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Toy Adaptation in a Laboratory Course: An Examination of Laboratory Interests and Career Motivations

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Toy Adaptation in a Laboratory Course: An Examination of Laboratory Interests and Career Motivations

Abstract

Curricula containing accessibility topics with positive societal impact are useful in career training and have shown promise in engagement of students from groups historically excluded from and underrepresented in engineering. Toy adaptation makes toys accessible to kids with disabilities and is a hands-on process that involves toy disassembly, circuitry assessment, and addition of an accessible switch. Previous work incorporating toy adaptation into curriculum has demonstrated that it is well-received by students and is especially impactful to women. However, it is unknown how student response to toy adaptation is connected to career interests and motivation of students, including those who are Pell-eligible and/or first-generation college students. Here, we incorporated toy adaptation into an undergraduate laboratory course and examined student response, laboratory interests, and career interests. We found that students responded extremely positively to the toy adaptation activity, including that they enjoyed toy adaptation, that it was useful, and that it increased appreciation for the positive effects of engineering. Additionally, we found that women felt significantly more empowered as a result of the experience as compared to men. Conversely, while Pell-eligible students also responded favorably to the module, they expressed significantly less agreement that the experience solidified their choice of studying engineering as compared to their non-Pell-eligible peers. All groups indicated that "interesting work" was most important to them in career selection and that "doing something impactful that helps others" was their favorite part of toy adaptation. Interestingly, we observed statistically significant connections between career interests and laboratory interests, wherein students who selected the technical, hands-on aspects of toy adaptation as most enjoyable were more likely to select "interesting work" as their most important career consideration. Ultimately, identifying curricular laboratory activities that are educational, engaging to all students, and that meet students' career interests is valuable in supporting a positive engineering educational experience.

Introduction

Incorporating accessibility topics into engineering curricula is important toward training future engineers in inclusive design, yet these topics are not commonly addressed in engineering curricula [1] . Beyond the didactic motivation to include inclusive design topics for career training, previous work has also described that including accessibility and disability topics can increase participation of students with disabilities and other historically excluded and underrepresented (HEU) groups in the engineering classroom [2]. In addition, societal impact has been shown to be particularly important to HEU students in career selection [3] and courses with a service focus are especially attractive to HEU students [4], [5]. Thus, curricula containing accessibility topics that positively impact society have utility in career training and engagement of HEU students.

Toy adaptation for kids with disabilities is one example of an accessibility topic with a direct community impact. Toy adaptation involves reverse engineering an electronic toy and soldering a universal activation switch so that the toy can be more easily activated by children with disabilities [6]. Toy adaptation has been previously added in curricular [7], [8], extracurricular [9], and outreach settings [9]–[11] and has received overwhelmingly positive feedback from student toy adapters, including demonstrating a significantly more positive impact on female students [8]. While it has been previously demonstrated that toy adaptation is well-received by students, it is unknown how student response to toy adaptation is connected to career interests and motivations of students, including of students who are Pell-eligible and/or first-generation college students.

In this paper, a toy adaptation lab module was incorporated into an existing core undergraduate bioengineering laboratory course and data was collected through a voluntary student survey.

Methods

Course

A toy adaptation module was incorporated into a 2-credit, third-year undergraduate core laboratory bioengineering course, Mass Transport and Systems Laboratory. In Winter 2022, total enrollment was 65 students. The course was run in four lab sections (i.e., no lecture component), with section size varying from 15 to 18 students. Sections met once a week for three hours. This toy adaptation module was placed in the course before the PID (proportional integral derivative) controller design lab.

