The impact of centering elements of engineering professional practice using art in a physical computing workshop for 9 to 13 years-old students in an under-served community

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***Abstract*—This Innovative Practice Paper describes the results from the 2019 Work-in-Progress (WIP) [1] proposal for a pre-college physical computing workshop aimed at under-served students. Recruiting under-served students into engineering and computer science activities can pose a challenge, as such activities are often viewed as complicated, boring, or exclusionary. We designed the workshop to mitigate these notions. Since students enroll in the workshop to create a collaborative digital art display versus enrolling in a strictly "coding" workshop, we sought to alleviate their unfamiliar or intimidating feelings towards engineering. Placing the workshop in a familiar location within the community was another strategy to create a reassuring environment designed to increase students' feelings of belonging. Additionally, integrating elements of software engineering professional practice (EPP) gave students a glimpse of the "real world" vocation to increase their affinity for engineering practices. We incorporate physical computing because it can increase motivation and self-efficacy in primary school students [2], and it pairs well with art to use custom-coded light, movement, and interaction as different media for creativity. Our goal in providing this workshop was to explore the following question: What is the impact of exposure to engineering design and professional practice through a collaborative workshop, which centers on art and physical computing, on increasing affinity toward engineering among 5th-8th graders in an under-served community? Twenty-eight students, ages 9 through 13 participated in a novel collaborative art-based engineering design workshop. Students were taught techniques in arts and crafts and coding Arduino and Circuit Playground Express micro-controllers utilizing sensors and LEDs. After the instructional phase, we teamed students to design, code, apply electronic fundamentals, and craft designs to create the final art display. The cumulative, resulting tech-art installation was an immersive, interactive exhibit hosted at a community library for one week. By using EPP elements to produce an exhibit aimed at community consumers, students develop a greater appreciation for engineering practices and receive positive feedback from their community. We examined the students' self-perception and affinity for engineering through pre and post student surveys and interviews. Their responses to interview prompts showed an increase in using engineering terms and principles. The survey questions revealed changes in their self-perception ratings in various categories.**

I. Introduction

Under-served U.S. populations, specifically ethnic minorities, participate in electrical engineering and computer science industries at a rate that lags their representation in the general population. Diversity, Equity, and Inclusion efforts from industry and academia focus on retaining students at the post-secondary education level. One strategy used to prevent college student attrition from engineering majors is to strengthen their engineering identity, defined as "self-beliefs of their interest, performance/competence and recognition within engineering" [3]. However, because attrition of under-served students begins in primary education, earlier intervention may strengthen students' engineering interest, performance, and recognition beliefs at a crucial period in developing career goals, ages 9-13 [4]. In this study, we focus on increasing positive self-perception and engineering affinity among 9-13 years old students, from an under-served community, by practicing a combination of research-based elements. We define positive self-perception as the participants' self-belief in their competency to use coding and electronics as they build a community art exhibit. We define engineering affinity as interest in or liking the engineering process, and engineering work [5]. Our premise is that participants who successfully interact with physical computing and EPPs will increase positive self-perception and engineering affinity. Students who develop engineering affinity during a pivotal time in establishing career aspirations move closer to incorporating engineering identity into their self-perception and may be less likely to abandon STEM pursuits. The WIP paper [1] reviewed recent work on this topic and utilized the outcomes presented as the underpinning for designing and implementing a summer [6] physical computing workshop. This full-length paper briefly reviews and adds to the WIP concepts and presents the workshop outcomes. In Section 2, we discuss the project objectives and our research questions. Section 3 revisits and expands upon the mechanics behind planning the workshop. Section 4 discusses the workshop in action and the practical implementation of our

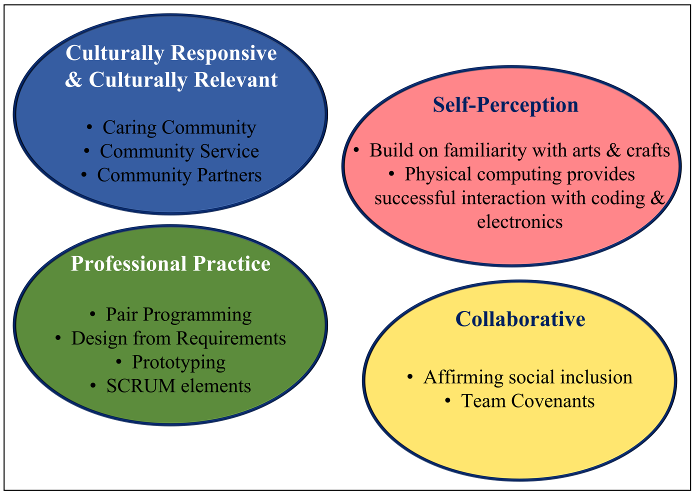

Fig. 1: Workshop and Structural Goal Elements.

structural goals. Finally, we discuss our collection and analysis of data, findings, and future work in Section 5.

