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# NAVIGATING ETHICAL CHALLENGES IN A ROBOTICS EDUCATION PROGRAM: DESIGN SOLUTIONS AT MULTIPLE LEVELS

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This design case presents a detailed account of how we navigated various ethical issues observed in a robotics program that aimed to engage underrepresented students in robotics and STEM experience. The ethical challenges we encountered revolved around uneven participant engagement and interpersonal tensions. We tackled these challenges by designing new program elements, such as coach guides and differentiated robotics tasks. Additionally, we focused on systemic factors, aiming to reshape power dynamics by enhancing resource access, integrating the engineering design process into the curriculum, and empowering coaches to guide group activities. These design solutions were in line with the care-based ethical theory and principle-based ethics perspective, emphasizing a balanced power structure, responsiveness to individual needs and experiences, and the promotion of learner autonomy and responsibility. The redesigned program demonstrated success, evident in robust attendance, high participant satisfaction, and positive feedback from families. This design case provides practical strategies and valuable insights for educators and policymakers dedicated to promoting equity in robotics education.

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## INTRODUCTION

The rapid growth in computer and STEM jobs demands adequate and robust STEM education. However, opportunities to develop essential knowledge and skills, such as computational thinking, are limited in K-12 schools (Mouza et al., 2020). Recognizing robotics as a promising approach to engaging students in computing and STEM, the Maryland State Department of Education (MSDE) awards a robotics grant annually to assist schools and organizations in preparing all students for workforce needs. In the fall of 2021, we successfully received the grant to develop a free, weekend robotics program for elementary school students and piloted it in spring of 2022. Following that, we secured another MSDE grant to implement the robotics program both in the fall of 2022 and subsequently in spring 2023.

This robotics program served as an informal learning environment, offering six to eight two-hour sessions each semester at a public university campus on Saturday mornings. The primary program goal was to expand participation in robotics education among underrepresented students, such as females and individuals from marginalized racial communities and low socio-economic backgrounds. All participants initially entered the program with very little experience with robotics. As an informal learning program, attendance

and participation were entirely voluntary. Our top priority was to ensure learner engagement through enjoyable and meaningful experiences. In the program's initial launch in the spring of 2022, our efforts centered on designing captivating content, activities, and managing logistical implementation. As we progressed into the program's second iteration in the fall of 2022, we noticed areas that warranted examination from ethical lenses, encompassing equity and justice, power and relationships, and learner autonomy and responsibility. This design case provides a detailed account of how we navigated these ethical issues and explored viable solutions.

In this design case, "I" pertains to the lead author, and "we" represents the entire author team. As needed, gender-neutral pseudonyms and pronouns were employed to reference specific program participants, protecting their personal information.

## OUR TEAM AND WORKING RELATIONSHIPS

A team of faculty members exhibited tremendous commitment to the robotics program in various roles. Despite our demanding full-time schedules, we willingly dedicated our Saturday mornings, beyond our regular work hours, to drive to campus and actively contribute to the robotics program. The first author served as the program lead. With a robust background in instructional design, I spearheaded the design, development, and implementation of the robotics program. I also trained the university students as robotics coaches and managed the logistics. The co-authors played a pivotal role in the program, contributing significantly by observing sessions and conducting surveys and interviews with families and coaches. These collective efforts enabled us to identify critical ethical issues, design solutions, and evaluate the program's effectiveness.

We operated as a highly productive group. Despite the challenge of having regular formal meetings due to everyone's busy schedule, we consistently engaged in informal conversations, typically at the end of each robotics session, to discuss the program. These discussions became fertile ground for generating and exchanging ideas and sharing opportunities. Through close collaboration and active engagement, we developed a strong sense of ownership of the robotics program, fostering trust among ourselves and maintaining open, transparent, and meaningful communication about program design and implementation. We take great pride in this supportive and energetic team dynamic, which contributed to the continuous enhancement and promotion of the robotics program. As part of our collective endeavors, this design case was jointly created to share our honest and in-depth reflection on the ethical dimension of the robotics program, seeking to elucidate how we identified, interpreted, and attempted to tackle the ethical challenges encountered.

## SPRING 2022: LAYING THE GROUNDWORK

When preparing the MSDE robotics grant application in the summer of 2021, we first reached out to the local school district to understand the landscape of existing robotics programs and identify the specific needs we should address. We discovered that although many middle and high schools had after-school clubs focusing on robotics competitions, entry into those clubs typically involved intensive tryouts assessing students' coding and math skills, placing those with little prior experience at a disadvantage. Unfortunately, access to robotics experience for elementary students was very limited. Few elementary schools in the district offered robotics programs. Although summer robotics camps were available for upper elementary school students, participation in these camps depended on family awareness and financial resources.

With the above understanding, when we initiated the inaugural robotics program in the spring of 2022, our intention was to expand robotics opportunities by establishing a *free* program tailored for students in Grades 3 through 5, with a specific focus on those from underserved communities. We prioritized students from Title I schools for program enrollment before opening the remaining spots to students from other schools. The program was hosted at our university on Saturdays, offering opportunities for participants to not only learn robotics but also to experience the university campus, sparking their interest in academic pursuits. Due to the ongoing impacts posed by the pandemic, we encouraged siblings and close friends to join, allowing us to group them at the same table while maintaining social distance from other groups. As a result, we recruited 12 participants from Grades 3 to 7 in spring 2022, including six African Americans, two Hispanic/Latino Americans, three white participants, and one with unknown ethnicity. Seven attended schools serving low socioeconomic status (SES) communities. Three undergraduate students were trained as coaches to facilitate the robotics sessions. The participants' age range, although broader than the original plan, presented minimal challenges. Since all participants were new to robotics, each coach could facilitate a group of four novice learners without much difficulty. The program was well received, demonstrating its effectiveness in fostering learners' computational thinking skills and STEM knowledge (Cai et al., 2023).

