BOARD # 198: Art and STEM for Student Engagement via Realization of Technology (Work in Progress)

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Abstract: Early attitudes and beliefs shape the trajectory of students' educational experiences. By expanding young students' perceptions of engineering, we seek to encourage them to see themselves as possible future engineers. This work presents a collaboration between faculty in the School of Electrical and Computer Engineering (ECE) at a large, public, research-intensive university in the Southern United States and teachers at a local metropolitan area elementary school. The elementary school reflects a student population that is 85% African American and is classified as a Title 1 school, indicating it operates within a low-income district. Given that many students belong to communities that have been historically marginalized in engineering, early intervention through engaging and creative programming could contribute to long-term improvements in equitable access to engineering education. The goal of this collaboration is to develop and evaluate sustainable, age-appropriate classroom activities that show the possibilities of engineering, art, and design.

Now in its fourth year, the collaboration has included a range of activities targeted to elementary school students, K-5 graders. These activities have evolved over time as we utilize the elementary school as a trial laboratory to understand how best to provide engagement and mentorship to elementary school students within logistical constraints. Activities have included "Girls Who Code," hands-on engineering activities in the elementary school classroom lead by senior design ECE students and involving elementary students in the creation of an interactive video game by mapping their artwork to game characters. In this paper, we incorporate the perspectives of the faculty instructors, elementary school teachers, and undergraduate students to share their experiences bringing these activities to life and how it has affected their own views of engineering.

We are focusing on engaging early learners since students' perceptions are formed at a very young age. Focusing efforts on early learners and STEM engagement through creative hands-on activities is the foundation of the strategy for this program. This paper will detail the guiding ideals of the program and discuss the practical challenges of building a sustainable collaboration between a Title 1 elementary school and university faculty members in an engineering department. As with any new program, there have been challenges, including transportation between campuses, integrating the initiative into the existing elementary curriculum, and maintaining long-term engagement with industry professionals.

The contributions of this paper are twofold. First, we detail an approach to using art and design to bring engineering practice to life, which differs from stereotypical depictions of the engineering profession that may push students away from seeing themselves as possible future engineers. Second, we share challenges that we have encountered in the process of building this fledgling collaboration, which may be useful to readers who are interested in creating programs in similar contexts. This paper shows some promising directions for engineering engagement in marginalized communities.

Introduction

In STEM education literature, the pathway to an engineering career is often depicted as a "leaky pipeline," in which women and underrepresented students disproportionately leave STEM fields at key educational junctures (e.g., the transition from high school to college) [1]—[4]. Although some researchers have argued for alternative metaphors beyond a "pipeline" [5], it is widely recognized that STEM attrition begins early in a student's educational journey. For instance, [1] found that "first-grade children held stereotypes that boys were better than girls at robotics and programming" (p. 92). Indeed, K-12 education, particularly in K-5 contexts, plays a pivotal role in shaping students' perceptions of their interests, abilities, and possible futures. It is important to help cultivate within students a sense of the "possibility of engineering" - not only to diversify the engineering profession, but also to encourage students to pursue a career with strong potential to be change makers in well-compensated positions.

While promoting STEM in elementary education is highly valuable, several challenges can hinder the effectiveness of such engagement efforts. Prior work has discussed the current challenges related to teacher preparation and confidence in delivering STEM content [6], as well as the need to better understand the pedagogies and practices that effectively support students' engagement with engineering, especially for different grade levels [7]. Additionally, understanding how educators conceptualize STEM education and implement best practices remains an ongoing concern [8]. University-K-12 collaborations are a promising avenue for increasing STEM engagement, but they come with their own set of challenges. Research on university-led engineering outreach programs has highlighted the need for structured frameworks for effective and sustainable engagement [9]. Additionally, significant differences in operational priorities, incentives, and constraints between higher education and primary education institutions mean that each collaboration is inherently unique [10]. Despite these challenges, outreach programs can play a crucial role in increasing STEM participation among students from underrepresented backgrounds by creating more equitable learning opportunities [11].