II. Project Objectives and Research Questions

This study aimed to examine if participation in a collaborative, community-based art project that included physical computing and elements of EPP can increase the affinity of under-served students toward the practice of engineering. The age group of 9-13 years old students falls within the critical period of orientation to social valuation [4] wherein youth choose or exclude future career options according to their formation of self-concept. By attracting these students to a collaborative art-based workshop that includes engineering practices, we aim to increase the likelihood that they will incorporate engineering into their self-concept and keep it within their scope of possible career choices. With this project, we sought to halt the process of self-selection out of the engineering field by exposing under-served 9 - 13-year-old students to a workshop designed to increase positive self-perception in coding and electronics. Questions we sought to answer:

1) Is there an increase in student positive self-perception regarding project-based physical computing experiences that utilize EPP during the workshop?
2) Is there an increase in student affinity toward engineering after attending the workshop?

In the WIP paper, we explained how each planned workshop element contributes to our structural goals [1]. Figure 1 summarizes the elements of our structural goals. Figure 2. summarizes how these items contribute to specific domains within Self-Perception and EPP. These goals aim to make participants feel valued, understand engineering practices, and develop a sense of academic and social belonging. [7]

III. Workshop Planning and Community Partnerships

The workshop was held in an under-served neighborhood in a mid-size city on the Western Coast of the United States

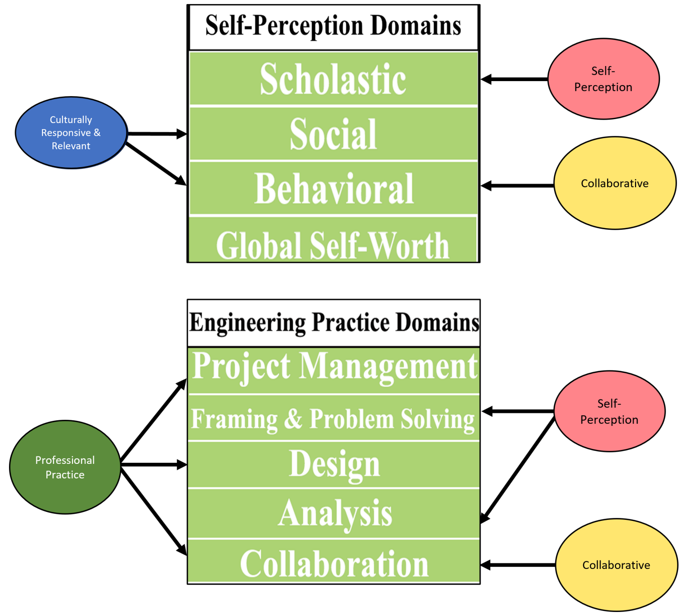

Fig. 2: Domains and Associated Workshop Structural Elements

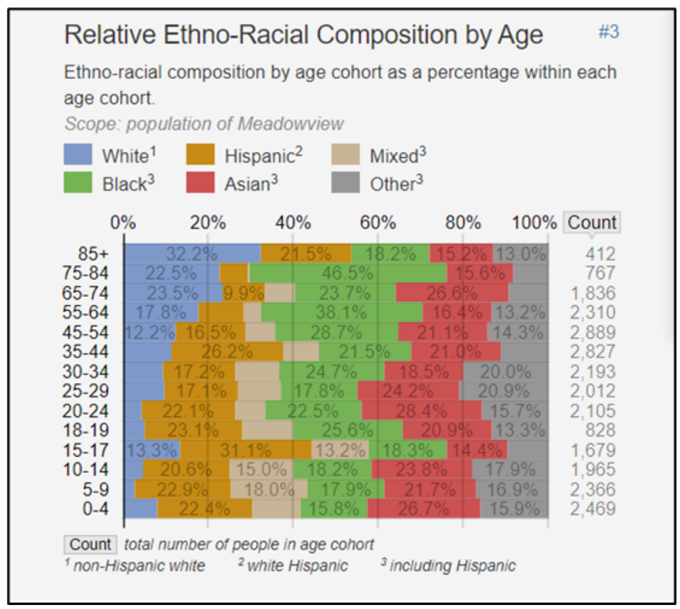

Fig. 3: Ethno-Racial Statistics for Workshop Neighborhood

[8]. Understanding the demographics of the population of 9-13-year-old children in the target audience was essential to determine we could provide the most supportive environment for participants. Figure 3 contains ethno-racial data for the targeted neighborhood by age group. The WIP paper [1] explained our plan to collaborate with artists, community partners, and local venues. We hypothesized that these tactics would allow us to meet the students on familiar ground, ease their comfort level and dispel perceptions of “otherness” in engineering, coding, and electronics.