## FALL 2022: RECOGNIZING ETHICAL ISSUES

In the fall of 2022, we welcomed back five returning students and successfully recruited an additional 12 new students, resulting in a total enrollment of 17 participants, spanning from Grades 2 to 6. The program design resembled that of the spring 2022 program, featuring a STEM-related theme and numerous hands-on activities conducted over six two-hour weekend sessions. The former coaches were unable to return to the program due to scheduling conflicts. Therefore,

three new student coaches, including two graduate students and one undergraduate, were trained to facilitate the program.

Typically, during each session, I supervised the overall implementation and sometimes assisted the coaches in facilitating group activities. I also seized the opportunities to chat with participant's families when they brought their children to the program. These casual conversations helped us gain insights into the participants and their backgrounds. Other faculty members conducted observations during each session. They meticulously recorded field notes or documented the program's implementation through photos and video clips.

Following the session's conclusion, we met to exchange our experiences and observations. Due to our established trust, we openly raised issues identified and explored possible reasons behind them. One recurring observation was the uneven engagement among students, manifesting in various ways: Some did not participate in the hands-on activities, sitting quietly at their tables. Others engaged in conversations with peers, instead of paying attention to the coach's instructions or working on the tasks. We collaborated to piece together our knowledge and observations of the program, often uncovering interesting insights. For example, one of us raised the question, "*I noticed Jordan frequently went out to find [their parent] and ask for a hug during today's session. Any idea why?*" I shared that I had chatted with Jordan's parent earlier and learned that they had a previous negative experience with school and had been homeschooling for an extended period. I surmised that, since this robotics program was a new environment for Jordan, they wanted to make sure their parent was present to feel safe.

Another issue we often discussed revolved around tensions among members at the same table. We observed a situation where two individuals, both returning members, held different opinions about how to build the robot. Each believed their approach was correct, as they did a similar activity in the last program, and neither was willing to negotiate or compromise. Consequently, they worked on the task separately. Unfortunately, the third member at their table, a new learner, felt left out and unsure of how to participate in the process. On another occasion, a group of participants were testing their codes with the robot. However, the robot accidentally fell off the table and broke, which triggered a heated discussion within the group. One participant turned to another and complained, "*You should fix it. You dropped it, so it's your responsibility.*" The other member defended, "*I didn't break it. I didn't know it would fall.*" Although these examples are typical kinds of conflicts in learning environments, they represent challenges to the goal of creating an inclusive environment for each student. We felt motivated to make adjustments to the curriculum and program environment to help students feel more comfortable working with coaches and friends.

## SPRING 2023: REDESIGNING THE PROGRAM

### Our Ethical Positionality and Design Considerations

As a team, we continuously discussed the various issues emerging from the robotics program, including those mentioned above. Through these group reflections, we gradually developed and refined our ethical positionality. We were always mindful that the primary program goal was to broaden access to robotics education, particularly for those with limited opportunities. This overarching goal directed our efforts to foster an inclusive environment to ensure all students felt welcome to participate and inclined to return and invite their friends. This guideline led to a greater emphasis on peer relationships and collaboration over competition and the rigid objective of task completion.

In alignment with the program goal, we viewed this robotics program as a dynamic informal learning environment (Burghardt & Hecht, 2020). This perspective guided our design to prioritize learner engagement and program experience over a single emphasis on academic growth.

Furthermore, we acknowledged the diverse backgrounds of our participants and approached the design with racial and cultural sensitivity. Throughout the robotics sessions, we often observed power dynamics influenced by individuals' characteristics, such as age, personality, and prior experience. Therefore, we strove to ensure equal participation and engagement.

### Design Context and Overall Design Process

The program enrollment in spring 2023 showed a diverse spectrum of participants, comprising five newcomers, seven returning for the second time, and four joining for the third time. Among the 16 members, ranging from Grades 2 to 6, seven were female, and nine were male. The group included five African-American participants, six Asian participants, four White participants, and one participant whose ethnicity was not provided.

The same three coaches from fall 2022 returned for the spring 2023 program. Additionally, we welcomed back a fourth coach who had been part of the team during spring 2022. We were delighted with the composition of the coaching team, not only for the improved coach-to-participant ratio (from 3:17 to 4:16), allowing for more individualized attention, but also for their collective experience with the program and established relationships with some participants. The four female coaches came from diverse racial and ethnic backgrounds (African American, Asian, Indo-Caribbean, and White), representing various disciplinary fields, including education, chemistry, information technology, and business. This diversity enriched our team and enhanced the inclusivity of our program design because

