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Promoting Belonging in Engineering through the Creation of Youth-Centered Technology-Rich Spaces

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Work In Progress: Promoting Belonging in Engineering through the Creation of Youth-centered Technology-Rich Spaces

Introduction

In 2024, we are not offering a novel idea when we contend that the promise of makerspaces to achieve inclusion across contexts has not been met [1], [2]. While such technology-rich spaces still have the potential to support youth from minoritized groups to create artifacts aligned with their interests and values [3], [4], there has been little work to understand youth's perspectives on developing a sense of belonging and ownership in such spaces [5]. Further it is our belief that engineering in K-12 and informal engineering education settings does not espouse a value of intentionally not causing or reducing harm to people and the environment, as evidenced by a lack of such language in the Next Generation Science Standards (NGSS) and most state standards.

The NGSS emphasizes the use of a three-dimensional science learning focused on interdisciplinary or "crosscutting" concepts, science and engineering practices, and disciplinary core ideas following the domains of physical, life, earth and space sciences, and engineering [6]. The NGSS defines engineering design into three components of defining engineering problems, designing engineering solutions, and optimizing the design solution; yet it is not until grades 9-12 that the standards insist that students should be assessing social and environmental impacts during optimization of solutions [7]. Understanding the interdependence of engineering and society is only explored in a separate set of practices, in which language does not directly state that engineering design can cause harm [7]. The omission of the developing engineering solutions surrounding reducing harm to people and the environment further supports claims that harm reduction is considered an afterthought in engineering design [8], [9]. The Framework for P-12 Engineering Learning which intends to offer support for schools in which engineering courses can not be implemented thoroughly due to lack of engineering education professionals or resources [10, p. 21]. However, in this framework the relationship between engineering design and technology with societal impact is framed under the concept of professionalism, referring to engineering ethics. The framework goes so far to state that, "technology by itself is neutral and does not affect people or the environment. However, it is the way in which people develop and use technology that determines if it is helpful or harmful" [10, p. 74]. Such a statement removes responsibility of harm from the engineers by displacing impact onto the users.

In this project, we are working to integrate youth as leaders in a youth-designed makerspace in order to encourage feelings of belonging in engineering and STEM in general. The youth leaders and project team leaders are creating and facilitating the programming at an after-school program. By sharing ownership of the project, we hope the youth will gain a greater sense of belonging and feel empowered to solve problems in their community. This program has completed eight weeks of a ten-week workshop within an after-school program assisting youth from resettled families with refugee and migrant experience in the United States Northeast. Our partnership, however, has existed for much longer (about 1.5 years). However, a significant amount of time has been spent developing relationships of trust between the staff and youth at the after-school program and us. The youth are aged between 8 and 18 years old. In this first iteration of the ten weeks, we spent much of the time introducing technologies and building a makerspace together. The overall study aims to explore how the implementation of youth

leadership in technology-rich spaces may: 1) support youth in leading explorations of how technology use, and creation can support a sense of belonging in engineering; 2) further develop a framework to center preventing harm to people and the environment along with youth; 3) explore the role that intergenerational relationships can play in informal student learning. In this paper, we focus on a session in which we introduced the concept of harm in engineering and report on initial findings of how the youth took up the concept of harm in a design challenge.

The way engineers define stakeholders of projects constrains their understanding of how their work may produce or reduce harm outside of their scoped definition of stakeholders [11]. It is challenging for students to conceptualize the needs of those whose identities differ from their own [12], and "students' reasoning (and cognition) about socio-technical issues are highly sensitive to context, and dynamic rather than stable or belief-like" [11]. This stresses the importance of understanding how students currently conceptualize harm and developing programs to develop a nuanced and operational understanding of harm in engineering.

Research Question

In this paper, we are interested in investigating the following questions: In what ways do youth in an after-school program conceptualize harm in engineering design? How do new youth leaders guide their group through a harm-reduction design activity?