A. Artist Collaboration

The lead artist was a multi-lingual, local paper artist who identifies as Hispanic. We also had another artist who identifies as Black and is familiar with several mediums. Both artists had prior experience working with children. In collaboration with these artists, we explored elements that could integrate paper art and craft with digital and electronic parts [9]. We approached the artists with the theme of a “digital garden” based on two ideas; extending work by Przybylla and Romeike [10], [11] in which students created small “flowers” using physical computing, and large immersive light-art installations such as those by Bruce Munro. The challenge was to design a project that would combine the individual learning provided by the former with the immersive, expansive exhibit provided by the latter. We chose specific art construction forms that would be easy to learn and complete within the 30-hour workshop.

B. Community Service Providers Collaboration

As an element of cultural responsiveness and relevancy, we established community partnerships [12]. We held pre-workshop art-making sessions and a week-long exhibition with the local public library. With the local Family Resource Center’s established relationship with K-8 schools, we distributed flyers targeting 4th-7th grade classrooms. Additionally, we set up hands-on activity booths at two community events whose intended audience included children from our target community. Partnering with these organizations helped to provide a familiar base of operations and legitimize the place of a technology workshop within the under-served community. In addition, our registration data showed that we reached families who would not have otherwise known about the workshop.

C. Local Teens as Teaching Assistants (TAs

We recruited a diverse staff of local high-school students by offering a stipend. Our goal for these “students as teachers” was to make the workshop atmosphere less intimidating. By using near-peer TAs, we aimed to contribute to a feeling of comfort amongst students. As shown in work by Kendall and Williams [13], receiving engineering instruction from peers contributes to student motivation. We observed the development of camaraderie between the participants and their near-peer TAs.

D. Workshop Instruction and Format

We followed the workshop timeline presented in the WIP paper [1]. We paired students [14] at the beginning of the workshop according to age, grade, and coding experience. We gave paired groups an instruction binder, one laptop, and one micro-controller with accompanying components. Most verbal instruction and direction were delivered ”one-to-one” on-demand by TAs and adults who roamed the space and remained readily available to explain concepts and help participants troubleshoot problems.

We incorporated an additional micro-controller, the Circuit Playground Express (CPX), and block-based coding because the CPX includes built-in functionality (sensors, sound, etc.) that would be difficult for novices to duplicate with Arduino, within the limited time frame. The CPX provided an accessible way for beginners to incorporate more functionality into their exhibit pieces. Students learned Arduino in the first few days, followed by CPX.

We geared the Arduino lessons toward increasing positive academic self-perception by making them self-directed, self-paced, and succinct. Students could take ownership of the work, learn by doing, and build confidence as they progressed. The lessons progressively built upon each other and covered only the discrete set of concepts and skills necessary to equip students with enough expertise to complete the tech-art project [15]. In addition, programming constructs such as loops, variables, syntax, and logic were progressively introduced as necessary concepts to grasp in preparation for the project. An example lesson is included in the WIP paper [1].

For the sessions involving Circuit Playground Express (CPX), we utilized a subset of Microsoft MakeCode lessons [16]. These programming lessons were brief enough to introduce students to the basic functionalities of the CPX, after which we provided a task that required students to explore other CPX functions on their own.

IV. The Workshop in Action

The workshop timeline (as outlined in the W.I.P. paper) included community building and skill-building stages in week one. In week two, the project building stage, the focus moved to collaboration and components of utilizing E.P.P. to complete the tech-art exhibit. We aimed to increase positive self-perception through multiple successful interactions during all stages.

A. Culturally Responsive and Relevant

1) CARING COMMUNITY: Daily communal meals contributed to the caring community atmosphere [20]. The 5:30-8:00 pm M-F workshop time is typically dinnertime in many households. To ”respect schedules and cultural norms” [12], we served daily dinners in a common dining hall furnished with round tables. Parents, siblings, and workshop staff were invited to eat dinners with the students. Midway through each session, we took a 15-20-minute snack break. By the start of the second week, students and staff began to form ad hoc groups to play games and socialize.

2) COMMUNITY SERVICE: Throughout the first week, we continually mentioned and reinforced the end goal of creating a ”tech-art” exhibit for public display to the community. We showed students pictures of other ”tech-art” creations and talked about the practice of combining technology and art [23].