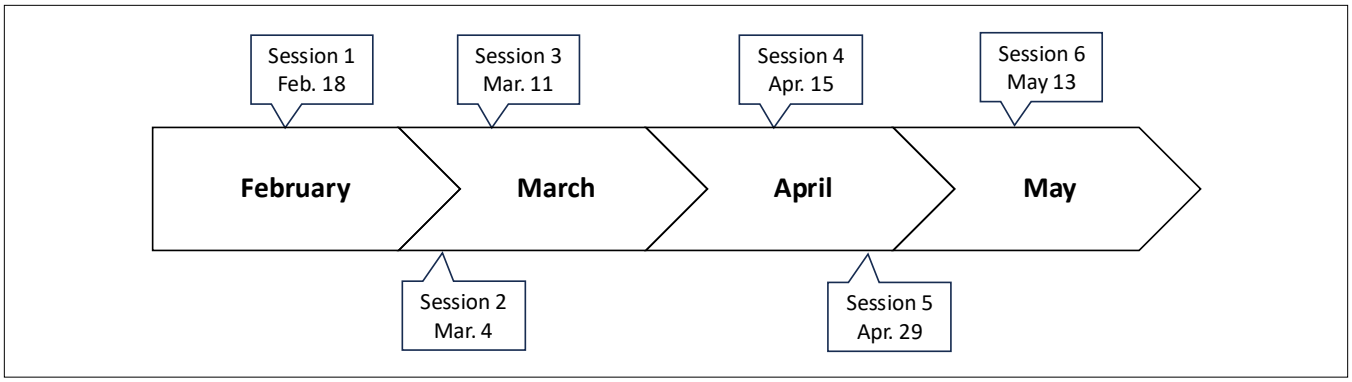


**FIGURE 1.** Program session schedule in spring 2023.

Session 1: 20230218

| | Topic & Main Content | Warm-up | Opening | Problem / Challenge: Engineering Design & Building | Problem / Challenge: Controlling & Coding Robots | Ending |
|---|---|---|---|---|---|---|
| 1 | Mars rover launch<br><br>Dust storm on Mars | *CT<br><br>*BPS<br><br>Name tags | Presentation_20230218.pptx<br>1. Introduction<br>2. Introduction to challenges<br>3. Engineering design process | **Beginner:**<br>Can you design and build a **shelter** to protect astronauts from the dust storm on Mars?<br><br>**More advanced learners:**<br>Can you design and build a fan for astronauts to use in the shelter?<br><br>Scaffolding activities:<br>- Disassemble<br>- Lable the electronics<br>- Build with electronics a & b<br><br>For coaches: Instructional Guide<br><br>For students: Handout or Activity Sheets | Drive the robot to go through a maze while avoiding knocking down any obstacles.<br><br>Introduction to coding<br><br>For coaches: Instructional Guide<br><br>For students: Handout or Activity Sheet | Wrap up<br><br>*Exit slip |

**FIGURE 2.** Draft design created using the table template. Table headings specify the session components.

participants could see their identities and academic interests potentially reflected among the robotics coaches.

The program redesign process encompassed intensive, multi-level team efforts within a tight timeline. Student coaches and faculty were on winter break until the last week of January, leaving only three weeks before the first session in spring 2023. Given the busy start of the semester, regular all-member meetings to discuss the program redesign were not feasible. Fortunately, we did not have to start everything from scratch. Through emails and conversations, we adopted the same "Mars" theme from spring 2022. I took the lead in outlining the program schedule and format based on previous programs. The spring 2023 program spanned from mid-February to mid-May, offering six two-hour sessions held at our university campus. Sessions were scheduled with a usual interval of one or two weeks, with an extended break between the third and fourth sessions to align with participants' spring break (see Figure 1). Following the format of the fall program, we conducted the first five sessions in a spacious classroom where the robotics kits were stored. The final session, designed as a showcase event, took place in the makerspace room on the same floor—a larger space accommodating participants and their families.

We followed the same structure employed in spring 2022 and fall 2022 to organize activities for each session, given its proven success in the previous implementation (Cai et al., 2023). I created a table listing the session components and used it as a template to collaborate with the coaches for specific activity design (see Figure 2). Given the coaches'


**FIGURE 3.** During the session opening, a coach introduced Mars Ingenuity Helicopter.

experiences, they were already familiar with these components and the flow of the session (Cai et al., 2023):

1. **"Warm-up" (10-15 minutes):** After sign-in, participants were taken to their seats and encouraged to work on informal hands-on activities. Typically, it was a free-build activity with minimal instructions provided. For example, "*Imagine you are traveling to Mars. Use the Vex Go pieces to build one thing you think important to have on Mars (no electronics)*".
2. **"Opening" (10-15 minutes):** This component marked the official start of the session. The coaches introduced a specific topic related to the program theme, using slides and/or videos. They often asked questions and invited individual participants to share responses (see Figure 3).
3. **"Build" (30-40 minutes):** A scenario or challenge was provided, and participants were encouraged to work in groups to design and build artifacts using the robotics pieces. For example, "*Can you design and build a spaceship to send astronauts to Mars?*"
4. **"Coding" (40-50 minutes):** Participants collaboratively coded their robots to perform various tasks within a theme-related scenario. For example, they programmed the "rover" to drive from Point A to Point B to conduct surface operations on Mars.
5. **"Ending" (10-15 minutes):** An exit slip was distributed for participants to rate their satisfaction with the session and share their overall session experience. Participants and coaches began cleaning up while waiting for the parents or guardians to sign off.

While I independently crafted the draft design for each session, collaboration with the student coaches and my faculty colleagues was crucial. Prior to each session, I organized two 1.5-hour planning meetings to work with the student coaches in refining the design and generating an implementation plan. These meetings were open to my faculty colleagues, allowing them to attend as their schedules permitted.

At the initial meeting, held approximately seven to ten days before the session, we collectively reviewed the draft design, focusing on ensuring that the content and activities would be engaging for all students. The coaches' knowledge and experience with the participants were valuable assets in the process. They provided insights into prioritizing content, arranging grouping and seating, and implementing activities to optimize the program experience. For instance, one coach suggested pairing Ariel and Charlie:

> *"Charlie is at a more advanced level than Ariel, but the pair works well together. Charlie makes Ariel feel comfortable*

*and is just a great kid in general. It's evident that Ariel does not feel confident taking the lead with coding and [they] often would rather sit back and watch. However, Charlie is aware of this, and will step by step go through each of their codes and explain why it has to be this way. I think this has helped Ariel a lot, and I've noticed Ariel trying more."*

Another integral part of the meeting involved the coaches conducting hands-on testing of the activities. They utilized the robotics kits, going through each step of the activities as if they were participants. This hands-on testing served as a co-design process, enabling us to collaboratively enhance instructions for clarity, adjust activity sequences, and create scaffolds for new and beginner participants, ensuring a more customized and inclusive experience.

After the first meeting, the coaches individually finalized their presentation slides before our second meeting, often referred to as the "*mock session*". This meeting was usually scheduled for the day before the session, in the same classroom where the session would take place. During the mock session, the coaches took turns presenting their slides to the rest of the team, who assumed the roles of participants and provided feedback. Following this, we worked together to set up the room, arranging tables to create five stations, each accommodating three to four students. A sixth station was designated for faculty to conduct observations. Coaches gathered materials, such as robotics kits and activity sheets, to set up their assigned stations for the next day. At times, depending on the planned activities, we would also pre-build robots or set up a field for testing robot movement.

