Designing from a Novel University Engineering Course as a Model for High School Education

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***Abstract*—K-12 teachers seek examples of relevant and appropriate content that engages a diverse audience for their courses. Naturally, teachers may look to universities for inspiration and even curriculum and course content. In this innovative practice paper, the researchers worked with an urban public high school that had an existing partnership with our home university; this was a natural place for high school teachers to find educational examples. Our university recently created a novel introductory robotics course which the leadership at the partner high school saw as an attractive model for an 11th grade engineering course. To help create the high school engineering course, we facilitated participatory design sessions with various educational stakeholders who had varying visions for the course; these stakeholders included high school teachers, university faculty, educational researchers, and undergraduate students who had previously taken the university robotics course. In this paper, the authors explore the ways in which ideas from the participatory design sessions shaped the first iteration of the engineering course. A design challenge the authors faced was incorporating the stakeholders' competing and sometimes contradictory visions for the course into instructional materials. In this paper, we present these methods of integration as a model for others seeking to adapt university engineering courses for a high school context.**

***Index Terms*—participatory design, K-12, robotics, engineering curriculum, computer science education**

I. Seeking authentic engineering education experiences for K-12

Recently, there has been an increased interest in wanting to integrate engineering into kindergarten through high school (K-12) across the United States [1]. This interest in engineering as a part of the K-12 curriculum is becoming important for both students and teachers [2]. With the growing awareness that engineering can be used to enhance K-12 curricula, educators and engineering researchers are beginning to provide real world scenarios that can help develop students' problem-solving skills, deepen student participation, and diversify representation [3]. K-12 teachers may find it challenging to develop engineering curriculum for the classrooms in which they teach. In the engineering space, this poses the question of how teachers can integrate an engineering curriculum into K-12 classrooms, and where they can find examples of the appropriate content to employ in their curricula? A natural place to source educational examples is from higher education, specifically from university engineering curricula, and often these occur in the form of university-school partnerships. Partnerships result in easier access to curriculum examples but can also raise a set of challenges (i.e., accountability, communication, and creating a shared vision or set of values among each partner).

We must acknowledge that the fields of software, computing, and computer science (CS) are lacking diversity in gender, race, ethnicity, geography, and family income, among many other barriers [4]. These technical fields are overwhelmingly male, while the majority identify as either Caucasian or Asian at both the university and high school levels [5]. Thus, if we source curriculum context borrowed from industry, we will be drawing on examples that are from male-dominated organizations lacking other forms of diversity. These examples may not send a message of inclusion to students. In both K-12 classrooms and higher education institutions, underrepresentation in CS is very evident [6]. Perhaps, if universities and K-12 educators work together to mirror our societal evolution [7] towards equality and equity, curricula can be designed and developed such that the number of girls and underrepresented minorities who participate in K-12 engineering education initiatives increases, and curriculum materials portray engineering in ways that are more likely to excite the interest of students from a variety of ethnic and cultural backgrounds [8].

In this paper, the authors present a study that explores the ways in which ideas from a participatory design session shaped the first iteration of an engineering course that was being designed for an 11th grade classroom at a diverse urban public school. The course proved to be unique as it adopted a project from a research institution's novel robotics curriculum. Taking account of the associated stakeholders (i.e., robotics faculty, university students who had taken the course before, education researchers, and teachers at the urban-city high school), this paper describes the process of engaging K-12 teachers in a participatory design session process as well as the interactions between the various stakeholders that influenced the evolution of course goals. A design challenge the authors faced was incorporating the stakeholders' competing and sometimes contradictory visions for the course into instructional materials. In this paper, we present these methods of integration as a model for others seeking to adapt university engineering courses for a high school context.

II. Engineering Partnership with an Urban Public School to Promote Diversity

Computer science (CS) remains a highly segregated field in K-12 education and at university and professional levels. The authors sought CS and engineering models that would support partnerships in the local community to promote diversity in order to increase the success of students throughout their careers. To create the conditions for more diversity, Goode [9] encourages K-12 schools to create an alliance between educational researchers, university CS administrators and instructors, and the director of science education in a large urban district.

The school we partner with in this study had an existing partnership with the College of Education at the authors' institution. Through this school-university alliance, the school had an opportunity to collaborate with the university's robotics program [10] that had recently piloted a novel introductory robotics course (ROB 101). In this section, we highlight the benefits of school-university collaborations and introduce the robotics course.

A. School-University Partnership Model

School-University collaborations promote diversity and iteratively bring knowledge from various partners in the university and teachers from within the K-12 community. Partnerships must often contribute to institutional goals (i.e., designing a curriculum) while balancing power between all parties. To create a successful transfer of curriculum, all partners should add to, learn, and benefit from a shared understanding of needs, values, skills, and resources that can actively support both K-12 teachers and students.