B. Collaborative

1) AFFIRMING SOCIAL INCLUSION: Upon arrival, the workshop director personally greeted all guardians and students with a cheerful demeanor. She also expressed specific words of appreciation for students’ work to their guardians upon departure after each session. We referred to all participants, youth, and adults, as team members to move away from distinguishing teachers as more important than students. We continually emphasized that each person had a gift to contribute to the project's production. These elements affirmed students' as valued participants in the workshop and contributed toward a caring community [19] [20].

2) TEAM AGREEMENTS: The lead artist introduced the concept of a team agreement [21] during the second day. She explained the idea of creating a set of agreed-upon rules of conduct and solicited input from the students about what they thought we should have in a team agreement. The students spent about 25 minutes discussing the concept and offered suggestions about what to include. On the third day, she presented a consolidated list of items as the Team Agreement. We gave each partnered duo a written copy. A staff member verbally recited the team agreement at the beginning of the next few workshop sessions.

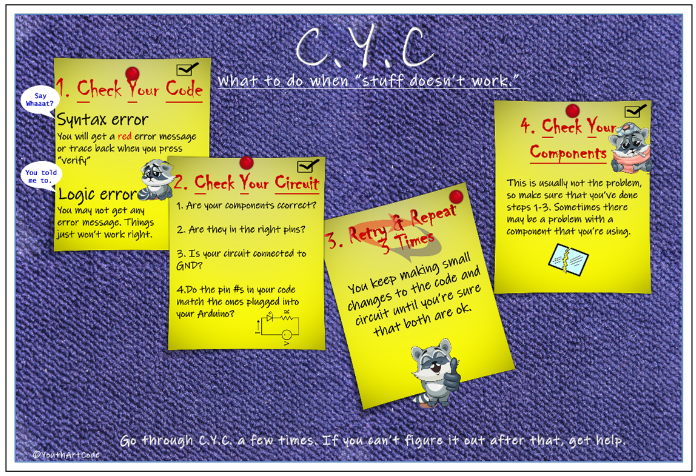

Fig. 4: C.Y.C. Troubleshooting Strategy for Arduino

C. Self-Perception Focused Elements: Skill Building Stage

1) TEXT-BASED CODING SESSIONS: We introduced text-based coding with Arduino on day one. To increase positive self-perception, we wanted to establish the student's ability to work through the "hard" stuff of text-based coding first [22]. Lessons started as simple as possible, using minimal components and code. We introduced new concepts such as the importance of exact syntax, how to read error messages, how to align components properly, looping constructs, variables, etc. As the lessons progressed in difficulty level, they followed the same format of introducing and explaining code and showing a diagram of the Arduino setup. Teaching assistants continually asked pairs if they required any assistance even if students did not appear to be struggling. Students commented that the staff was very helpful and eager to assist. This ready availability of help led to greater ease and assurance as lessons increased in complexity.

2) NORMALIZE ERRORS: For the Arduino lessons, we groomed participants to expect problems (syntax, logic, and circuit errors) and affirmed them for acknowledging issues they encountered. As a precursor to this, we had the staff create Post-it notes noting problems we encountered during training. We placed these notes on a whiteboard to show the participants that having problems was typical and expected. We gave each pair a set of Post-it notes, directing them to write down problems they encountered and display the notes on the work-space wall at their station. We set the expectation that each team would have at least one problem to share with the group. In our closing meeting for the session, we asked each team to describe a problem from one of their Post-it notes. As errors arose, the teaching staff showed students how to use the C.Y.C. steps (Figure 4) to discover where their setup had gone wrong. The staff also explained how to read trace-back errors and understand what they meant. As they became more familiar with the routines of coding and building circuits, students developed a level of self-sufficiency and relied less on staff assistance.

3) BLOCK-BASED CODING: When we introduced block-based coding with Circuit Playground Express (CPX), most students found it easier and more enjoyable (although students with prior experience in Arduino stated a preference for "real coding" [22].) The introduction of sensor input and event-driven coding added another dimension to the usefulness of micro-controllers that would have taken more time and added components using Arduino. The CPX development environment [16] has a tab option that shows the text code generated by the blocks. We showed students that even though they were doing block-based coding, they were producing text code "behind the scenes." We explained that block-based coding eliminated syntax errors but not logic errors. Students enjoyed the interactive nature of the CPX sessions provided by the built-in sensors and buttons.

4) INCREASING SCHOLASTIC SELF-PERCEPTION: At the end of each lesson, we created a "Challenge-Time" assignment for students to complete before moving on to the next lesson. In this assignment, we asked students to modify the setup created during the previous lesson. The challenge affirmed their success at completing the last lesson and then prompted them to make a change and re-enforced the lesson's concepts, allowing the student to demonstrate their ability to solve a problem independently. For example, in Figure 5, after lesson 1, we challenged them to change the pin number for components from 3 to 4. For the CPX challenge assignments, students were given a set of actions to program and provided with an obscured block-code diagram as shown in Figure 6.