Toy Adaptation Module

Introduction (pre-lab): Prior to the lab session, students were assigned a presentation to review. The presentation provided an introduction to HuskyADAPT, a student organization supporting accessible design and play technology [9], as well as the motivation and basics of toy adaptation and key circuitry concepts (e.g., voltage, current, resistance, switches). Soldering safety tips were also reviewed. Our goals for incorporating the toy adaptation module included providing students with an opportunity to:

- work together as a team towards an end goal and hone team working skills through collaboration
- make a difference in the local community by increasing access to accessible and developmentally important toys, and apply knowledge to create a positive societal impact
- hone technical skills including soldering and circuit analysis, and gain hands-on experience in problem-solving
- participate in hands-on exploration of circuitry concepts
- engage in conversations and reflection regarding concepts of accessibility of universal design

Lab Session: Teams of ~3 students were randomly assigned one of two toy options to adapt. Toy options were selected by the teaching team due to availability in the quantities needed and appropriate level of complexity in the adaptation process. Each team station was equipped with toy adaptation kits borrowed from HuskyADAPT, which included soldering irons, switches, wire, screwdrivers, files, and safety glasses. A lab handout (Appendix A) was provided to the students, as well as HuskyADAPT general toy adaptation instructions (adapted from The Ohio State University Toy Adaptation Program guide: https://bpb-us-w2.wpmucdn.com/u.osu.edu/dist/9/25806/files/2020/03/How-To-Adapt-a-Toy-One-Page.pdf). Although the emphasis was on the hands-on aspects of this lab, students were required to document their work by taking photos of key steps in their procedure and describing key steps, culminating in the submission of one lab memo per group as a post-lab write-up. This lab memo was graded for completion. Students were also asked to fill out a post-module survey.

Adapted toys were given to HuskyADAPT and subsequently donated to schools, clinics, individual families, or other community groups that requested them.

Assessment via Post-Module Anonymous Survey

After the toy adaptation experience, students were invited to participate in an anonymous online survey (Appendix B). Students were informed that the survey was anonymous and voluntary, choosing not to participate would not impact their grade for the class, and results would not be reviewed until after final course grades were submitted. Of the 65 students in the course, 53 (82%) completed the survey.

The survey included Likert-scale, ranking, and open-ended questions about the toy adaptation experience and career motivations. Additionally, the survey included voluntary questions on demographics related to gender identity, racial and ethnic identity, first-generation college student status, status as an international student, eligibility for a Federal Pell Grant or State Need Grant, and disability identity. To allow respondents to describe themselves without being limited to predetermined answers, demographics-related questions on gender and racial and ethnic identities were open-ended. Open-ended responses were then grouped into categories to allow for comparison amongst groups. For example, in response to “How do you currently describe your gender identity? Please specify, or indicate if you prefer not to answer”, the responses of “cisgender female", "woman", and “cis woman” were grouped as “women” for subsequent analysis. To preserve survey anonymity, for any self-reported identities fewer than $n = 5$ (10%), we did not report group-averaged responses. For example, in response to the question about gender, 62% of respondents identified as women ($n = 33$), 26% identified as men ($n = 14$), 2% identified as non-binary ($n = 1$), and 9% ($n = 5$) preferred not to answer. When running statistical tests by gender, women and men were compared and the other respondents were not grouped or compared.

Human Subjects

Assessment of this work involved data from anonymous student surveys. The University of Washington Human Subjects Division determined that the activity of human subjects research described in this manuscript qualifies for exempt status (IRB ID: STUDY00013973).

Statistical Analysis

Likert-scale data and ranked data were analyzed using a two-tailed Mann-Whitney U test, with statistical significance accepted at a p-value < 0.05. For both Likert-scale data and ranked data, averages were computed (i.e., a 2.5 average ranking would be computed if 50% of students ranked it second most important and 50% of students ranked it third most important.) Additionally, relationships between career and laboratory interests were analyzed by a z-score test for two population proportions, with statistical significance accepted at a p-value < 0.05.

Results and Discussion

Likert-Scale Student Perceptions of Toy Adaptation Experience

Students were asked to rate their level of agreement with statements adapted from the five elements of the MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) Model of Academic Motivation [12] regarding their perceived impact and usefulness of the toy adaptation module. In agreement with the previous work [8], students overall reported enjoying toy adaptation.