This paper describes the current state of one such collaboration. While not all insights will be universally applicable, this work may provide useful guidance for those interested in initiating or deepening intentional partnerships between universities and K-5 educational settings. We detail a collaboration between Georgia Tech and Hope-Hill Elementary School, a Title I school in the public school system three miles away from the Georgia Tech campus. In the United States, a Title I school means that the school receives federal funds to support students from low-income families. These students are a particularly vital population to engage and cultivate STEM interest, as outreach efforts can provide them with exposure to careers in STEM fields that they might not otherwise consider [12]. Effective outreach strategies, such as incorporating design-based learning and hands-on projects, have been shown to improve student engagement and learning outcomes [13].

We have been working with Hope-Hill Elementary School as a trial laboratory since 2022. The rest of the paper describes the two "cycles" that have defined this collaboration thus far. First, though, we describe background information to help contextualize the "art" and "design" activities that are referenced later in the paper. Below, we introduce the Electronic ARTrium project and establish the design thinking framework that guides this work.

The Engineering Design Process in the context of an Elementary School Collaboration

The framework that we used to understand the Engineering Design Process is shown in Figure 1. This process identifies six stages of design (Ask, Imagine, Plan, Create, Test, and Improve), which mirrors many other design frameworks [14]. Not only is this design framework explicitly taught as ES, but we also use this framework to understand the progress of this collaboration. In each of the cycles below, we use the Design Process to structure the presentation of the materials.

Figure 1: Engineering Design Process

Cycle 1: April 2023 to May 2024

Ask and Imagine

One objective of this program is to engage with students during school time in the classroom. But, to accomplish this, we would need to be able to align our efforts with existing educational standards so that the class time would be able to achieve multiple ends. By collaborating with the elementary teachers and examining the state's teaching standards [15], we resolved to identify at least two standards related to the design process that would be viable to the elementary school teachers. We also considered the importance of creating opportunities for elementary students to interact with college students as role models and mentors. Thus, we imagined a college course where ECE students would engage in design thinking to create hands-on artifacts that linked art and engineering through the design process. The top teams from the Georgia Tech class would visit the Hope-Hill classroom at the end of the semester and work with the students to teach the Engineering Design Process through hands on activities.

Plan and Create

We utilized ECE 3011: Design Fundamentals, a junior-level design class at Georgia Tech, to engage college engineering students in creating engaging artifacts that demonstrate the possibility of art and engineering. The ECE 3011 students applied the engineering design process to conceptualize and build a device that interacted with the user via a unique sensor and included mechanical movement, sound, and lights. Across Fall 2023 and Spring 2024, three groups were selected to visit an elementary classroom and collaborate with 3rd and 4th grade students for a day. The first ECE 3011 team created a hydroponic garden. During the visit to the Hope-Hill classroom, the college students demonstrated their project and worked with the elementary students to build their own mini-gardens [16]. The project and their classroom material are shown in Figure 2. A YouTube video showcasing their project can be found at the ECE Design Fundamentals Museum [17] or on YouTube [18].

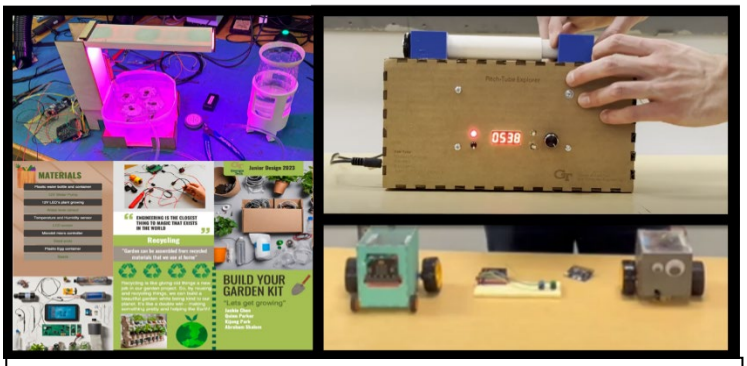

Figure 2: Left: Fall 2023, Build Your Garden Kit. Right: Spring 2024, Top: Team A10 Pitch-Tube Explorer, Bottom: Team A7 MathMazing

In Spring 2024, two teams visited Hope-Hill. One team of students made a musical kit that would change tone like a trombone when the length of tube is adjusted, displaying the frequency of the tone on a user display (Figure 2). The other team created a maze solving robot that would move forward after the user answered math questions. The teams documents can be found on the ECE Design Fundamentals Museum [17] and on YouTube [19-20].