5) ART SESSIONS FORMAT: Intermixed between coding lessons were paper-crafting sessions teaching flower making, leaf making, stem making, and other construction skills using a variety of papers, paints, and other crafting materials. Crafting sessions were hands-on and produced materials that served as resources for the final project implementations. The artist first demonstrated how to perform a particular task and then gave students the materials to practice the task and increase their skill, giving further guidance as needed. Some students found crafting sessions to be relaxing and fun, while others found them challenging. When students expressed harsh judgment of their pieces, staff verbally esteemed each student's work,

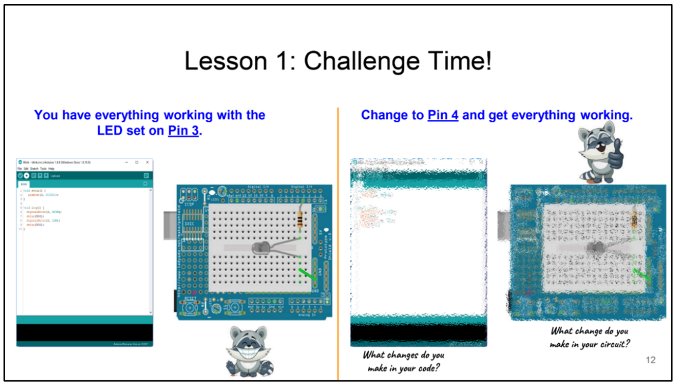

Fig. 5: Challenge Time for Arduino Lesson 1

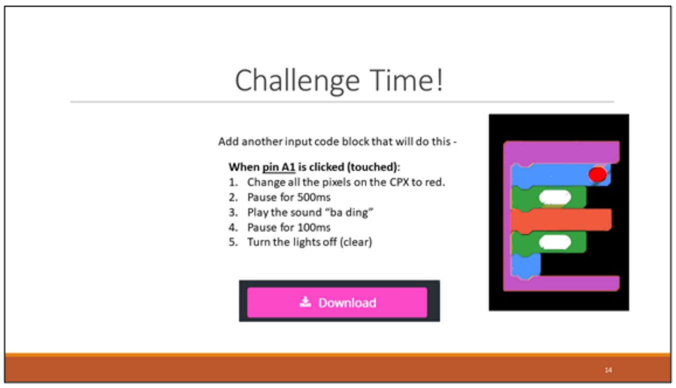

Fig. 6: Challenge Time for CPX Lesson 1

emphasizing that the uniqueness of each piece was what made it worthwhile.

6) PREPARE FOR THE PROJECT BUILDING STAGE: In the skill-building phase, we introduced students to requirements and design concepts in a practical and hands-on manner. Having gone through a series of coding lessons to produce prescribed actions, we asked students to develop their own ideas. Using the CPX, they had to design their own sequence of micro-controller actions under the following requirements: 1: Have at least four different actions, and 2: Do not re-use any actions covered during the previous CPX lessons. They first had to write out the actions on a sheet of paper and show the plan to a staff member before writing the code. We introduced students to the ideas and terms of design, requirements, and planning through this process. This exercise served as a precursor to the project building stage during which we would re-introduce, at a larger scale, the process of fulfilling requirements, planning, and documenting a design and building based on the plan. At the end of week one, all students demonstrated a level of proficiency in coding and crafting. We prepared to join paired students into teams of four. We polled students individually about the role that they wanted to play on their team and gave the options: coder, artist, or both/either. Given this input, we ensured that each group had a mix of coders and artists, paying careful attention to match skill levels and temperaments.

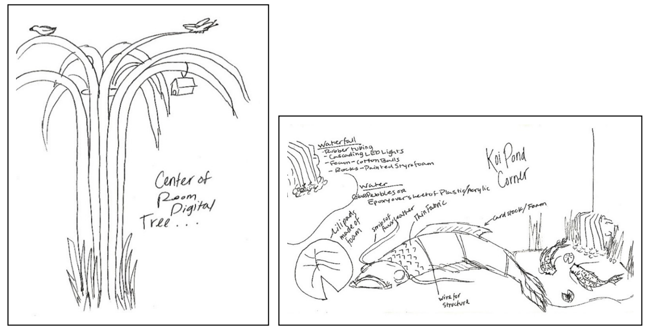

Fig. 7: Sample Artist Sketches

D. EPP Elements: Project Building Stage

We began to focus on project building and elements of EPP in week two. The lead artist had already sketched out several designs that incorporated micro-controllers with paper and other media to create garden-themed elements such as LED trees, glowing fish, and lighted flowers (Figure 7.) We let the participants examine these sketches.