When asked to rate "I enjoyed the toy adaptation experience" from 1 (indicates strongly disagree) to 5 (indicates strongly agree), the average rating was 4.85 with a standard deviation (SD) of 0.41 (Figure 1). Additionally, when asked to what extent "Toy adaptation helped me appreciate how engineering can have a direct, positive impact on people", the average rating was 4.70 (SD = 0.54). Students responded with a similarly high level of agreement that the experience was useful, helped form connections with teammates, resulted in a feeling of empowerment, and helped contribute to a sense of belonging in engineering. Students also agreed that the toy adaptation experience solidified their choice of studying engineering.

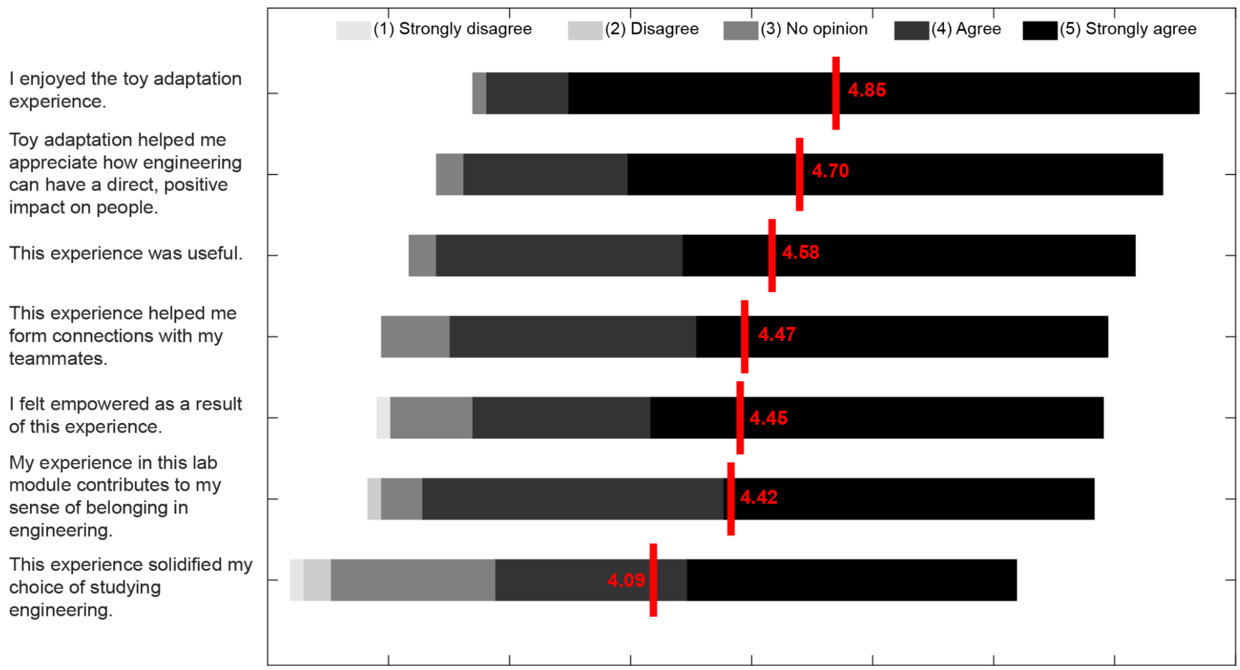

Figure 1. Student responses regarding toy adaptation experience. Participants (n = 53) responded on a Likert scale: 1 = strongly disagree (light gray) to 5 = strongly agree (black). Responses were plotted as a floating bar graph centered around their mean (red vertical line and number). Questions were placed in the order of their average rating.