Research Context

Following our previous work [13] with the after-school program, we have continued programming for five more sessions, one before the summer break and four during Fall 2023. Over summer break, the research team ordered tools and supplies to create the makerspace at the youth club. Beginning in the fall, the research team and the youth began to design the makerspace and create community guidelines. During the third fall session, the youth were presented with a harm reduction workshop, which began with a presentation on harm reduction and its implications for engineering. Following this, youth were split into small groups to begin an activity centered on harm reduction in engineering to make decisions about the location of a bridge in a fictionalized context. Afterward, youth were tasked with drawing and creating a prototype of the bridge using craft objects found in the makerspace. A focus group interview was completed with the youth leaders to understand their experience during the workshop. Our paper will be centered around this session specifically. To answer our research questions, we share the design, implementation, and observations of the harm reduction workshop below.

Activity Design

A third-year undergraduate student on the research team (lead author on this paper) created the activity and accompanying worksheet based on their experiences in engineering courses. The instruction in the activity comprised defining the term, applicability to engineering topics consistent with the participants' age range, and using craft tools to build a prototype. This was done in a PowerPoint presentation presented by a research team member prior to the beginning of the activity. Additionally, following the previous work and outcomes with our youth participants, we provided scaffolding for the participants to discuss value-based trade-offs and not be fixated on providing one "correct" answer [13]. We created a bridge design challenge for the students based on these ideas (Figure 1).

The bridge design challenge drew from a similar project in a first-year engineering reflection course and a second-year engineering foundations course in the authors' academic program based on work by Chen and Wodin-Schwartz [14]. The bridge design project began with a prompt from a city mayor hoping to connect two parts of town with a bridge. However, the bridge had to begin and end in specific zones on either side which were to be demolished to make way for the bridge. Context was also added in the prompt, saying, "The Mayor says they trust your decision as long as you can explain it!" to help alleviate the youth's fears about preemptively having a "correct" answer. Six zones were created, three on each side, of which youth had to decide one on each side to demolish to construct the bridge. In creating the zones, careful attention was given to crafting the background of each zone in order to tackle real-world issues at an age-appropriate level while additionally being cautious not to cause uncomfortable feelings for the youth. The zones were created to give enough context to allow youth to reflect on their personal experiences and knowledge of harm reduction and avoid explicitly triggering language. Overall, the six zones more broadly tackle issues of gentrification, urbanization, lack of green spaces, displacement of communities, and disruption of animal habitats. The author of the zones pulled ideas from their own experience growing up in Springfield, Massachusetts, to help craft authentic experiences. However, in keeping things at grade level and making room for youth to insert their ideas and experiences, all backgrounds are primarily vague and do not explicitly suggest harm will come to the zone. For example, "The Park," although highlighting what will be lost, there is also language to suggest that another park is available—leaving plenty of space for youth to compare this with their nearest parks and playground compared to our fictional space. Prior to building the prototype bridge, youth were instructed to write down their zone choices and justifications for building on them on the worksheet.

Figure 1. Bridge design activity prompt

The activity was also designed intentionally to create small groups which each youth leader would spearhead. The only additional instruction given to the youth leaders was that they were in-charge of ensuring completed worksheets were handed back to the research team members. Giving the youth leaders free range to lead whichever way they saw fit also allowed researchers to evaluate their leadership styles and feelings of confidence and belonging with the topic.

Research Design

We use interviews, observations, video recordings, and field notes to answer our research questions about how youth conceptualize harm in engineering and how youth leaders support their teams in working through an engineering activity centered on preventing harm. Assent and consent had been collected from participants in Week 0 of the project the previous winter. Verbal assent was obtained for youth participants by researchers onsite and consent was collected through forms distributed to guardians by the afterschool program staff. All assent and consent verbiage emphasized that data in the form of video, audio, and physical artifacts may be collected from the youth throughout the duration of the study. Youth were allowed to participate in workshop programming without assent or consent and any data collected from youth was discarded appropriately. During the first session of Fall 2023, assent was recollected from youth. Video data was collected for both the activity at large and group working time. After data collection, the research team analyzed the data together, discussing pertinent themes and dynamics to answer the research questions. Based on several generative discussions within the team, each member of the team wrote a summary to synthesize findings using an analysis of narrative approach [15], [16]. Below, we share a discussion based on this analysis organized by introduction to the harm reduction workshop, each of the teams' dynamics with sections named after the pseudonym of the team leader, and the wrap-up team presentations. To be brief, in this Work in Progress paper, we have omitted a majority of the narratives, but we can make anonymized narrative findings available upon request. All names used are pseudonyms and researchers are referred to as R1, R2, R3.

