphere of iterative design and working through problems in a team as opposed to an individual producing a final answer.

For the second author, even before the gym project began, he received encouragement and support from the management at TIC. They frequently expressed their belief that he could become a great leader. When they decided that the second author should be the supervisor, they showed great confidence in his skills, which in turn made him believe in himself and his ability to lead. The important characteristic of this influencing factor of support was that it was continuous. One instance of support would likely not have been sufficient to instill the second author or first author with the self-confidence necessary to pursue these new positions.

Another factor that had an effect on how each felt upon starting their respective portions of the project was that they were not starting from scratch. The first author did research on what outdoor gym equipment already existed and began her designs from those images. The second author began work on the project by helping the artisans with tagging welds and other small construction jobs. He had also worked with the design drawings in class. These

familiarities and his previous knowledge base provided him with a starting point from which to begin taking a larger role in the project.

**Research Question 3: How does combining community projects with classroom learning affect an engineering student's development?**

Making community projects available to engineering students and incorporating them in their learning provides a semistructured way for students to experience engineering in a real-world context. It builds the confidence and problem-solving and teamwork skills of the students participating in them. Traditional classroom learning's focus on earning good grades and finding one correct solution can be a hindrance in real-world contexts, noted in Jonassen et al. (2006), as it was to the first author when she began designing the gym. Her previous class groups had been relatively small—two to four people—had well-defined problems and solution requirements, and exhibited low pressure to do the highest quality work. Contrary to classroom projects, community projects promote student interaction with and learning from professionals in their field of study as well as related fields. They also create a positive, motivating pressure to perform well because the students care deeply about the outcome of the project.

For the second author, taking part in the gym project gave him a way to give back to his community. The personal connection that he had with the gym and the people who would be benefiting from it made him feel that he should ensure that the project would be a success. In addition to gaining real-world experience, the second author was also able to become more involved in his community. When the project affects the place where a student lives, the impact and desire to perform well increase. The second author took an interest in the project because of the community connection and stepped up to become more involved because he had previous leadership experience, some relevant knowledge, and the support of his school's management.

**CONCLUSION**

Both the first and second authors found that community engineering projects develop different skills than classroom projects because they offer students a way to work on the real-world engineering problems that have fewer guidelines and require work in larger teams. Due to their connection with their community, students are more motivated to work on and become more involved in community projects. The benefit that the community can



**Figure 3.** The second author at the completed outdoor gym.

gain through these projects can push students to become more involved in more aspects of the project.

Students will choose to take on leadership roles in such projects when they have some confidence in their own abilities and the confidence of their mentors and team. This support from others is key in building student self-confidence. Having either previous leadership experience or relevant skills or knowledge will also help students feel confident in their ability to lead.

TIC and the community now have access to a gym, the engineering students at TIC were able to learn 3D modeling and printing in a way where they saw direct application of their lessons, and the authors have gained valuable leadership skills. TIC has also been able to grow its student base since the beginning of this project and now teaches over 30 students with plans to expand further. The first author plans to use these skills in future engineering and service projects in mechanical

engineering and engineering education. The second author (Figure 3) has since worked on more welding projects at TIC and around his community. He has chosen to study welding and fabrication full time; his work as the supervisor of this project has better prepared him for future career paths in leadership roles.

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