The high school we collaborated with was unique because of its location in an urban city where the school community district is 2.5 percent White, 82 percent Black, 1.4 percent Asian or Asian/Pacific Islander, 13.7 percent Hispanic/Latino, 0.2 percent American Indian or Alaska Native, and 0.1 percent Native Hawaiian or other Pacific Islander. In addition, 0.1 percent of students are two or more races, and 0 percent have not specified their race or ethnicity. 49 percent of students are female, and 51 percent of students are male. In the school district, 58.1 percent of students are eligible to participate in the federal free and reduced price meal program while 10.5 percent of students are English language learners [11].

When there are partnerships between education researchers and university administrators [9], faculty, teachers and alumni, better decisions can be made around the amount and allocation of resources for programming to attract more students into STEM. A goal for early exposure to university-level engineering content in K-12 curricula is to give students a higher sense of self-efficacy and the confidence needed to pursue higher education in engineering and/or future careers [12]. The Robotics program at our institution is committed to cultivating talented generations of roboticists starting from their K-12 experience through their continued participation in the workforce [10].

B. Introducing a Novel Introductory Robotics Course

The Robotics program recently piloted a novel introductory novel course: *ROB 101 – Computational Linear Algebra* that was designed to help students understand that mathematics is the language of engineering. Coding is what is used to make students believe and realize math is the language an engineer needs to speak in order to make systems work; thus, students learn mathematical content [13].

The undergraduate course used Julia, an open-source dynamic programming language. The course content was delivered in the form of Jupyter notebooks that can be run in a web browser. Julia's many features are suited for high-performance numerical analysis.

The math topics ***treated*** in the robotics course were made operational through computational exercises in the program. Some topics included in the course were sets of linear equations, scaling large sets of equations through vectors, matrices, determinants, and matrix inverses, and LiDAR point clouds. In our design process, the high school team decided to focus much of their attention on the first project in Rob 101. The project asked students to input LiDAR point cloud data from a robot's sensors and visualize them. The *context* for the project was robotics (e.g., the source for the LiDAR data) but the content was more about mathematics and computation. The authors found that this balance (mathematics in a robotics context, made operational through computing) was appealing to the high school experts designing their engineering course in an urban city high school.

The program completed their pilot in the Fall 2020 semester, where it was recognized that students who participated in the pilot class were also inspired to take new courses, expanded or confirmed their engineering fields of interest, joined labs to conduct undergraduate research, joined project teams in critical roles, and retained and applied course knowledge [10].

In addition to this, the program will be extending offers to create Distributed Teaching Initiatives with other Minority Serving Institutions where they will provide explicit planning in course offerings to include remote participation of students from HBCUs, collaborate with students on a summer camp for high school students, and develop course content online (i.e., lecture videos, course notes and supporting material). The department recognizes these initiatives as structured in a way that can explicitly remove some systemic barriers for underrepresented students and builds supporting mechanisms for students to succeed [10].

III. Approach

Diverse partnerships bring together many voices and perspectives which can sometimes be contradictory to each other. At the university level, faculty work with students who have been vetted through a rigorous admissions process, while working at the frontiers of knowledge to develop new approaches. Public high schools accept all students of age in their community with the goal of engaging and educating students to be successful citizens, while realizing that not all students will matriculate into university. High School teachers do not necessarily have the background, knowledge, or experience of a university robotics faculty member. Thus, a curriculum should be created that a teacher can successfully use in an 11th grade public school engineering classroom.

In this section we will describe how the tensions were explored. We played a role in creating participatory design sessions where teachers could explore a variety of instructional approaches and technological tools for implementing the novel robotics curriculum. We describe how the partners collaborated to successfully draw inspiration and examples from the University robotics course for the high school engineering course.

A. Using Participatory Design as a Research Method

Participatory design (PD) has become a commonly used methodological approach given its promise of democratizing the design process, most notably stemming from its origin in political decision-making. Recent studies have focused on leveraging PD methods to engage with marginalized and underserved populations [14] [15] [16], as an approach to collaborative user-centered activity, beginning its origins in Scandinavia with trade unions around the 1960s and 1970s [17]. This history of participatory design research also includes participatory action research in community development and action research in schools and in communities [18]. The researchers use PD in an engineering education context. In the field of education, there are two goals for PD. One is to design educational products (e.g., curriculum) while the other is to ensure usability and utility of the product in these settings. Stakeholders must be engaged in a collaborative design process where each partner or participant has an equal voice and opportunity to share their unique expertise in contributing to the design, implementation, and use of the product [19]. PD has been used in a variety of studies; some of which include work that focuses on redesigning class instruction materials, teacher and student PD in educational technology [20].

In order to determine the needs of the 11th grade engineering course, the authors decided to use PD because: (1) it is people-centered; (2) it supports empowerment; (3) it recognizes the inseparability of theory and practice and the commitment to improving both [21]; and (4) is recognized by curriculum developers as a tool and methodology to draw out knowledge. Using these elements, the authors explored the various needs and wants of the stakeholders, which included high school math and engineering teachers, robotics faculty, education researchers and faculty, and current university students who had previously taken the undergraduate version of the course who now act as the course's teaching assistants.