Findings and Discussion

Harm Reduction Workshop

Findings. The opening harm reduction presentation had approximately nine youth, including three of our youth leaders, Graphite, Chartreuse, and Auburn. Research team member, R1, led the presentation while three other members were available to join in the discussion and support. When introduced to the concept of harm, youth were focused on harm as a physical attack on an individual as completed by an individual such as: "[online account] hackers," "thieves," "stalkers," and "murderers." However, when redirected by images on the slide of "What is harm?" and a prompt from a lab member citing that he himself causes harm because he drives a car, youth were able to identify more examples of large-scale harm such as: "bad people," "people who buy factories," "the President," "[leaders] who only care about the money." When prompted with the question of "Who is responsible for reducing harm?" youth cited: "good people," "shelters," "life centers" [about care facilities], "Mr. Beast," and "Black Lives Matter." Youth also debated whether or not leading a vegan or vegetarian lifestyle is reducing or causing harm, citing "killing plants is getting rid of oxygen we need" as a mechanism of causing harm and "saving animal lives" as a mechanism for reducing harm. R1 asked the youth if they believed that the individuals they identified as causing harm should also be responsible for reducing harm. Youth agreed and continued this conversation by describing how individuals who want to make good choices are often limited by the choices provided to them.

Youth were then prompted to think about how engineers can reduce harm. Vermillion replied "An engineer reduces harm by looking for ways to cure diseases but that can also do experiments… experiments can be bad for people… they have to make sure what they do is

okay." This allowed for segue into conversation surrounding how engineers have to ensure they focus harm in their work. A method of reducing harm prompted was collaboration, and youth replied to an example of an engineer wanting to make a vitamin would have to collaborate with "doctors," "nurses," "biologists", "scientists", "the government", "the FDA", "the advertisement companies", "manufacturers." Finally youth were asked to recap a definition of harm reduction to which Vermillion responded "harm reduction is reducing inequalities or direct harm for people, the environment, like the whole world."

Following this discussion, the research team introduced the activity "Ethics in Developing New Infrastructure," in which youth were asked to define the word ethics and infrastructure. An older youth was immediately able to define infrastructure as “the way something is built”, which prompted R1 to further define examples of infrastructure for all youth. However in defining ethics youth were confused, some examples of proposed definitions were, “ethnic,” “logical,” “biological.” R1 prompted a question if lying was good or bad, at this point youth were able to debate about situations in which lying was good, bad, or somewhere in between. Therefore R1 defined ethics around societal concepts and ideas that help individuals understand if their choices are good or bad. Therefore, based on youth responses and conversations, the team member reframed the prompt as "thinking about the good and bad in building new places." The team member then emphasized the need for youth to follow community guideline rules and ensured the youth leaders could lead their teams in any way they saw fit. Youth leaders were invited to the front and labeled teams one, two, and three; at which point more youth walked in so teams were created by counting off by threes. Auburn appeared almost immediately uncomfortable with her team, Graphite professed that he had all of the smart youth, and Chartreuse immediately began calling for all of his team to go to him. Pastel, our only other female identifying student, began to vocalize that she did not want to be separated from Auburn which prompted similar feedback from Auburn. However, they both dejectedly returned to their groups after further prompting from R1.

Discussion. Overall based on discussions throughout the presentation it was clear that youth defined harm and harm reduction as a cause and effect of a singular action done by an individual or greater entity; where harm was the result of making a bad decision and reducing harm the result of a good decision. Additionally, the ability to cause and reduce harm was based on the intrinsic morals of the individual or entity, where those who caused harm were labeled as bad people and those who reduced harm as good people. Regardless, those who caused harm most often were individuals in positions of power due to economic status or professional role, whereas those who reduced harm were often part of broader cultural movements, social services, or healthcare organizations. Which suggests that youth believe that reducing harm is a responsive role rather than proactive duty that decision makers should be focused on. Until prompted by the research team member asking if the factory owner is responsible for reducing harm, all of the youths' comments supported the idea of the opposition of good people and bad people. After this point, some youth were able to describe the nuances of decision making and trade-offs in the role of harm as demonstrated by the prompt of how engineers should reduce harm or in the conversation surrounding vegan or vegetarian lifestyles. This method of understanding making trade-offs was further evident in the final designs of the project.