Open-Ended Responses to Toy Adaptation

The survey also included an open-ended question "what did you think of the toy adaptation experience?" Of the 52 responses to this question, 100% were positive regarding their experience. The activity was commonly described as fun, interesting, and approachable, and students appreciated having the opportunity to solder and engage in hands-on work for a good cause. Representative comments included:

> "I really enjoyed it. I've never soldered before so it was new to me. I loved learning a physical, hands-on skill while also knowing that what I was doing will actually help someone and that the toy that I adapted will be played with by a kid."

> "I think it was a fun experience. It was a simple task and it's good that we can have a win-win situation where students can get experience and lab time while also making adapted toys for children to use."

> "It was wonderful! Easy enough to understand, but with enough technical aspects to be engaging and challenging. I loved the purpose behind it. This felt like such a meaningful project."

We also provided an additional opportunity later in the survey for students to provide additional comments regarding their experience with the toy adaptation module. Multiple students responded with an enthusiastic request to keep this new module in the course curriculum. Students also cited they appreciated the opportunity to converse with their teammates and the instructional team more closely during this lab exercise. Representative comments included:

> "I really enjoyed this lab and would encourage the teaching team to keep it in the curriculum for next year."
>
> "It was a super fun lab!! I would definitely do it again!!!!"
>
> "I really liked the conversational nature of this lab! I got to know my group members + the TAs [teaching assistants] a lot better with this."
>
> "I just really really loved it."
>
> "Please keep this in the syllabus! Highly educational and very fun :)"

Perceptions of Toy Adaptation by Gender

Of the survey respondents (n = 53), 62% identified as women (n = 33), 26% identified as men (n = 14), 2% identified as non-binary (n = 1), and 9% (n = 5) preferred not to answer. In agreement with prior work [8], women responded significantly more strongly to "I felt empowered as a result of this experience" ($p = 0.024$, two-tailed Mann-Whitney U test) (Figure 2). Unlike prior work [8], significant differences by gender were not observed in response to usefulness or the direct, positive impact observed. This difference in findings could be due to differences in our studies including course level, student area of study, sample size, region of the institution, or fraction of students responding to the survey.