B. Pre-Interviews with Stakeholders

Designing curriculum can be an iterative process. To do this, we held pre-interview sessions with each of our partners to understand their initial thoughts on what technology should be used in the 11th grade engineering curriculum (e.g., raspberry pi, desmos, geogebra, and jupyter notebooks). Desmos and geogebra are both interactive web applications which have been created for learning and teaching mathematics from primary school to the university level. In our interview sessions, an important question we asked was whether the concepts from ROB 101 would reinforce prior content knowledge about functions, graphs, and quadratic equations that were learned in their 10th grade engineering and math courses.

1) Robotics Faculty: Robotics faculty designed the undergraduate course content; they emphasized authenticity and integration when simplifying and redesigning content at the K-12 level. The robotics faculty did not view their students as special in any way nor did they explicitly recognize a student had been admitted into the university. They told us:

- A significant benefit of this course was its authenticity, e.g., "ROB 101 is how math is really done by engineers."
- They saw that mathematics and engineering naturally integrated, e.g., "*I didn't realize math and engineering courses were two different subjects. Adapting ROB 101 for 11th grade engineering sounds like a great plan.*"
- They thought that the class was easily learned by anyone with a high school degree, e.g., "*We assume zero programming knowledge for ROB 101 students. This way, we do not need to be worried about what they have learned so far and give them a chance for a fresh start.*"

2) High School Teachers and Education Faculty: The high school mathematics teachers and education faculty we interviewed were more concerned about the needs and challenges of public school students residing within the urban city. They found the robotics curriculum that was being provided by the robotics faculty inspiring, but recognized their students would find the math challenging for various reasons as shared below:

- They were worried about how their students thought about mathematics, e.g., "*A lot of students will be coming with damaged math identities from having a year or two without a math teacher* [due to COVID-19]."
- They saw a value in using technology to support student learning, e.g., "*Having [tools] like khan academy or desmos will help push their thinking on topics...*"
- They were concerned about giving students the opportunity to take the material at a slower pace than the undergraduates with significant revisiting of concepts, e.g., "*There will be some initial confusion around [certain] topics but I think that'll be worked out well with practice and repetition.*"

3) Learning Assistants: Lastly, we interviewed the learning assistants. The learning assistants were undergraduate students who had previously taken the university course in its first offering. We asked them what their experiences were when they took the class and what they could advise us with as the authors work to design the high school course. They reflected on their struggles and told us that "the [course] material was very hard." In particular, they found the application of mathematics for image manipulation most challenging and provided us with some learning objectives to consider for the high school course.

From the discussions the authors had with robotics faculty, high school teachers, education faculty, and learning assistants, we realized there was a need for algebra to be taught explicitly in the engineering course. Algebra can be used to support computational thinking, programming, and contextualizing engineering projects, like sensors, for robotics projects [22]. Undergraduate faculty take algebra knowledge as a given. Teachers at the school felt that students' algebra skills would not be strong enough to go on into the robotics curriculum without supporting and enhancing their algebra understanding.

Programming can be implemented into mathematics [23][24], and as appears in the robotics example, engineering curricula [25]. The point of the programming is to make mathematics more authentic to the actual practice of engineering. In this way, the programming embedded in the high school course might become more engaging. The faculty saw programming as part of the authentic nature of the course; teachers saw programming as a way to connect mathematics and engineering together.

While teachers highlighted the need to reinforce algebra in the design of the high school course, they were uncertain about how to teach subjects (i.e., image manipulation) without having much prior knowledge. The authors provided the teachers with a task-specific language to support the teachers because the tools can be used without prior training to complete useful tasks in a short period of time [26].

C. Learning Objectives to Explore with Task-Specific Programming Languages

There were three challenging learning objectives that we heard from our pre-interview sessions with the learning assistants. They are: (1) equations can be used to describe sections of a graph, thus, they can also describe sections of a picture; (2) colors can be specified by using equations; and (3) pixels can be conditionally selected to test the color value in the given pixel(s). The task-specific language supporting the learning of (i) image manipulation, along with (ii) introduction to systems of linear equations, (iii) vectors, matrices, and determinants, and (iv) matrix manipulation constitute the four units that make up the final project for the high school engineering course.

IV. Participatory Design Sessions to Address Instructional Design

Due to COVID-19, we were unable to host our two participatory design sessions in person. Instead, we held our sessions online while recording the session over Zoom. We observed the teachers, our co-designers, and captured data about their thoughts on learning, usability, and tool preferences as they interacted with our selection of technology tools. After each activity topic, and their respective tools, we asked our co-designers for feedback on how to improve those activity worksheets.