The session implementation was similar to previous semesters, as described earlier. Immediately after the session, the faculty team convened to reflect on the session, discussing what went well and what needed attention with a continued emphasis on learner engagement. Following the session, each coach completed a written reflection, focusing on the overall session experience, participant-coach interactions, participant-participant dynamics, challenges encountered, and coaching skills. These reflections from both faculty and coaches were revisited as we began the design process for the next session.

**FIGURE 4.** Classroom setup for the robotics session.

### Solutions Designed to Address Ethical Challenges

Throughout our design process, we consistently worked to enhance the ethical dimension of the program. When facing ethical tensions, we focused on identifying the underlying reasons rather than addressing them superficially. Below, we elaborate on the solutions designed at various levels to address the ethical challenges.

#### *Improving access to resources and coaches*

Uneven engagement among participants was a recurrent issue during the robotics sessions. We attempted to explore this concern from multiple lenses to understand its root causes. The combination of faculty meetings and coach reflections helped us gain valuable insights. When delving into the reasons, my faculty colleagues, as observers, often brought up ideas that the coaches were initially unaware of because they concentrated on the group of participants with whom they closely worked, rather than considering the dynamics of the entire classroom. For example, while the coaches frequently mentioned individual factors, such as interest or fatigue, as potential reasons for low engagement, faculty pointed out deeper systemic issues at play. Applying

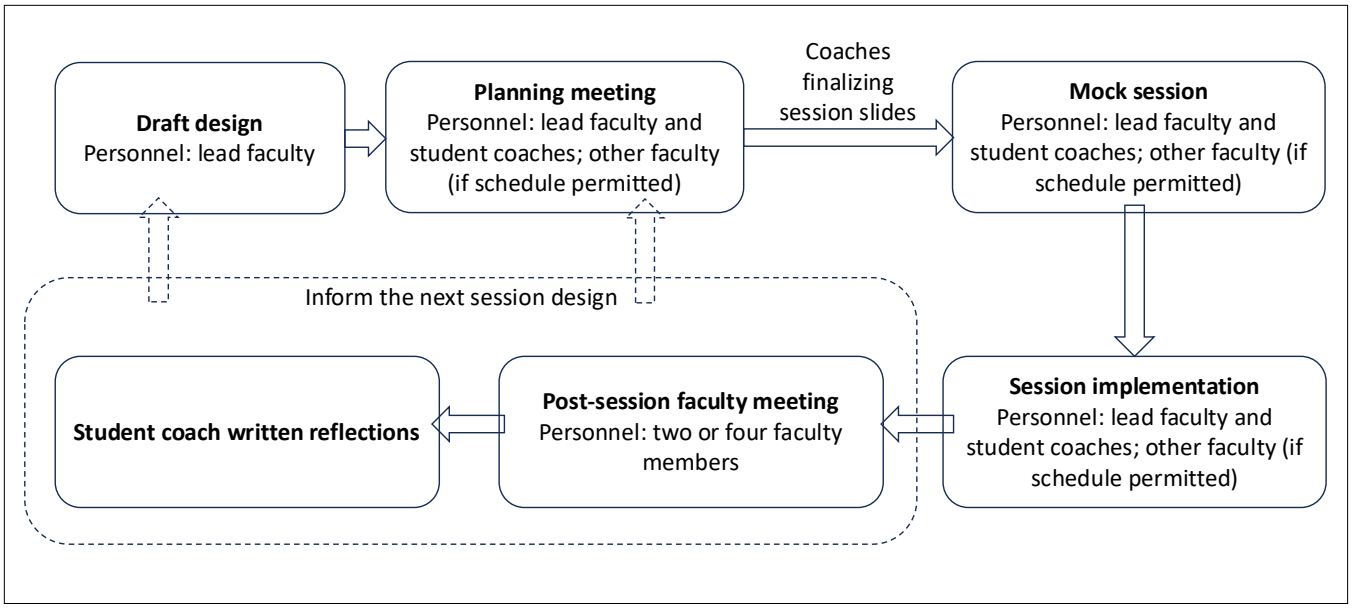


**FIGURE 5.** Design process of each robotics session.

the perspectives of care-based ethics (Chowning & Fraser, 2007, p. 22), we examined the program's physical space, resources, and the roles of coaches, aiming to identify any aspects embedded in the program structure that might unfairly affect the experience of certain groups.

This analysis revealed that resource constraints and distribution could be systemic factors contributing to low or uneven engagement. Before spring 2023, three or more participants had to share a single iPad. Those seated closest to the iPads often had the first chance to code robots. Sometimes lapses in device sharing occurred, leading to fewer opportunities for others. Furthermore, with only three coaches available, some had to supervise two stations simultaneously, making it challenging to provide equal learning experiences to all. This setup often led students to compete for resources and the attention of coaches. Those who were new spoke softly or hesitated to seek help often found themselves in a vulnerable position, unintentionally excluded. According to care-based ethics (Chowning & Fraser, 2007, p. 22), changes are needed to transform the systemic structure so that all learners are empowered to fully participate and benefit from the program.