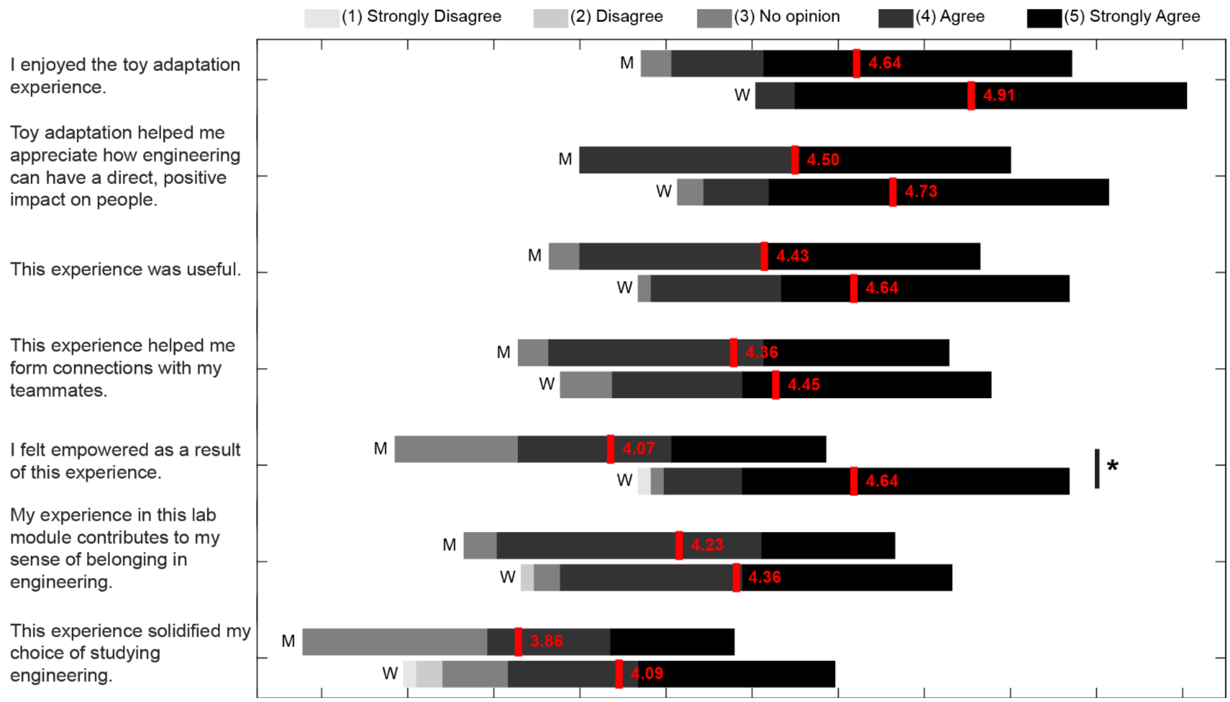

Figure 2. Student perceptions of toy adaptation experience by gender. Men (indicated by M; n = 14) and women (indicated by W; n = 33) responded on a Likert scale: 1 = strongly disagree (light gray) to 5 = strongly agree (black). Mean values are indicated by the vertical line and number. Statistical significance is indicted by the asterisk (*) and defined as $p < 0.05$ after a Mann-Whitney U test.

Perceptions of Toy Adaptation by First-Generation College Students and Pell-Eligible Students

Of the survey respondents, 10 identified as first-generation college students (i.e., do not have a parent/guardian who completed any college coursework), 38 indicated they were not first-generation college students, and 5 students preferred not to answer. When asked to indicate Pell grant eligibility, 14 identified as Pell-eligible, 33 as not Pell-eligible, and 6 preferred not to answer. Of all respondents, 6 identified as both Pell-eligible and first-generation. Since approximately half of first-generation college students receive a Pell Grant [12], this similar trend in our work is in alignment with expectations.

No significant differences were identified between first-generation and non-first-generation students with regards to their perceptions of the toy adaptation module (Figure 3). Although not statistically significant, responses from first-generation students trended lower, on average, for each of the prompts, except for the usefulness of the experience. Most of the averages were high, above 4.00, indicating that students overall appreciated and benefited from the experience. The lowest ratings were from first-generation students' agreement with the toy adaptation experience solidifying their choice of studying engineering (mean 3.70, SD 1.16).