A. Creating Activity Sheets

In participatory design, researcher observations are traditionally recorded while participants actively use or work with an object or tool [27]. After having sessions with our stakeholders about what they envisioned for the curriculum, the first author created activity sheet guides using four different, but simpler, technology tools that could be used to support learning each of the four units in the curriculum. The authors looked for tools that teachers could make modifications to in twenty minutes or less [28] but also familiarize themselves with the tools easily.

The authors created activities for the participatory design sessions. These activities were meant to be possibilities for the high school engineering course. They could be used as-is, but were not designed to be. Rather, they were meant to serve as *design probes* [29]. They served as a concrete instance of a possible learning activity which the participants could use as a comparison point in their design discussions. They could talk about doing something *similar*, *dissimilar*, or even *addressing an entirely different learning goal.*

Dealing with traditional instruction manuals or guides for the first time, often takes up a large portion of time, creates frustration among the user, and can introduce cognitive load issues [28] especially if they have little to no prior experience working with technological devices. Instruction manuals tend to be long; many feel like they do not have the time or need to get through the entirety of the documentation. Minimal manuals avert these issues [30] because they are significantly shorter in length, focus on specific tasks that help the user become familiar with the tool, reduce the maximization of user errors, and are more interactive. It is for these reasons we chose to use minimal manuals (which will be referred to as activity worksheets) as a guide in the design of the activity worksheets to scaffold use of the tools.

There were three activity topics we expected teachers to cover (i.e., quadratics, image manipulation, and matrix transformation). Each topic had between two and three activity worksheets where each worksheet represented a different technology tool we wanted teachers to explore (i.e., desmos, geogebra, julia, and pixel equations). These activities used in our participatory design session enabled the authors to: (1) ease the learning process of the technology tools to the teachers; (2) acquaint teachers with the technology tools and envision their students using these tools in a class session; and (3) have conversations around the technology tools after the teachers had completed the activity worksheets (see Fig. 1).

The teachers were asked to work on the activity worksheets for ten minutes in our PD sessions. Teachers that finished their activity worksheet early were given the option to work on additional sections of the worksheet (i.e., exploring and going beyond), if they wished. Once the ten minute period was over, we engaged in further discussion described in the Data Collection and Analysis section.

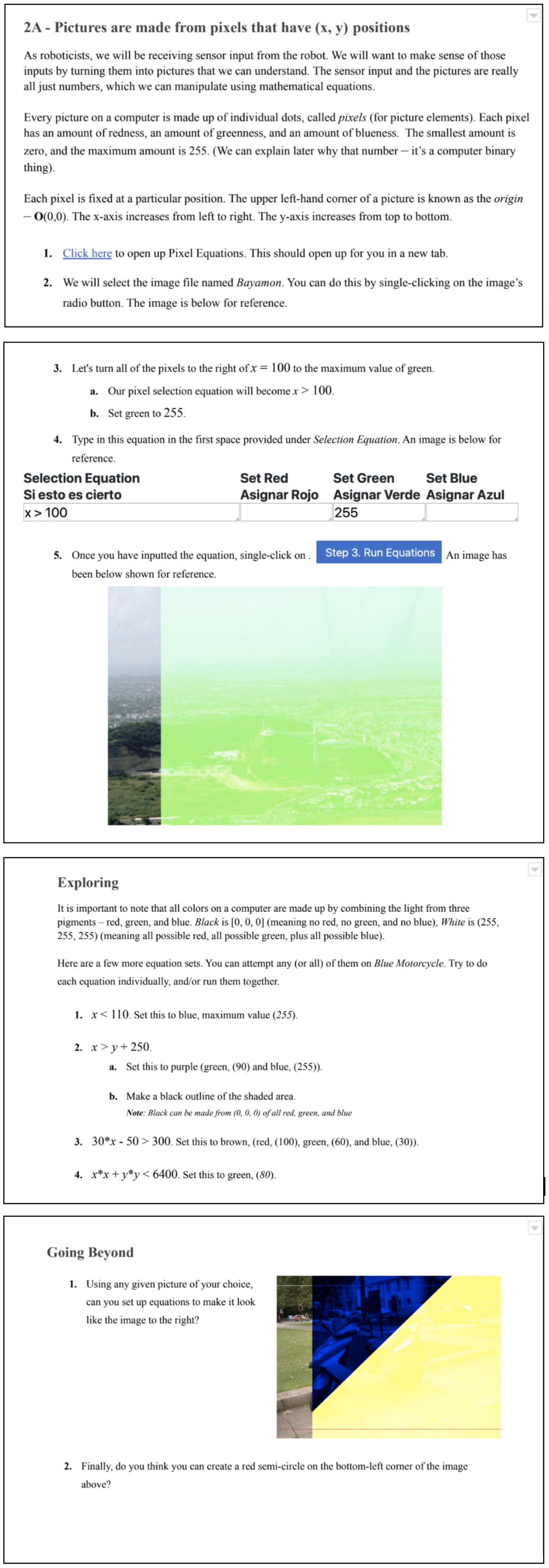

Fig. 1. An example of an image manipulation activity worksheet using a task-specific programming tool.