Test and Improve – Perspective of HHES STEAM Program Specialist

As the STEAM Program Specialist at Hope-Hill Elementary School, I felt this collaboration was extremely beneficial for our students. Not only did the partnership give our students the opportunity to work directly with Georgia Tech engineering students, but it also allowed our students to create solutions with real world relevance. I felt this collaborative opportunity was very beneficial for our students. Our students were able to work and learn from Georgia Tech mentors. Georgia Tech students were also able to utilize the engineering design cycle to engage our students in developing solutions for different engineering tasks. Lastly, this opportunity taught students the importance of partnership and how to collaborate strategically.

Although the collaboration with Georgia Tech was a great success, there are some areas we would need to work on in order to improve the success of the program. For one, the college students were required to pay $40.00 and get fingerprinted to work with the elementary school students. Next, transportation can be an issue for the students to get to Hope-Hill Elementary School. Lastly, we would like Hope-Hill students to visit Georgia Tech and get to see their artwork. This too is a financial barrier because we would need money for the buses to transport the students.

As a STEAM school seeking state certification, the Georgia Tech collaboration outreach was extremely beneficial for our students. The collaboration demonstrated how the engineering design process is utilized beyond the elementary school classroom. It allowed our students to work effectively with mentors to enhance their learning. Lastly, it gave our students the opportunity to experience STEAM education outside elementary school.

Cycle 2: April 2023 to Present

Background to Cycle 2: Electronic ARTrium

Electronic ARTrium is a multi-disciplinary laboratory at Georgia Tech focused on designing and building immersive, interactive, and public art exhibits [21]. The current project is to create a human-sized video game *Bee My Guide: An Interactive Journey Back Home*. In the game, the player helps a lost young bee find its way home with the help of animatronic narrators and image processing to control the game.

Ask and Imagine

Cycle 2 began shortly after Cycle 1, and the two initiatives continue as parallel collaborations with different teachers at Hope-Hill Elementary School. Cycle 2 focuses on introducing 2nd grade students to the intersection of engineering and art. Inspired by the STEAM movement (science, technology, engineering, art, and math), we desired to create an age-appropriate experience where students could interact with art [22] and show how art can be used to improve technology. The Hope-Hill 2nd grade art class was asked to draw unique art that could be incorporated into the Electronic ARTrium as skins on different animals. This approach highlights the synergy

between engineering and art, demonstrating how artistic creativity can be combined with technological innovation. The 2nd graders were taught about animating video characters, and later encouraged to attend the Electronic ARTrium Exhibit.

Plan and Create

The creation of Mr. Bee and the other characters in the game require the use of mesh, rigging, and armature. We will look at how to create Mr. Bee to understand the process used for creating animated video game characters for the game. The process starts with a mesh model, but the mesh model lacks structure. Armature is the bone structure given to the mesh to allow for rigging. Rigging is the movement of armature and armature structures to create movement within the mesh. Having armature within the mesh will allow for Mr. Bee to gesture and move.

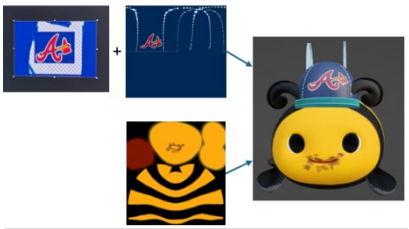

Figure 4: Brother Bee Texture Paint

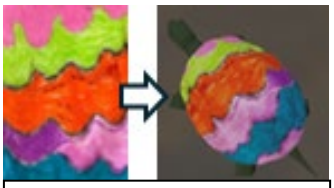

Figure 4: Example of ES Art Applied to Turtle

Mr. Bee's family and friends must all have unique appearances based on artwork or the desired look of the character. Texture paint is where you create the color or design to be added to the mesh. Texture Paint and Shading sections allow for color/skin to be added to your mesh. For example, creating a hat to have specific details, Figure 3. The Electronic ARTrium had nine animals created to allow the Hope-Hill students the opportunity to contribute to the project. The above process was utilized to apply art generated by the Hope-Hill 2nd graders to the skin of the virtual animals. The animals were placed into each level of gameplay. The animals were also placed on an interactive web site that showcases the student art, Figure 4 [23].