WWe emphasized the fantastical and creative/non-realistic designs as an example that their teams could design anything they wanted if it met the garden theme requirement. We then explained that each team would come under contract to produce at least two pieces for the exhibit, one piece pre-designed by the guest artist and one that the team would design itself. We revisited the concept of understanding requirements and planning a design before building. Available materials were laid out in the workshop space, and we invited participants to view, touch, and explore all the available elements from which they could construct their pieces.

We incorporated the five dimensions of EPP as integral components during this stage of the workshop. Our goal was that successful interaction with EPP would increase engineering affinity in the participants.

1) DESIGN : We tasked student teams to design one or more pieces for the exhibit given the following constraints and requirements:

1) All pieces had to conform to a "garden" theme.
2) All pieces had to utilize paper elements.
3) All pieces had to utilize at least one micro-controller.
4) If their piece required more than one one-meter long LED strip, an Arduino micro-controller had to be used.

The teams first provided sketches of their design and met with staff to discuss their ideas and the materials needed to produce their design. Examples of student sketches are shown in Figure 8. Once we all agreed on the design and materials, teams had to create a prototype to demonstrate that they could carry out their design. The prototype also helped to refine their ideas. After completing their prototypes, several teams modified their design or initially requested materials.

2) PROJECT MANAGEMENT: The Agile software development inspired principles of sprint planning, and daily standups [17], [18] were the primary instrument used to incorporate project management into the experience. Students planned

Fig. 8: Sample Student Sketches

TABLE I: Constructed Pieces from Sketches

their projects and discussed their plans with the workshop director. We held daily stand-up meetings at the end of each session, during which each team responded to three questions: What did you accomplish today? What do you plan to accomplish tomorrow?, What is blocking your progress? The daily stand-up meetings helped students stay organized and identify the next steps and additional materials needed to complete their project. If teams required supplemental materials, a staff person provided the acquired materials the next day. In addition, during stand-ups, we gave teams the option of requesting a "consultant"(TA or staff) as a resource to fill in any knowledge, human resources, or skill gaps. The meetings appeared to give the teams actual ownership of their projects and solidified their intention to produce the deliverables.

3) ANALYSIS: The analysis dimension was the most challenging to incorporate because the wording in the survey [24] specifically involved math skills, calculations, and equations. We took the liberty of abstracting this wording to overlap with computational thinking [25], where the act of writing code falls partly within this domain. We directly incorporated the analysis aspect of "identifying what we need to know to solve a problem or complete a project [5]." Since both coding and paper crafting skills were necessary to complete the project, teams identified how best to perform different aspects of creating the piece. For the coding elements, they identified the type and number of micro-controllers and LED strips that they would need to make the desired effect. For the paper-craft elements, they identified which materials and techniques they would need to employ. They also determined whether they would require the use of a consultant.

4) COLLABORATION: We emphasized collaboration in the project phase as team members work with each other to create their finished pieces. Self-identified "artists" and "coders" worked together to discuss design ideas and create a consolidated proposal for their team contract. Once contracted, they divided the work into smaller parts that individual team members could complete. Team members (and staff) routinely contributed to others' work to finish each piece. Additionally, cross-team collaboration was encouraged. We believe that collaboration was the most exercised EPP element for this workshop stage.

5) FRAMING AND PROBLEM SOLVING: In this area, participants had to apply their acquired knowledge and skills to create an art piece for a public exhibit. They engaged in the process of creating a prototype and making modifications to their initial designs based on input from team members and trial and error. Some members found it necessary to learn or improve upon skills to complete their design elements. Several teams had to solve unexpected problems during construction while implementing their design.

V. Data Collection, Analysis, and Findings

We collected data from pre-/post surveys and participant interviews. For the survey, we utilized a customized version of the What I am Like Scale (WIAL) survey, which has been effective in measuring self-perception in adolescents [24]. The WIAL questions are based on the What we Am Like and Self-Perception Profile for Children (SPPC) [26]. For the interviews, we questioned participants using prompts concerning self-perception and their experience during the workshop.