V. Data Collection and Analysis

A. Participants

Our protocol was reviewed by the university's human subjects review board, and was judged to be exempt from further review. We held two participatory design sessions to get further insight into the teachers' experiences as they navigated the activity worksheets. The sessions were recorded, and the recordings were transcribed by a professional. We had four participants who were recruited by our on site co-author. Each participant was given a pseudonym to assure their anonymity.

- Alyx is a curriculum designer and education researcher.
- Wendi is a math education researcher.
- Tiara is a 10th grade engineering teacher.
- Henri is an 11th grade mathematics teacher.

There were three reasons for selecting teachers as our participants: (1) they were a primary stakeholder; (2) teachers were able to give us informed advice from their reflection on their years of experience working with students. They are able to make recommendations that are likely worth following to create learning activities for students; and (3) teachers happen to be decision-makers which means that activities and technology tools cannot get adopted without their approval.

B. Analysis Methods

In this qualitative study, the data collection consisted of recording the participatory design sessions. Interviews were transcribed verbatim and analyzed thematically [31] to determine the participants' unique perspectives of the technology tools and worksheet activities we provided. Some questions we asked in our sessions were: "were the tools useful?", "how could the tools and activities be improved?", and "would your students be able to interact with these tools and activities?".

The first author identified emergent themes from the transcribed data from the recordings of our participatory design sessions. Next, two co-authors revisited the data (i.e., interview log of codes, themes, and quotes) and developed a codebook that contained overarching themes that illustrated math and engineering pedagogical practices, values, attitudes, while also answering the questions that were listed in the Data Collection section. The co-authors met again to discuss the data and refine codes and themes over several weekly meeting sessions.

VI. Thematic Findings

Our findings are the four themes that emerged from our participatory design sessions. Based on our study, K-12 education researchers and teachers need to focus on the following aspects: (1) allowing students to explore for priming/comfort; (2) motivational play; (3) prior knowledge; and (4) self-efficacy of students and teachers. The themes in this section have been drawn from multiple quotes. We provide some quotes as examples from our data.

A. Exploring for Priming

Teachers in our participatory design sessions expressed the need to take extra time to explore certain features of the technology tool before they could go on and solve problems that were given in the activity worksheets. Priming students can involve showing the technology tools to students ahead of class time so they have enough time to play around with the tools and material that they are likely to be assessed on. Often, priming can be used to (1) familiarize students with the material before its use; (2) introduce predictability into the information or activity, thereby reducing stress and anxiety; and (c) increase student success [32].

- **Alyx**: "*I was playing around with how to make a line. It took me a little bit to figure that out.*".

Participants were asked to write a quadratic equation, using the the format noted below,

$$y = ax^2 + bx + c \tag{1}$$

by clicking on a series of buttons. Fig. 2, shows the steps the participants followed in one of our activity worksheets: *Quadratic equations with desmos*. In the quote above, Alyx expresses some difficulty writing the equation because she had to use buttons in the interface to insert variables and operators into her equation rather than type them. After playing around with the buttons for a while, Alyx was able to complete the task given on the activity worksheet.

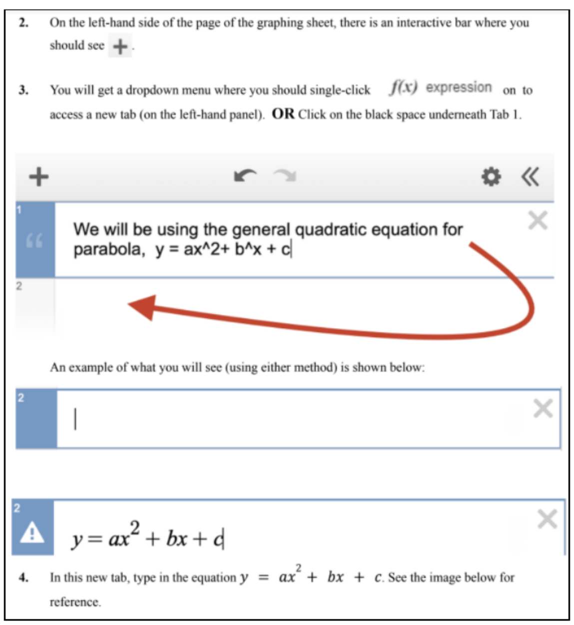

Fig. 2. A screenshot of our quadratic equations activity worksheet with the desmos tool.

B. Motivational Play

Teachers told us that play is often considered an important part of high school curricula. Motivational playing engages students in the learning process, increases their attention and focus, motivates them to practice higher-level critical thinking skills, while promoting meaningful learning experiences [33].