Test and Improve – Perspective of HHES Art Teacher

From the perspective of the elementary school educator, the partnership was a valuable way for students to take their art beyond the classroom. The project created an opportunity for real-world connections, showing students how art can be applied to a variety of fields, professions, and experiences. It provided a space for students to imagine how they might use their art skills in the future and added a layer of dynamism to their drawing and painting project. Furthermore, the project tangibly addressed one of the Georgia State Standards [24]:

> VA2.CN.1 Investigate and discover the personal relationships of artists to community, culture, and the world through making and studying art.
>
> > c. Recognize ways that artists are involved in communities and careers (e.g. architects, painters, photographers, interior designers, educators, museum educators).

In this vein, the program could have been strengthened by having more direct interaction between the Georgia Tech students creating the animals and the 2nd Graders creating the patterned skins. With transportation and scheduling as a barrier, I do not know how feasible it would have been, but creating more opportunities for classroom interaction between Georgia Tech and Hope-Hill would have strengthened the connection students had to the project. It would have been valuable to hear directly from those working on the project, rather than hear about it from their teacher. Hopefully, students who created the skins in 2nd Grade will be able to visit

the Electronic ARTrium to see hands-on how their paintings were applied. To support the project and students' connection further, I could have utilized technology more in the Hope-Hill art classroom. Using a program such as Animated Drawings would have given the 2nd Grade students a small taste of what can be done with their art.

Insights from Two Cycles of Collaboration

Over the past two years, the author team have worked engage young learners with STEAM topics through accessible, age-appropriate activities. In the spirit of the design process, this collaboration is always a work-in-progress trying to better reach its aims and objectives. However, there have been key positives and lessons learned from this experience that may support other educators seeking to build similar programs:

Cycle 1: Classroom interactions

The ability to meet students in the classroom allowed for the greatest impact on the widest audience. Having college students participate in the elementary school setting created a win-win situation where both elementary and college students walked away with a greater understanding and a positive experience. The negative sides to this cycle included the school system is not set up to have multiple student volunteers come to the classroom and the university students had to jump through a lot of red tape. Additionally, to engage in the classroom the projects had to meet the [State Standards] that the teachers were currently covering without compromising the existing, relatively demanding pace. To get into the classroom was very challenging and required a lot of communication and work on both the side of the elementary school and the university.

Cycle 2: Technology Enables Engagement

Painting patterns to be used as textures for video animated creatures in the Electronic ARTrium exhibit provided excellent age-appropriate learning experiences for both 2nd graders and undergraduate students, while creating a visually interesting feature of the exhibit. Further, the Hope-Hill project was very low cost to the professor. Finally, a positive experience was the enthusiasm for this activity at all levels. The art teacher at Hope-Hill is eager to continue the engagement, and the undergraduate students frequently expressed their pride in working on a project that included STEM outreach to elementary students, e.g., mentioning it – unprompted – in their required presentations. The only downside to this cycle was the lack of in-person connectivity.

Future Work and Conclusions

The next stage of this work will seek to determine a way to increase the amount of face-to-face interaction we can foster between university students and elementary school students. We are going to explore ways of engaging both in-person and virtually.

This work highlights the importance of early STEM engagement as a means of broadening participation in engineering, particularly for students from historically marginalized communities. Through our four-year collaboration, we have demonstrated how creative, hands-on activities incorporating art and design can expand young students' perceptions of engineering and help them envision themselves as future engineers. By leveraging the enthusiasm and expertise of university faculty, undergraduate mentors, and elementary school teachers, we have developed sustainable programming that integrates into the elementary classroom while inspiring

both students and educators alike. Through this relationship, we have documented key pragmatic lessons to help bring two educational communities together.

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