A. Quantitative Data - WIAL modified survey

The WIAL self-perception survey scale has five specific domains: Scholastic, Social, and Athletic Competence, Physical Appearance, and Behavioral Conduct. It also has a Global Self-Worth sub-scale [24]. The Affect Toward Engineering Professional Practice survey [5], which aimed to measure affinity toward engineering practice, identified five domains of measurement: Collaboration, Design, Framing and Problem Solving, Analysis, and Project Management. We modified the WIAL instrument to include the EPP dimensions of Framing

TABLE II: WIAL Survey Results

Group	Pre-M(SD)	Post-M(SD)	t(13)	p(.1)
Social	3.03 (.76)	2.79 (.48)	-1.4	.183
Framing / Problem Solving	2.95 (.55)	2.77 (.53)	-1.66	.121
Collaboration	2.34 (.72)	2.62 (.69)	2.075	.058
Behavior	3.01 (.61)	3.04 (.52)	.118	.908
Global	3.13 (.52)	3.05 (.49)	-.536	.601
Scholastic	2.58 (.59)	2.86 (.61)	1.832	.090

and Problem Solving, and Collaboration. To this end, we replaced questions from the Athletic Competence and Physical Appearance domains with questions related to the Framing and Problem Solving and Collaboration domains in the EPP survey and removed all references to the word "school." We collected twenty-five WIAL surveys during the first two days of the workshop and stored them without evaluation. However, after the workshop, we realized that some errors had been made during the survey collection. As a result, we only retained fourteen complete and identifiable WIAL surveys from the last day that also matched surveys from the beginning and used only this data for the two-sided T-test (Table II.)

Results from the modified WIAL survey show an increase in Collaboration (EPP) and Scholastic (self-perception). However, the WIAL does not show any significant difference in all other domains.

B. Qualitative Data - Interview Questions

An adult staff person interviewed twenty-five students during the first two days. Over the last two days of the workshop, the staffer interviewed nineteen students. We asked several questions, some of which we present here:

- Pre-workshop questions
  - What do you think will be the hardest part of this workshop?
  - What do you think will be the easiest part of this workshop?
  - If the group split into a coder team and an artist team, what team would you be on and why?
  - What do you think will be the hardest part of this workshop?
- Post-workshop question
  - What role did you play on your team?
  - What part was the hardest?
  - What part was the easiest or most fun?

We posed the post-workshop questions to look for:

1) The role they had predicted for themselves versus their chosen role during the construction phase.
2) Their expectations of difficulty versus what they found difficult in fact.
3) Their expectation of what would be easy versus what they really found easy or fun.

Our preliminary step was to wrangle and visualize the combined interview transcripts using Trifacta, Browserling, and WordArt. Next, we coded the data using a priori codes to examine what students felt would be the "hardest" and "easiest" portions of the workshop. We also wanted to know if their anticipated area of difficulty correlated with the roles they predicted for themselves. We compared this data to their post-workshop responses. Of the twenty-five participants, we compared the pre-/post responses of eleven, as some students did not provide complete answers regarding their preferred role.

1) BEFORE RESPONSE ANALYSIS: The initial visualization revealed that "coding" often occurred when students were asked to anticipate the easiest part of the workshop. However, when asked about the anticipated hardest part of the workshop, a theme of "errors" and "fixing" was apparent in the visualization. The beginning interviews occurred on days one and two, and Arduino sessions were already in progress. Further analysis of coded interviews revealed that several students referred to coding as "typing" and made a distinction between coding and errors. One 9-year-old female student responded, "The easiest part is typing... The hardest part is when you have an error and you have to fix it. Because the errors are kind of hard to figure out, so you pull the error page, like on the computer. It's a small thing, and we pull it up to see what's wrong. The first thing that pops up that's what the error is, so then you can fix it, and it just turns out to be easy again." Other students found the coordination of code and micro-controller to be challenging. One 12-year-old female responded, "The hardest part is coding and circuit wiring because one thing wrong could just ruin the whole thing so you have to make sure you're thorough and that you get everything exactly how it's supposed to be."

2) THE ROLE OF ART: One premise for the workshop was that students would come with a base level of self-efficacy in arts/crafts due to its inclusion in primary school activities, which could serve as an attractive base through which to integrate engineering affinity. To discover which aspect of the workshop seemed attractive to students, we asked, "If the team was divided between artists and coders, which role would you pick?" Surprisingly, an equal amount picked artist (6) and coder (6), with one student choosing both roles. Some students shied away from the artistic elements. One 10-year-old girl responded, "I'm not really an artistic person." 9- and 11-year-old siblings who had prior experience building circuits replied, "(the hardest part will be) building the flowers because we never done it before." However, other students looked forward to the art. One 11-year-old girl responded that she would pick the artist role, "I like all kinds of art like sculptures, pottery, you know things like that yeah. . . just like all kinds of art." Of the students who predicted a coder role, only two thought that coding or circuits would be the easiest aspect of the workshop. This indicates that, even though students may have found coding difficult, they still wished to assume the role.