- **Alyx**: "*If we're thinking about having students explore some of the code and point out what they notice and wonder, for example, it might be that some students may enjoy doing that after they see what it does*"
- **Wendi**: "*I do feel like I got to explore more in Julia. It wasn't overwhelming to use Julia for that [activity], even if I was thinking in another programming language. And it's almost where students get familiar with programming languages...*"

The quotes stated above, by Alyx and Wendi, were from their reflection on using the technology tools the activity worksheets required. Alyx, with the least programming experience, found it helpful to play around with technology tools just to see what happens. In doing so, and because of her, students might be encouraged to do more with technology tools. Wendi, who has more programming knowledge, did not feel overwhelmed by Julia. Because she did not feel overwhelmed, it allowed her to explore the technology tool even more.

C. Prior Knowledge

The teachers in our participatory design sessions expressed the importance of revisiting and connecting with knowledge from previous courses (i.e., 10th grade math and engineering). In a participatory design session, a teacher mentioned how they had used a technology tool (e.g., desmos) in a math class the year before; the teacher was confident that students would be familiar and have knowledge of technology tools used from previous courses (i.e., 10th grade math and engineering) that will support their learning in the 11th grade engineering course.

- **Tiara**: "*I was thinking a lot about what prior knowledge that students would need [...]*".
- **Henri**: "*Last year, our current juniors had the most experience with desmos. I also think that if kids are already familiar with desmos in some way, shape, or form, then they can fall back to that if they need to if they get stuck*".

Participants were asked to solve quadratic equations with desmos (see Fig. 2). As Tiara was thinking aloud, she was thinking about what content experience and technology tool experience students would need to know in order to succeed. Tiara explained (not shown in quote) that students were already familiar with desmos because they had already been using it throughout the year. Because of their prior experience, students may have an easier time navigating future content than Tiara did. Tiara had less familiarity/knowledge of the technology tool. Henri, who was in a different participatory design than Tiara, echoed similar thoughts.

D. Self-Efficacy

There are [many] teachers who are yet to progress beyond using technology for their own productivity and creating teaching materials for their students [34]. Teacher self-efficacy is a teachers' belief in their ability to effectively handle the tasks, obligations, and challenges related to their professional activity. A teacher's self-efficacy can play a key role in influencing important academic outcomes (e.g., students' achievement and motivation) and their well-being in the working environment

[34]. Because self-efficacy can influence the actions a teacher chooses to take, especially in the face of impediments, it suggests that teachers with a higher level of self-efficacy tend to interpret challenges as opportunities for growth and are willing to enact sustained efforts, whereas teachers with a lower level of self-efficacy tend to perceive challenges as indicators of insufficient abilities and may give up early to avoid threats to personal competence [35]. An example of a participant with lower self-efficacy is given below:

- **Alyx**: "*I'm the one least familiar with the contents so I'm going slow*".

Alyx was working with the desmos tool for quadratics (see Fig. 4). While working on the activity worksheet, she told us she would be going slowly, and because of that, she was a few steps behind from the other participants who were in her participatory design session. She seemed to compare herself to others (who had more programming proficiency).

VII. Discussion

This study involved the facilitation, mediation, and observation between various stakeholders, who also acted as our co-designers. Sourcing curriculum content from the university was inspiring to other partners, but the teachers brought additional perspectives that the university had not accounted for. We recognize that a successful transfer of curriculum can only occur if there are shared values between university faculty and K-12 teachers.

Our stakeholders included university faculty, teachers, and previous students of the university robotics curriculum. Each had their own expertise and set of values for how they envisioned the 11th grade engineering course.

First, the robotics faculty created the course content. Conversations between the authors and robotics faculty showed that they place a strong emphasis on how 'real' engineers use math because it is the [official] language of engineering and therefore, students need to learn how to speak in mathematics in order to make systems work. Thus, learning the language of engineering would make any student a successful candidate for a technical job in the future. In addition to this, the robotics faculty also placed value on the authenticity of "real" robotics when it is being introduced (and simplified) at the K-12 level.

Second, the high school teachers challenged themselves on how to bring the robotics course to their 11th graders. As they reviewed the robotics curriculum, they realized that their goal was to bridge and reinforce certain algebraic concepts (i.e., functions, graphs, quadratic equations, etc.) from 10th grade math and engineering courses to the 11th grade engineering course. Part of the need for reinforcement of course content was due to COVID-19. The difficulty when many schools around the world switched to remote learning environments was maintaining the interactivity, authenticity, and accessibility of course materials.

An important finding was that the teachers we worked with valued making their course content engaging, where the focus was on play. Robotics faculty, however, do not emphasize play; instead, they value an advanced audience. Our high school teachers knew that enjoyment and motivation were important, and would be evidenced when students were wholly engaging in the learning tasks [19] without being overwhelmed.