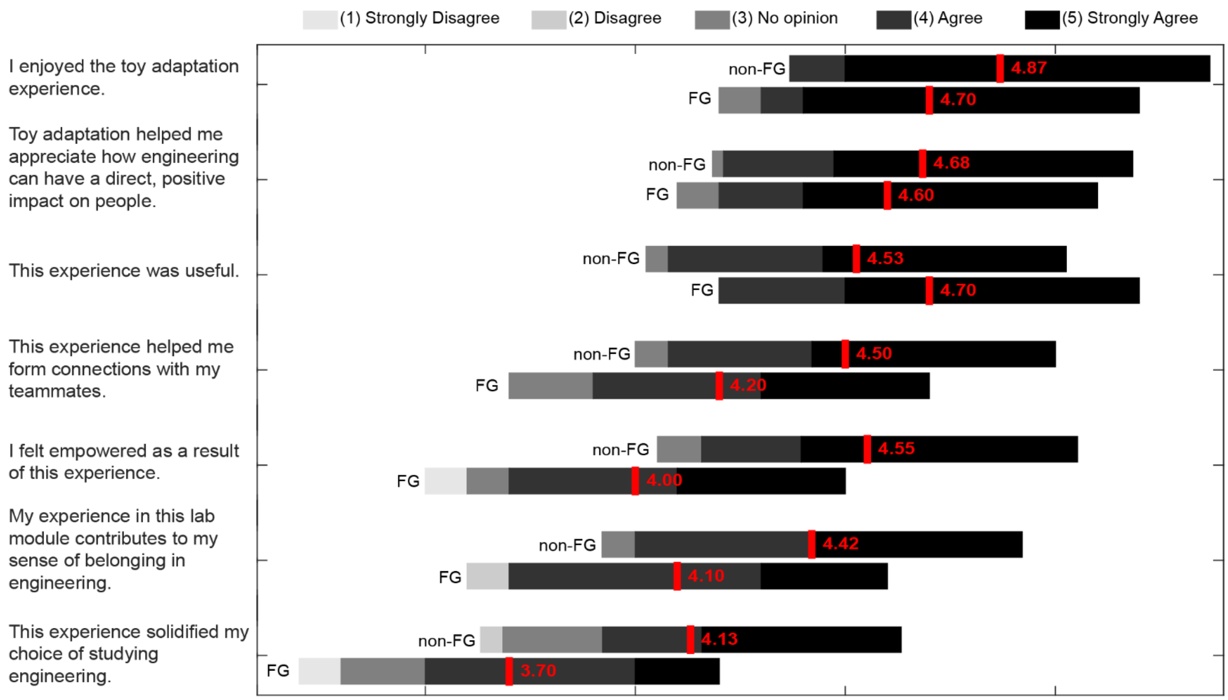

Figure 3. Student perceptions of toy adaptation experience by first-generation vs. non-first-generation. First-generation participants (indicated by FG; n = 10) and non-first-generation (n = 38) responded on a Likert scale: 1 = strongly disagree (light gray) to 5 = strongly agree (black). Mean values are indicated by the red vertical line and number.

When comparing Pell-eligible to non-Pell-eligible, agreement that toy adaptation solidified their choice of studying engineering were significantly lower (p-value = 0.016 , Mann-Whitney U test) (Figure 4). Pell-eligible students' significantly lower responses about this experience solidifying their choice of engineering supports prior work regarding the complex interpersonal, community, and institutional challenges that Pell-eligible students can experience in engineering programs, including economic status putting them at an institutional disadvantage and creating an impression that they do not fit in with other engineering students from more privileged backgrounds [13]. Given this, it is unsurprising that Pell-eligible students agreed significantly less that this one-week module solidified their choice of studying engineering. We were encouraged, however, that the Pell-eligible students agreed that the experience in the lab module contributed to their sense of belonging in engineering (mean 4.21, SD 0.89).