3) AFTER RESPONSES ANALYSIS: Visualizations of the responses indicate that coding played a more dominant part in the participants' minds at the end. Analysis of coded interviews revealed that, while students mentioned coding more often, the prevalent topic centered on their project design

TABLE III: Pre-workshop Interviews

Student	Predicted Role	Predicted Hard	Predicted Easy
EM	Coder	None	Coding
SM	Artist	Assembling the large final piece	Wiring circuits
RB	Artist	Wiring circuits	Coding
BR	Coder	None	Wiring circuits
DK	Coder	Wiring the circuit	Art
RM	Artist	Coding	Art
BN	Coder	Coding	Art
KN	Artist	Coding	Art
JH	Artist	Coding	Art
TN	Coder	Coding	Art
VC	Coder	Coding	Art

TABLE IV: Post-Workshop Interviews

Student	Actual Role	Actual Hard	Actual Easy/Fun
EM	Both	None	Coding
SM	Coder	Coding LED strips w/ Arduino	Painting, experimenting
RM	Both	Art	Coding
BR	Coder	Coding LED strips w/ Arduino	Coding CPX
DK	Artist	Art	Art and Electronics
RM	Artist	Design decisions	Design decisions
BN	Coder	Design decisions	Coding
KN	Coder	None	Coding CPX
JH	Artist	Construction	Friends
TN	Both	Construction	Coding
VC	Both	Construction mistakes	Construction successes

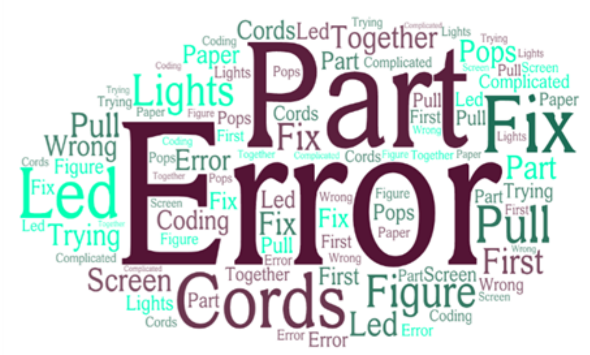

Fig. 9: Word Graph of Hardest Before Responses

and construction. For example, one 11-year-old boy whose design included an LED snake stated, ”(the hard part was) thinking how we were going to make the head. It took two days. (the easiest part was) deciding what we were going to use as the body of the snake.” Another 11-year-old boy, whose design included a fish in a pond, stated, ”I only failed once on the fish. (the fun part was) making the pond and showing the lights to others.” The 11-year-old girl who also worked on the same team said, ”(the hardest part was) coding the Neopixel strips for the pond. I had the help of a TA, but we had to keep starting over again because it kept finding errors in the code. So I had to do it over and over again ... (the fun part was) painting the bin different shades of blue and playing around with the materials to see what it would turn out to be.” One 10-year-old girl whose project was lighted paper flowers stated, ”(the fun part was) doing the coding and making it work. Sometimes it was hard to make it work.” A 9-year-old boy, whose design was a tree with coded CPX ”lemons,” stated, ”I made a base. I failed two times in building the tree. (the hardest part was) making the tree not fall down or breaking.” Several students took on a different or an additional role than they’d predicted, indicating they had expanded their self-perception to include a new role. We believe the affirming, community environment facilitated this expansion. One 11-year-old boy who knew no participants prior to the workshop and chose the artist role indicated a willingness to try coding in the future, ”I’m definitely coming next year for sure...I get to hang out with my friends and also learn different things and experience like the work of coding.”

VI. Conclusion, Limitations and Future Work

The workshop offered youth ages 9-13 the opportunity to experience working within the domains of engineering professional practice (EPP) by combining physical computing and art to create and build their own designs. We hoped to increase self-perception and affinity for engineering in this workshop. Results from the modified WIAL survey show an increase in the Collaboration, and Scholastic domains, corresponding to increases in self-perception and EPP. However, the WIAL showed no significant difference in all other domains. The short duration may not have been sufficient to affect the social and behavioral domains, which have a deep-seated nature. Also, we relied on participants to make experiential inference between their practical experiences and each domain, whereas a more explicitly named link calling for meta-cognitive reflection may have more impact. This possible need for longer duration and explicit discussion of how their experience fits within each domain may also help to increase self-perception in Framing and Problem Solving. Although the original WIAL survey has been validated, our modification of the survey was a limitation in this study. The novel combination of the WIAL survey with EPP domains requires further investigation.

Student interviews showed an increased awareness of and affinity with code/coding and the design and construction process. Since we place coding, design, and construction within both the Analysis and Framing and Problem-Solving domains of EPP, we may partially interpret student experiences as falling within these domains but cannot clearly show an increased affinity based on the limited answers to our interview questions. Future workshops may need to be longer, more explicitly emphasize the critical components of EPP,demonstrate how different parts of the workshop fit into each domain, and allow students to conduct meta-cognitive reflection on their experience. In addition, future interview questions could be refined to uncover more specific data pertaining to this study’s goals.

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