The PowerPoint presentation surrounding harm reduction was ultimately very brief and was not presented to approximately half of participants due to late arrivals to the programming. Therefore the explanation of the activity to incoming youth was left to youth leaders and all other youth present for the presentation, which was not ideal. At this point it is apparent that for the youth harm and harm reduction was only largely tied to good people versus bad people, we can only assume that youth had intentions of creating their projects as good people. In addition to the swiftness and missing youth for the presentation, researchers were also only able to cover collaboration as one approach to reduce harm in engineering. Although collaboration is essential to reducing harm, this provided youth with limited ideas to develop their conceptualizations [17]. We should have also focused more on what collaboration should entail, historical solutions, and connecting harm to both intended and unintended consequences. Finally, when we formed groups we were not cognizant of how the gender dynamics would play out [18], [19]. In retrospect, we should have allowed Pastel and Auburn to stay together.

Group Graphite

Discussion. The dynamic between Graphite, Vermillion, and the rest of the group demonstrates the increased efficacy of project-based education when a sense of ownership or belonging is achieved [20], [21]. Additionally, the group's conceptualization of harm reduction seemed to be limited by individual conceptualization of more nuanced ways in which harm may occur as a result of engineering activities. Vermillion demonstrated the greatest personal investment in the project as he provided the justification, the design, the majority of fabrication, and referred to the bridge as "his" despite not being the designated leader or receiving any direction from the designated leader to do such. However, Graphite allows this behavior asking Vermillion, “what do you want me to write?” or “what do I do?” Which allows Vermillion to continue going forward with his ideas.

Vermillion provides all of the group's justification for placement that considers harm including: pollution from the factory and the potentially failing safety of the family homes. Although there was mention of the environment in the foundational presentation the students were given, the link between the factory and harm to the local community in the form of pollution seems to be a connection formed solely by Vermillion between the new material and his existing conceptualization of environmental harm. The inverse of this was how Graphite and Vermillion were dismissive of the displacement of local labor since the townspeople 'can work on the bridge' or 'in a different town.' This is a topic unlikely to be explored by younger students and more challenging to conceptualize than direct environmental destruction.

Group Chartreuse

Discussion. In this group only two students were present for the harm reduction presentation, Chartreuse and Pastel, as all of the other group members joined immediately after the activity was introduced and throughout the building process. Chartreuse throughout the workshop was determined to have all members contribute to the bridge design and building. Despite late and unfocused new arrivals, this group did exhibit a decent amount of collaboration and discussion when it came to the bridge. Chartreuse took charge and filled out the worksheet sheet while inviting the other group members to contribute. Having a short and noticeable time limit at the end pushed everyone to tune in and focus on the bridge. Despite Chartreuses’s leadership style of trying to involve each and every team member; the harm reduction outcomes

of the activity varied throughout the group. This depended on the students level of involvement and focus on the designing and building.

A recurring theme in this group was Pastel being left out of the group attributable to her gender. She expressed frustration about being the only girl in the group and appeared to feel unincluded. There was a point of conflict when Pastel wanted to choose the ice cream shop on the worksheet, and she was not feeling heard. When R1 walks over, Pastel repeats this saying, “It’s not fair they’re not going to listen, I’m the only girl!” However Chartreuse suggests that voting for the group decisions will help with fairness, R1 agrees with him despite Pastel's continued frustrations. Regardless, Pastel’s outward expression of her emotions further emphasize the importance of recognizing gender dynamics when creating groups.

Group Auburn

Discussion. Throughout the process, Navy takes on the primary role in terms of writing, directing, and speaking. Despite referring to Auburn as the leader multiple times, he mainly engages with her, and others, to criticize the work she is doing; at various points he argues that, “I did this before,” in response to her attempting to participate in bridge design He generally gets along by working by himself and leaving the other members of the group to work by themselves as well. He led by doing his own work and telling others what they should be doing. However, there were one or two points when he tried to involve some of the younger members, and he was courteous in his attribution of the bridge to Maroon (who was there basically only for this building process).