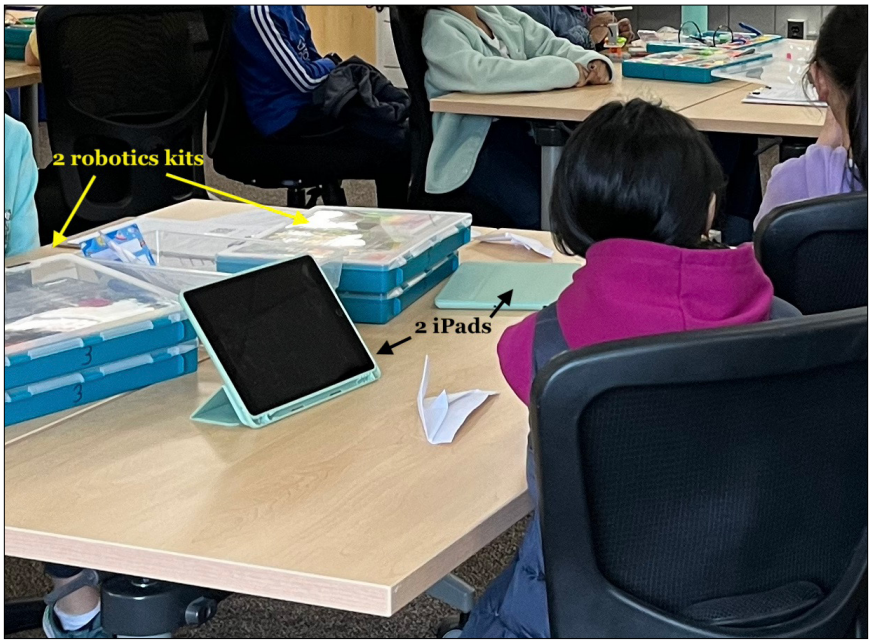


**FIGURE 6.** A station equipped with two iPads and two sets of robotics kits, accommodating three to four participants.

Fortunately, our budget enabled us to purchase more materials and employ an extra coach in the spring of 2023. I also consistently brought in middle schoolers with advanced robotics skills to assist as volunteers. These changes allowed for a more equitable distribution of helpers and materials, with three or four participants sharing two sets of robotics kits and two iPads (see Figure 6). Each station was facilitated by a coach, a volunteer, or me, eliminating the need to share coaches. As a result, the sessions appeared more organized and ran more smoothly.

### *Leveraging role of coaches*

With a diverse group of participants, collaborative learning and peer relationships were complex and often created ethical tensions. Some returning members, feeling more

knowledgeable about robotics, often assumed more prominent roles than new participants. Similarly, age played a significant role, with older students sometimes dominating collaborative activities. Moreover, as robotics tasks grew more complex, there were greater chances of making mistakes. As observed, some members placed blame on others when facing setbacks, which would negatively impact the overall group experience.


**FIGURE 7.** Presentation slide shared in the session.

During our meetings, we engaged in extensive discussions on grouping strategies to mitigate power imbalances and foster positive relationships. Drawing on prior experiences, we typically allowed groups that worked well together to remain in the same station to nurture the steady growth of peer relationships. Similarly, we often assigned the same coaches to a station, providing participants with a sense of familiarity and security.

We also designed coach guides for each collaborative task. These guides, aligned with the principles of justice (Chowning & Fraser, 2007, p. 21), included notes to assist coaches in facilitating group tasks. For instance, students were prompted to negotiate their roles, opting to be either a "*builder*" or a "*journalist*". They then followed the instructions to switch roles in the middle of the process. In coding tasks, participants took turns coding robots with iPads, as guided by the coaches. This approach promoted a fair distribution of duties, as well as equitable treatment of every member.

Furthermore, acknowledging the crucial role of coaches, we provided them with ample flexibility in managing and shaping peer collaboration and asked them to conduct written reflections after each session in the spring of 2023—a component that proved very helpful. Through reflections, coaches examined the group dynamics and assessed the effectiveness of their facilitation strategies. Coaches explained they were mindful of learners' needs and preferences and respected their choices. For example, if students were struggling with a task, the coach would first ask if they needed help instead of immediately offering assistance. If it took a group a long time to complete an activity, instead of rushing them, the coach assured the group that it was fine to work at their own pace and they would be able to continue in the next session if they could not finish. We found our coaches' attunement to student needs fostered a supportive environment.

We were particularly impressed with our coaches' flexibility, openness to identify issues, and willingness to experiment with new ideas. Below are two quotes from coach reflections, demonstrating their growth as reflective educators that benefited all participants.

> *"In the first session, I tried to take a step back and let the kids take more control, and that led to some conflict and unequal collaboration. This time I really took control of delegating tasks, and I made it clear that if it looked like one person wasn't able to participate, I would switch control. That statement alone definitely helped. I think this team needs a lot more direct facilitation, and that seemed to work for us."*

> *"During the Mar[s] exploration activity, Robin wanted to complete everything, but [the other group members] seemed to be doing it only because I told them they had to . . . Stickers are a great way to motivate the students to contribute more to the task, which is a surprise to me. Dividing up the work for them worked, since the students would get very focused on their task with a strong motivation to finish it."*

### *Embedding new elements in curriculum design*

The Mars curriculum for the spring of 2023 program was adapted from the one implemented in spring 2022. It introduced space-related facts and highlighted human achievements in space exploration, engaging participants in building and coding their own "Mars rover" using robotics pieces (Cai et al., 2023). We retained certain activities from the past programs, especially the theme-related, non-coding, group activities. For example, students worked in pairs to explore Mars geology by interacting with a 3-D map from the iPad. These activities allowed everyone to attempt even without sufficient knowledge or computing skills and were well-received by all participants, as identified through session observations and discussions with coaches (Cai et al., 2023). This type of activity adheres to care-based ethics by prioritizing relationships among learners and emphasizing participation, engagement, and experience of all members.