Each of our findings has implications for what we should consider when adapting university engineering curricula for a K-12 context.

- **Prior Knowledge:** If students are given an environment or technology tool that they have used before, it is more likely that they will be able to relate both their content knowledge and their technological expertise. In our study, teachers reminded us of how students had used desmos the year before. If students were using it again in the following year, they would be reminded about when they used the technology tool for the first time and what context it was used in. Students would also already be familiar with the technology tool and thus, may not struggle relearning the tool.
- **Priming:** Priming gives students the opportunity to play with an environment, and is a form of active learning. When we design activities for students to use in the classroom, it can help taking into consideration whether the material content and technology tools students use are new; they may need time to familiarize themselves in order to succeed. Experience can help students who have had little to no exposure to the technology tools or to the material content being learned. The following are important characteristics of effective priming: (a) it should occur in an environment that is relaxing; (b) the primer should be patient and encouraging; and (c) priming sessions should be short. It is important to note that priming is not in the form of teaching, correcting, or testing [6].
- **Motivational Play:** Giving students opportunities to explore might lead to wondering what other equations work, inputting the equations into the tool, and then making observations and realizing many other things can be done. This is a form of active learning that can increase a student's focus while motivating them to think critically.
- **Self-efficacy:** Low levels of self-efficacy can make teachers take up a longer time to make sure they are either accurate and/or take the time to understand what they are doing (especially if this would be done in front of students). An example from a participant with lower self-efficacy tells us that we need to explore ways in which we are designing tools that are quick to learn and use, in order for teachers to be confident teaching advanced content.

Although innovation in higher education engineering is a great source for innovation in high school engineering education, we need to understand that there are differing and competing values for each stakeholder. This paper points to the importance of the different values of each of our co-designers. K-12 teachers placed greater value on connections, engagement, and play students make with curriculum, while faculty place a larger emphasis on the authenticity of course content and career placement. The faculty we worked with did not really engage or learn about the needs of K-12 students. The authors coming from the University were thus placed in the unique position to mediate discussions between each co-designer in order to negotiate, and make explicit, a shared set of values for designing new curriculum content for the 11th grade engineering course. The outcomes from these participatory design sessions are what impacted the curriculum and adoption of activities.

REFERENCES

[1] Purzer, S., and Quintana-Cifuentes, J. P. (2019). Integrating engineering in K-12 science education: Spelling out the pedagogical, epistemological, and methodological arguments. Disciplinary and Interdisciplinary Science Education Research, 1(1), 1-12.

[2] Pleasants, J., and Olson, J. K. (2019). What is engineering? Elaborating the nature of engineering for K-12 education. Science Education, 103(1), 145-166.

[3] Stehle, S. M., and Peters-Burton, E. E. (2019). Developing student 21 st Century skills in selected exemplary inclusive STEM high schools. International Journal of STEM education, 6(1), 1-1.

[4] Code.org. (n.d.). Code.org's approach to Diversity and Equity in computer science. Code.org. Retrieved from https://code.org/diversity.

[5] Bruckman, A., Biggers, M., Ericson, B., McKlin, T., Dimond, J., DiSalvo, B., and Yardi, S. (2009). " Georgia computes!" improving the computing education pipeline. ACM SIGCSE Bulletin, 41(1), 86-90.

[6] Ryoo, J. J. (2019). Pedagogy that supports computer science for all. ACM Transactions on Computing Education (TOCE), 19(4), 1-23.

[7] Amo, D., Fox, P., Fonseca, D., and Poyatos, C. (2020). Systematic review on which analytics and learning methodologies are applied in primary and secondary education in the learning of robotics sensors. Sensors, 21(1), 153.

[8] National Research Council. (2009). Engineering in K-12 education: Understanding the status and improving the prospects. National Academies Press.

[9] Goode, J. (2008, March). Increasing Diversity in K-12 computer science: Strategies from the field. In Proceedings of the 39th SIGCSE technical symposium on Computer science education (pp. 362-366).

[10] Grizzle, J. W. (2021). Robotics undergraduate program proposal. Michigan Robotics. Retrieved from https://robotics.umich.edu/ug/

[11] Detroit Public Schools Community District. (n.d.). Retrieved from https://www.usnews.com/education/k12/middle-schools/michigan/detroit-community-schools-101037

[12] Yoon, S. Y., Evans, M. G., and Strobel, J. (2012, June). Development of the teaching engineering self-efficacy scale (TESS) for k-12 teachers. In 2012 ASEE Annual Conference and Exposition (pp. 25-466).

[13] Ntemngwa, C. and Oliver, J. S. (2018). The Implementation of Integrated Science Technology, Engineering and Mathematics (STEM) Instruction using Robotics in the Middle School Science Classroom. International Journal of Education in Mathematics, Science and Technology (IJEMST), 6(1), 12-40

[14] Davis, M.L., Jason, L.A., Ferrari, J., Olson, B., and Alvarez, J. (2005). A collaborative action approach to researching substance abuse recovery. The American Journal of Drug and Alcohol Abuse, 31: 537-553.