This works somewhat well, but Auburn, being the only girl as well as the extra criticism and pressure of being the leader, does not have the confidence to even work on the project on her own, mostly because she isn't really being left to her own devices or encouraged in any way. While gender plays an important role, the large age range of the members of the group also played a role in group dynamics. Navy is approximately 14 years old and Auburn is 12 years old, while all other male group members fit in the 8-10 age category, making it so the team majority sided with Navy. This is evident immediately from the body language and positioning of the youth; in a circle of about 5 chairs all male students are turned towards each other in one half of the chairs while Auburn is left on the opposite where she spends most of her time avoiding eye contact with Navy and watching Pastel.

Additionally, the pressure of the situation also increased tensions between Navy and Auburn. While Azure and Cerise were pretty content just working on their drawings, Navy and Auburn became increasingly stressed by trying to build the physical prototype before the time was over. As Auburn attempts to gather supplies she returns to Navy’s disapproval of, “Where were you? You were supposed to be the student leader!” Before instructing the other members to find the legos despite the supplies Auburn had returned.The constant reminders of Auburn's leadership position, coupled with a pre-existing anxiety and confusion about the task and Navy's criticism, caused her to leave the group and the activity and not feel comfortable continuing.

Group Presentations

Findings. After R1 announced the build was over she asked for volunteers to begin presentations as discussed prior to the design and build phase. R1 asked Chartreuse to present as the youth leader, and he insisted that Vermillion would be presenting. Vermillion immediately

wanted to begin presenting and started by stating, "my bridge is," before getting paused by R1 calling for all of the youths to focus on the presenters. With new found group focus Vermillion corrects himself to begin "our bridge is made with," in which he goes into detail about specific engineering specifications the bridge would have including the length, size, and material of support beams. Vermillion states that the park and factory were the desired zones of the bridge were the park and the factory because "there is already a duplicate version of park nearby…factory would probably be harmful considering there are community homes, gardens, park because it would probably mutate the plants and not be good for environment." R1 asks for another group member to explain how their bridge design reduces harm, without engagement R1 prompts the youth leader, Graphite to explain, "the factory because we can replace.. the people that work there.. they can easily build other things… the park there's another one nearby exactly like it." R1 responds back to the group, highlighting that people still have a place to play and assisting people in getting jobs building the bridge.

Chartreuse's group volunteers to go next, once all youth congregate around the bridge, the team members call out the person who made it and call out Yellow. Yellow begins with, "here is our colorful bridge" followed by detailing some of the engineering specifications as modeled by Vermillion but with less detail and foresight. R1 asks about the location to which Yellow promptly responds "the factory and the zoo," R1 asks for another group member to explain how the bridge is reducing harm. Chartreuse almost immediately says, "the factory is polluting the air s … we can't leave the animals, but if we move the factory there wouldn't be so much pollution and we are protecting the animals." Vermillion immediately asks if he can ask questions and after approval asks, "If you're stopping pollution why are you moving the animals?" to which Yellow happily replies, "God bless you, next question." Which leads to laughter and applause for the group. R1 and R3 compliment the bridges on their unique designs and praise youth for their involvement in the activity before moving forward to the next design.

Finally all the youth gather around Auburn's group for the presentation which is started by Navy. Navy begins by highlighting the youth who built the bridge before stating, "we built this bridge in a rush because we need to get it up and running 'cuz you know we need people from East to West. We are getting rid of the park, cuz there's another one nearby, and the uhhh, community homes to make the city safer." After the Navy provided some low-level specs about the bridge design, R1 asked for another group member to explain how their design is reducing harm, to which Navy replies, "our group leader should talk, group leader, group leader!" Auburn, frustrated, says "because it's a bridge, I don't know" R1 encourages her that she knows and offers guidance, eventually allowing her to read off their group's worksheet. Reading Auburn says, "we're getting rid of the park because there's another one nearby that's just as nice…as well as the community homes because they are making the area unsafe." R1 asks who's being protected and another student quickly replies "people and animals." Vermillion chimes in to ask if their design will be funding new homes for the elderly to which Navy replies, "The elderly? We're funding new homes for everyone." Vermillion asks Auburn to answer repeatedly and she quickly responds "He ALREADY answered." R1 and R3 wrap things up again by applauding and congratulating all of the youth on their hard work.