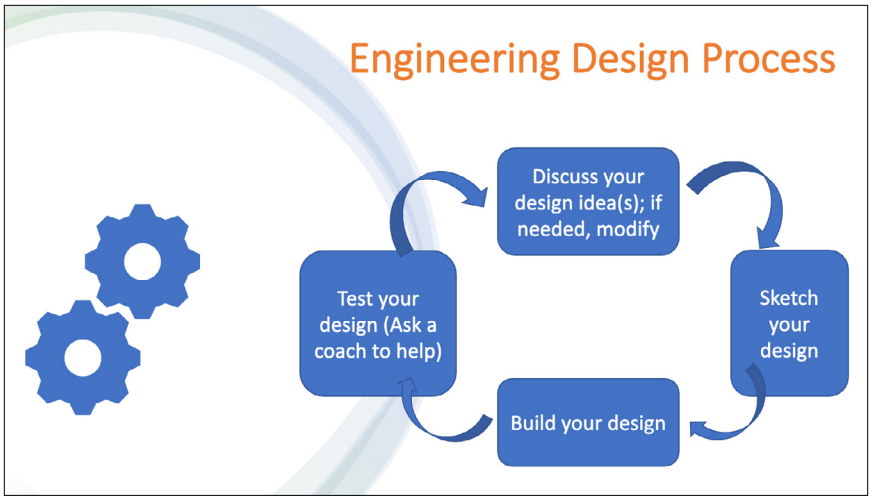


**FIGURE 8.** Presentation slide on engineering design.

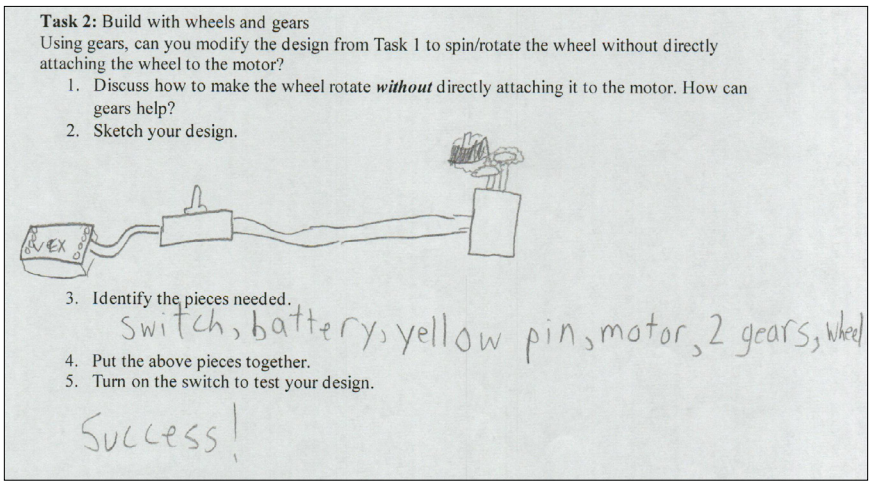


**FIGURE 9.** Activity sheet providing step-by-step guidance on engineering design process.

Students with little robotics or computing experience felt comfortable participating since the focus was not being right or wrong but working with others to explore topics that were new to everyone.

However, an analysis of the curriculum revealed two gaps: Firstly, while the content, such as videos, showcased STEM professionals from diverse backgrounds, it did so implicitly. In the spring of 2023, we addressed this by incorporating Mae C. Jemison's accomplishments into the curriculum and presenting them during one of the session openings. The coaches and I collectively made this decision during our planning meeting to explicitly highlight the contributions of minority astronauts, hoping to inspire all participants, particularly those from underrepresented backgrounds.

Secondly, the curriculum emphasized problem-solving outcomes but lacked guidance on the process. This could be another systemic factor potentially hindering program experience and interpersonal relationships, because without appropriate guidance, participants may inadvertently blame groupmates or avoid taking responsibility when encountering challenges. In response, we applied care-based ethics to shift the focus from activity completion to the collective experience in problem-solving (Chowning & Fraser, 2007, p. 22). Specifically, we incorporated the engineering design process as a core element in the curriculum. It was introduced using a slide during the opening of the first session, emphasizing that testing, modifying, and communicating with peers are integral to success. In each subsequent session, this slide was revisited before group activities. Coaches consistently reminded participants that the goal was not achieving perfection but rather collaborating to continuously test and improve design, fostering a positive mindset for the iterative process of problem-solving. Additionally, we co-designed activity sheets to provide step-by-step instructions, guiding participants in applying the engineering design process to complete robotics tasks (see Figure 9).

### *Expanding and differentiating robotics tasks*

In previous programs, participants were given two to four hands-on tasks per session, and all were guided to start with the first task. However, we quickly realized this approach would no longer work. In spring 2023, our participants varied in their levels of robotics experience, ranging from those completely new to robotics, intermediate learners, to advanced members, including two three-time participants who were members of their schools' robotics teams. It became apparent that designing a program to be engaging and challenging for all would be a substantial undertaking. Additionally, the Mars theme from the spring of 2022 was already known to four returning members. Therefore, a crucial design consideration was to ensure these returning members could derive a fresh experience from the program, despite their familiarity with the theme.

When drafting each session design, I began by developing foundational activities tailored for new participants. Frequently I adapted activities from past programs due to the tight timeline. Following that, I crafted extended challenge tasks for returning members. To provide them with a novel experience, I primarily employed two strategies: elevating the challenge level of activities (e.g., incorporating more advanced coding skills) and introducing the use of

**Scaffolding activity, implemented as needed:** Build with gears

1. Scan the QR code to learn how gears work.
2. Build a gear train.
3. Discuss how gears work (Direct their attention to how we can make the gears spin by rotating only one shaft).

**Task 2:** Build with wheels and gears
Using gears, can you modify the design from Task 1 to spin/rotate the wheel without directly attaching the wheel to the motor?