[15] Hussain, S. et al. 2012. Participatory Design with Marginalized People in Developing Countries: Challenges and Opportunities Experienced in a Field Study in Cambodia. International Journal of Design. 6, 2 (2012), 91–109.

[16] Racadio, R. et al. 2014. Research at the Margin: Participatory Design and Community Based Participatory Research. PDC '14: Proceedings of the 13th Participatory Design Conference: Short Papers, Industry Cases, Workshop Descriptions, Doctoral Consortium papers, and Keynote abstracts - Volume 2 (Windhoek, 2014), 49–52.

[17] Ehn, P. (1993). Scandinavian design: On participation and skill. Participatory design: Principles and practices, 41, 77.

[18] Naimipour, B., Guzdial, M., and Shreiner, T. (2020, October). Engaging pre-service teachers in front-end design: Developing technology for a social studies classroom. In 2020 IEEE Frontiers in Education Conference (FIE) (pp. 1-9). IEEE.

[19] Kent, J. (2005). Group inquiry: A democratic dialogue?. In Research and Inequality (pp. 89-103). Routledge.

[20] Wilkerson, M. H. (2017). Teachers, students, and after-school professionals as designers of digital tools for learning. Participatory Design for Learning, 125-138.

[21] Shrader, G., Williams, K., Lachance-Whitcomb, J., Finn, L. E., and Gomez, L. (2001, April). Participatory design of science curricula: The case for research for practice. In Annual Meeting of the American Educational Research Association, Seattle, WA.

[22] Barcelos, T. S., Muñoz-Soto, R., Villarroel, R., Merino, E., and Silveira, I. F. (2018). Mathematics Learning through Computational Thinking Activities: A Systematic Literature Review. J. Univers. Comput. Sci., 24(7), 815-845.

[23] Fisler, K., Schanzer, E., Weimar, S., Fetter, A., Renninger, K. A., Krishnamurthi, S., and Koerner, C. (2021, March). Evolving a K-12 Curriculum for Integrating Computer Science into Mathematics. In Proceedings of the 52nd ACM Technical Symposium on Computer Science Education (pp. 59-65).

[24] Franklin, D., Conrad, P., Boe, B., Nilsen, K., Hill, C., Len, M., and Waite, R. (2013, March). Assessment of computer science learning in a scratch-based outreach program. In Proceeding of the 44th ACM technical symposium on Computer science education (pp. 371-376).

[25] Bråting, K., and Kilhamn, C. (2021). Exploring the intersection of algebraic and computational thinking. Mathematical Thinking and Learning, 23(2), 170-185.

[26] Newman, C. B., and Jackson, M. B. (2013). Collaborative partnerships in engineering between historically black colleges and universities and predominantly white institutions. Fostering success of ethnic and racial minorities in STEM: The role of minority serving institutions, 13, 181-191.

[27] Kawulich, B. B. (2005, May). Participant observation as a data collection method. In Forum qualitative sozialforschung/forum: Qualitative social research (Vol. 6, No. 2).

[28] Lam, N. (2011). Project-based learning in teaching English as a foreign language. VNU Journal Of Foreign Studies, 27(2). Retrieved from https://js.vnu.edu.vn/FS/article/view/1476

[29] Guzdial, M., and Naimipour, B. (2019, November). Task-specific programming languages for promoting computing integration: A precalculus example. In Proceedings of the 19th Koli Calling International Conference on Computing Education Research (pp. 1-5).

[30] Carroll, J. M. (1990). The Nurnberg funnel: Designing minimalist instruction for practical computer skill. MIT press.

[31] Carroll, J. M., Smith-Kerker, P. L., Ford, J. R., and Mazur-Rimetz, S. A. (1987). The minimal manual. Human-computer interaction, 3(2), 123-153.

[32] Terry, G., Hayfield, N., Clarke, V., and Braun, V. (2017). Thematic analysis. The SAGE handbook of qualitative research in psychology, 2, 17-37.

[33] Zhou, N., Nguyen, H., Fischer, C., Richardson, D., and Warschauer, M. (2020). High school teachers' self-efficacy in teaching computer science. ACM Transactions on Computing Education (TOCE), 20(3), 1-18.

[34] Characteristics Overview Chart - University of Nebraska. (n.d.). Retrieved from https://www.unl.edu/asdnetwork/uploads/featured-articles/Priming.pdf

[35] Engaging students in learning. Center for Teaching and Learning. (2022). Retrieved from https://teaching.washington.edu/topics/engaging-students-in-learning/

[36] Overbaugh, R., and Lu, R. (2008). The impact of a NCLB-EETT funded professional development program on teacher self-efficacy and resultant implementation. Journal of Research on Technology in Education, 41(1), 43-61.