As a final wrap up R1 asks, "Who is responsible for reducing harm?" to which the students shout back "Us," in which R1 prompts for a more clear answer. One student responds

with "everyone" and once again is asked for clarity, to which all of the students begin to chime in, "People, government, me, nurse, Doctors, teachers!" R1 asks more specifically, "What about the engineers, should the engineers worry about reducing harm?" which is meant with a mixture of negative and positive feedback. R1 questions back "An engineer shouldn't worry about harm" and a majority of students reply saying that engineers should worry about harm. Finally R1 asks, "why do we want engineers to worry about harm?" to which two students reply "To stay safe" and "To keep the world nice." Finally R1 thanks the youth again for participation, and instructs the youth to clean up the space before leaving the room.

Discussion. The final group presentations reflected the group dynamics in the designing and the building of the bridge. Vermillion of Graphite's group takes full ownership of the physical design and harm reduction planning of the bridge. This was the only group that did not properly build the bridge across the water, as the group's final decision of the park and the factory stayed on the east side of the river. Additionally following Graphite's laid-back leadership style, his understanding of how their decision may reduce harm showed no greater understanding than Vermillion's despite an age gap of approximately five years. In Charteruse's group presentation, Pastel had not voiced any thoughts or opinions despite being present for the initial harm reduction presentation. Yellow, the youth who presented for the team, was not present for the initial presentation, hence R1 asked for another student to present their harm reducing ideas. Chareturse was able to step forward as a leader to explain the harm reduction ideas. Finally, Auburn's group presentation further highlights the taunting that Auburn experienced during the project. Despite participating in the initial presentation, she did not feel confident in voicing her opinions and ideas.

Similar to the results following directly after the initial presentation, it is evident that youth understood less about the nuances of harm reduction rather than understanding trade-offs. Youth used principles of reducing impact to the environment or human life to make their decisions. For example, when groups selected the park, their justification included that a neighboring park had similar features. Youth that selected the community homes felt that because the homes were becoming unsafe to live in it was okay to build there. However both suggestions don't include possible further issues of accessibility of the park and the displacement of an entire community. Suggesting that youth likely did not ideate further than their initial trade off decisions. Additionally, as noted after the initial presentation, youth viewed decisions as either causing harm or reducing harm, more simply put as being good or bad. Therefore understanding that their decision may be harmful resulted in ignoring the question, as shown by Yellow in Charteruses presentation, or by feeling very overwhelmed or confused as demonstrated by Auburn and Navy. Youth finding it difficult to understand the greater implications of harm reduction while designing and engineering may be attributed to their age, therefore having a limited understanding of fundamental issues occupying society, as well as a poor definition of how harm reduction thinking can be applied to design.

Reflections and Future Work

Youth received no negative feedback about their design from the research team. This was done in part to allow youth to build confidence and create a sense of belonging in the environment. However, had researchers questioned the students directly about the possibility of their decisions causing harm, for example, pointing out the disruption of community in placing

the bridge in that zone, youth may have been better fit to conceptualize the nuances of decision making. These questions could have also been framed as questioning youth about why they did not pick other zones. This may have possibly allowed them to build on their understanding of harm and harm reduction. Additionally in the final wrapping-up of the programming, youth were evidently still confused on what the role of engineers should be in reducing harm. The idea of making trade-offs for the greater good in itself may be a stepping stone in understanding the role that engineers play in harm and harm reduction, however further work must be focused on accurately exploring these nuances with youth.

The findings of this workshop activity will help contribute to ongoing study of building a harm reduction framework in collaboration with youth. The National Academy of Engineering proposed that the engineer of 2020 would combine engineering science and interdisciplinary efforts in order to solve large world problems [22]. However, 20 years later there still lacks a clear framework that uses such collaboration with principles of harm reduction to solve these problems. Continued study of introducing harm reduction at a K-12 level will be necessary to prepare students to become the engineers that may help assist in such problems. We hope to collect more information about changing youth perceptions about engineering design, harm reduction in design, and the significance of youth leadership and collaboration in creating feelings of belonging to assist in the building of such a framework.

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