**FIGURE 10.** Scaffolding activity.

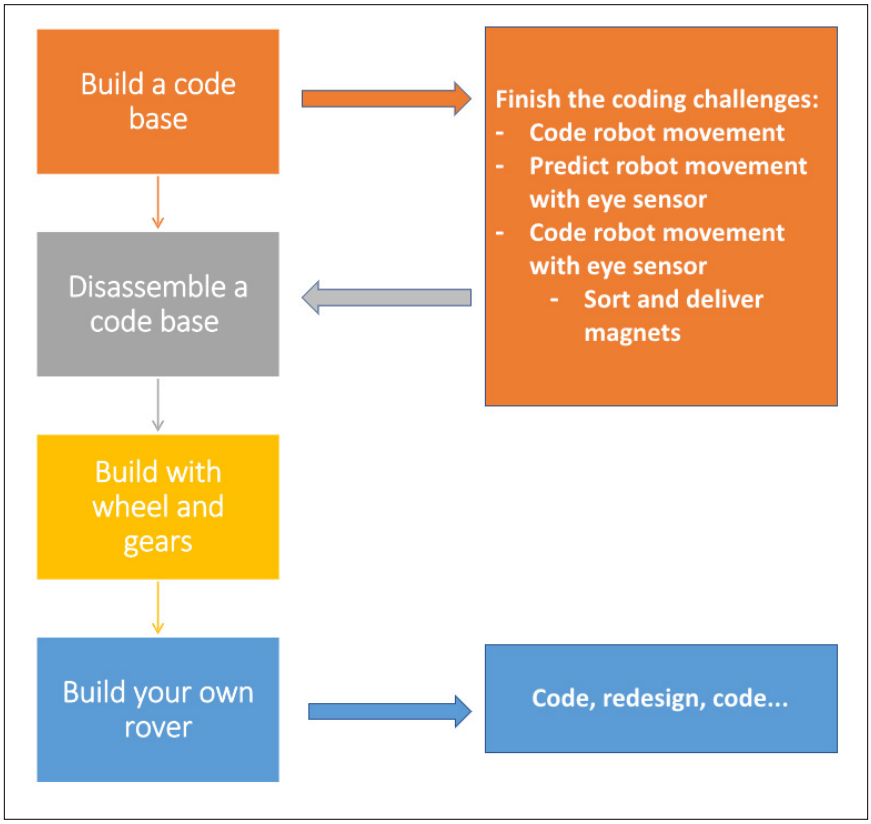


**FIGURE 11.** An example series of robotics tasks.

new robotics pieces, such as electronics and gears, which they had not encountered before. The draft design then underwent thorough discussion and testing in the planning meetings. Coaches frequently recommended the creation of scaffolding activities to assist participants, especially beginners, in acquiring the skills required to progress from basic to advanced levels. For example, through hands-on testing, coaches and I co-designed a scaffolding activity (see Figure 10) for the task displayed in Figure 9, which participants found highly beneficial.

Through the process outlined above, we developed 37 robotics tasks in the spring of 2023, representing a significant increase from the 18 developed in spring 2022 and the 22 in the fall 2022. These tasks covered a spectrum from foundational to moderately advanced levels, accompanied by a variety of scaffolding activities to engage all participants. During the session's "building" and "coding" components, we typically presented an entire series of tasks to all participants while providing differentiated learning paths. Participants were assured that they had ample time to work on the tasks, with the option to continue in the next sessions if needed. They were encouraged to choose their starting point or skip certain tasks based on their individual proficiency and confidence. As illustrated, we presented the series of tasks in Session 4. Since the new members started "*Build a code base*", some returning participants opted for the coding challenges. Others decided to skip ahead to "*Build with wheels and gears*", since they had already completed the preceding activities in previous programs. The flexibility inherent in this design reflects the principle-based ethics perspective (Chowning & Fraser, 2007, p. 21), as it conveyed to learners that their knowledge, skills, and experiences were recognized and respected, promoting learner autonomy and fostering a sense of empowerment.

## CONCLUSIONS AND REFLECTIONS

Our redesigned program achieved remarkable success. We maintained a robust attendance record in spring 2023, with an average of 5.3 out of 6 sessions attended per participant, showing a notable improvement from 4.7 out of 6 in fall 2022. Participants thoroughly enjoyed their program experience, providing satisfaction ratings ranging from 4.6 to 4.9 out of 5, surpassing the ratings of 4.6 to 4.7 in fall 2022. Additionally, in the fall of 2023, we received a university award that recognized our "*unique programming*" which exemplified "*the university's commitment to serving the public good*".

However, what made us most proud was the feedback from families. Reading their comments, we felt certain that our program made a positive impact on expanding participation in robotics education, engaging young learners, and sustaining their interest in STEM. All the hard work was truly worth it!

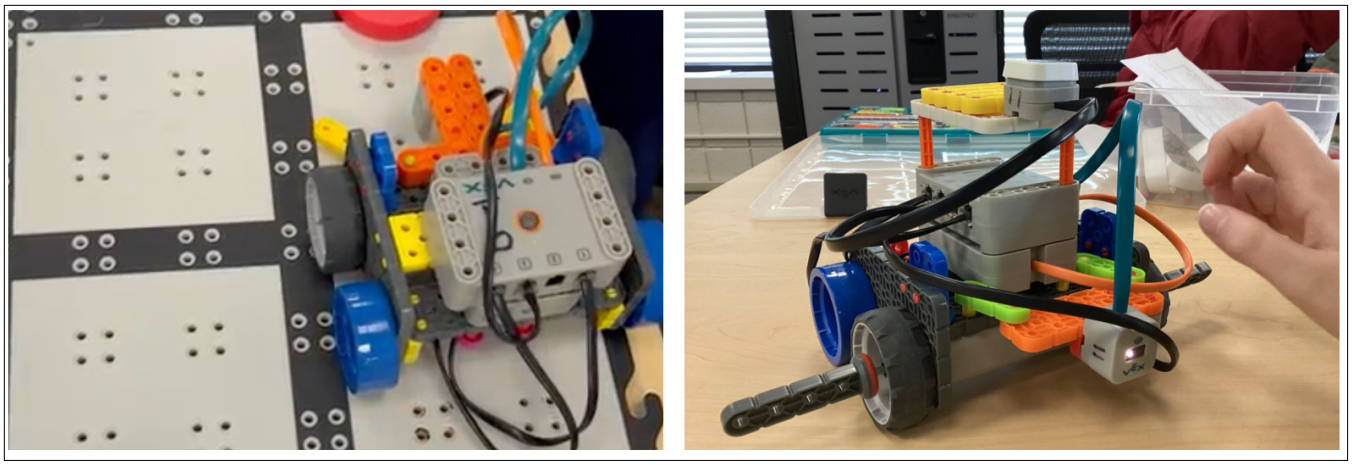

**FIGURE 12.** One group was completing the coding challenge on the field, while the other was designing their own rover.

> *"[Robotics education is] not readily accessible to students and…home because of the materials needed. The items are somehow pricey so this opportunity is really helpful for families like us."*
>
> *"Our child thought the sessions were engaging, fun and asked to return to any subsequent sessions."*
>
> *"This program is one of the best they have attended - informative, engaging and challenging."*
>
> *"Our child attended the First Lego League competition … as a result of their participation in the program... They also encouraged … peers to try the same program."*
>
> *"They're getting more confident with engineering in general at school. This lead(s) to them joining a robotics club at school so it has made a great impact on them."*

Throughout the robotics program, we encountered ethical challenges centered around uneven engagement and tensions among participants. Our team approached these issues from multiple ethical lenses. For example, we developed the coach guides to promote fair sharing and taking turns among the participants at the same table, following the principles of justice. We expanded and differentiated robotics tasks to be responsive to individuals' needs and experiences, demonstrating respect for learner choice and autonomy (Chowning & Fraser, 2007, p. 21). The priority recruitment of students from underserved communities, the diverse backgrounds of coaches, the highlighting of minority STEM professionals underscored our commitment to ensuring inclusiveness and sensitivity to cultural, racial, and ethnic differences.

In analyzing the previous underlying structure of the program, we identified certain systemic factors that may be the root causes of a power imbalance. When access to resources and coaches was more limited, activities were structured in an open-ended format to allow participants to explore freely, the experience of certain participants was disproportionately affected. Some individuals were more likely to assume more prominent roles, having more resources and opportunities, often due to their age or greater experience with robotics or the program. In contrast, participants who were new, younger, quieter, or hesitant to seek help were often left out and appeared passive or disengaged. Aligned with the care-based ethical theory (Chowning & Fraser, 2007, p. 22), we refrained from labeling participants as "active", "motivated" and others as "disengaged" or "non-interested". Instead, we focused on changing power structures by enhancing access to resources, integrating the engineering design process into the curriculum, and leveraging the role of coaches to guide group activities. As a result, all members were more engaged and experienced more enjoyment in the program.

We felt very fortunate that our budget allowed us to purchase more devices and hire an additional coach in spring 2023. Expanding resources for participants alleviated many challenges and tensions. However, we became aware that resources alone would not automatically create inclusive environments and experiences. Therefore, we developed coach guides and asked coaches to both instruct and guide students to take turns to foster a culture of sharing and equitable participation. We also incorporated the engineering design process into the program curriculum to help learners grasp that the problem-solving process requires collaboration and involves making and accepting mistakes as constructive steps toward improvement. The participants became familiar with the iterative design thinking process when developing solutions to robotics challenges. The inclusion of minority astronauts in the presentations helped inspire minority students to consider STEM-related careers and improve their confidence when collaborating with others. These systemic changes fostered care-based ethics by promoting peer relationships and mitigating power imbalances. We were particularly delighted to observe the positive outcomes that occurred at the individual level. For example, one parent shared that their child had an increased comfort with setbacks and failures. Another noticed their child could focus more effectively.

Addressing ethical challenges was complicated, with no clear steps or instructions to follow. Sometimes we had to react to unforeseen situations, feeling a bit out of control. As one coach mentioned, there was "no way we can know beforehand" about issues such as unexpected student absences due to illness, requiring last-minute changes in grouping, or the accidental breaking of a robot, which interrupted the flow of activity. Through extensive collaboration during meetings and sessions, faculty and coaches built mutual trust and respect. Many times, coaches' suggestions on activity design were adopted through group discussion and testing during the planning meetings. This empowered coaches to explore and adapt their approaches based on their own judgment when interacting with the students or dealing with unanticipated challenges. Simultaneously, we ensured a shared understanding of the program's goals and priorities and focused our efforts on establishing a supportive and inclusive experience for all students, particularly those from underprivileged communities. Achieving a shared understanding was effortless, likely because the coaches themselves came from underrepresented backgrounds and believed in the need for more minority members in the STEM fields. One coach shared that she wanted to keep pushing herself "to be the representation" that students need. With a focus on inclusive and positive experience for all students, coaches naturally emphasized equitable participation and peer relationships, rather than merely completing tasks or mastering coding skills.

We also considered our team's deep investment in the program as a significant success factor. Our team, consisting of faculty and student coaches, made a concerted effort to understand each participant's characteristics, including their personality, preferences, and needs. This depth of insight enabled us to design activities that resonated with them. With faculty observers and student coaches present during the sessions, we gained a comprehensive understanding of how participants interacted with their peers. This information informed the design of seating and coaching strategies to promote positive interpersonal relationships. The faculty team actively participated in the program, even though the sessions were scheduled outside our work hours and were primarily facilitated by student coaches. This visible involvement of faculty members allowed families and participants to witness the active role we played, building trust and relationships between the program design team and participants' families. These relationships continued to assist us in understanding the program dynamics and promptly identifying and addressing emerging issues.

Finally, we believed our success stemmed from genuinely placing the interest of participants and their program experience at the forefront. The central focus of our design efforts was to create experiences that were equally engaging to all members, acknowledging that without engagement, participants might not attend or return, given the voluntary nature of the free program. This commitment led us to consider everyone's needs and interests, offering differentiated experiences, so that members from diverse backgrounds and robotics skill levels all felt welcomed, challenged, and had meaningful experiences.

## REFERENCES


Cai, Q. Hong, H. McNary, S., & Song, L. (2023). Developing a robotics program to support students' computational thinking: A design-based study. *TechTrends, 67*, 965–976. https://doi.org/10.1007/s11528-023-00907-0

Burghardt, M. D., & Hecht, D. (2020). Designing informal vs formal education activities – what we've learned. *International Journal of Designs for Learning, 11*(2), 39-35. https://doi.org/10.14434/ijdl.v11i2.27321

Chowning, J.T., & P. Fraser (2007). *An ethics primer.* Seattle WA: Northwest Association of Biomedical Research. https://www.nwabr.org/

Mouza, C., Pan, Y., Yang, H., & Pollock, L. (2020). A multiyear investigation of student computational thinking concepts, practices, and perspectives in an after-school computing program. *Journal of Educational Computing Research, 58*(5), 1029–1056. https://doi.org/10.1177/0735633120905605