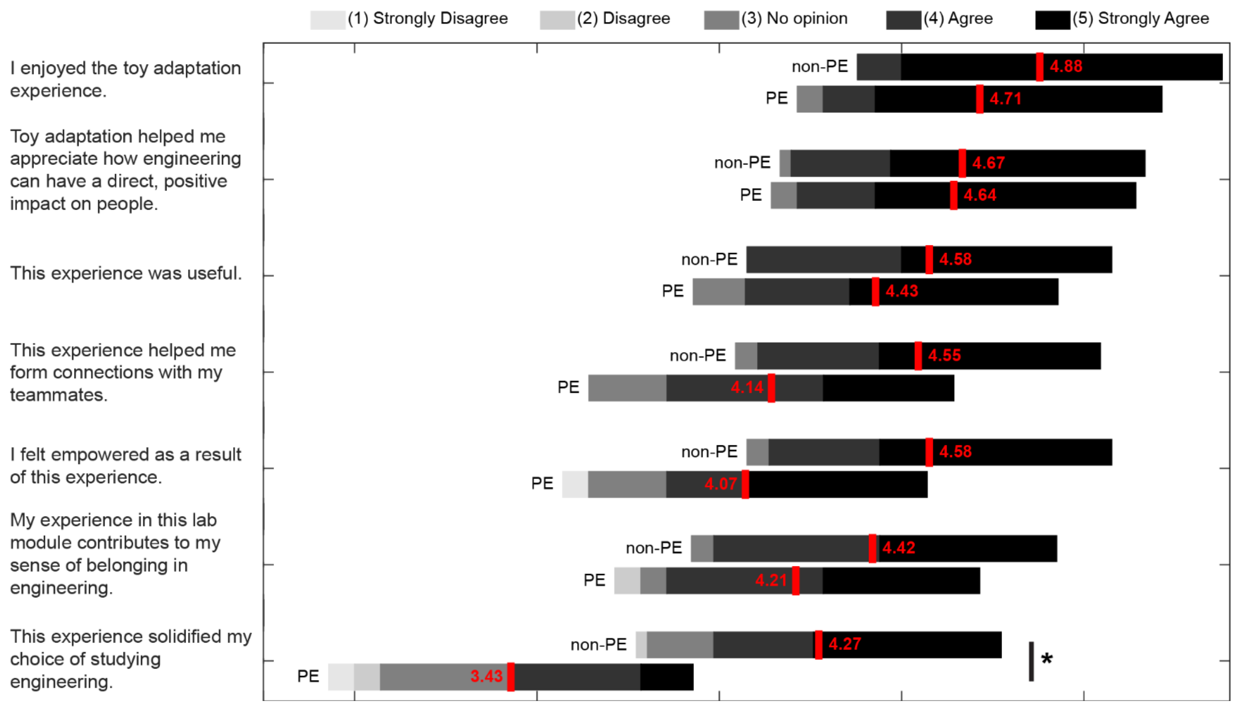

Figure 4. Student perceptions of toy adaptation experience by Pell eligibility. Pell-eligible participants (indicated by PE; n = 14) and non-Pell-eligible (indicated by non-PE, n = 33) responded on a Likert scale: 1 = strongly disagree (light gray) to 5 = strongly agree (black). Mean values are indicated by the red vertical line and number. Statistical significance is indicted by the asterisk (*) and defined as $p < 0.05$ after a Mann-Whitney U test.

Perceptions of Toy Adaptation by Other Demographics

Of the 53 respondents, 11% (n = 6) identified as a race and/or ethnicity that has been historically excluded from engineering, 74% (n = 39) identified as a race and/or ethnicity historically overrepresented in engineering including, and 13% (n = 7) preferred not to respond. More specifically, 4% (n = 2) identified as Black or African American, 6% (n = 3) identified as Latino, 2% (n = 1) identified as Pacific Islander, 47% (n = 25) identified as white or Caucasian, and 26% (n = 14) identified as Asian (non-Pacific Islander).

Additionally, 2% (n = 1) of respondents had a disability, 87% (n = 47) did not have a disability, and 9% (n = 5) preferred not to answer.

Finally, 6% (n = 3) were international students, 87% (n = 47) were not international students, and 6% (n = 3) preferred not to answer.

As is the situation across many academic institutions and STEM (science, technology, engineering, and mathematics) workplaces, our institution and department do not represent the diversity of our region or country, largely due to systemic inequalities [13]. As a result, our respondents included a low number of students historically excluded from engineering based on their race or ethnicity, as well as a small number of students with disabilities. We therefore did not examine responses by these identities; nonetheless, understanding how these identities relate to student experiences with toy adaptation warrants future study.

Laboratory and Career Interests

In order to investigate connections between the toy adaptation laboratory and career interests, students were asked to rank factors of importance in career considerations (Figure 5). When asked "what is most important in considering what type of career work to pursue," 58.5% selected "interesting work", 32.1% picked "makes a difference, is meaningful", 7.5% selected "availability of jobs in the field", and 1.9% indicated "prestigious field" as their highest rank. Other options included "salary", "challenging work", and "recognition (e.g., honors, awards). These seven options were selected based on career factors previously used in National Academy of Engineering surveys [3].

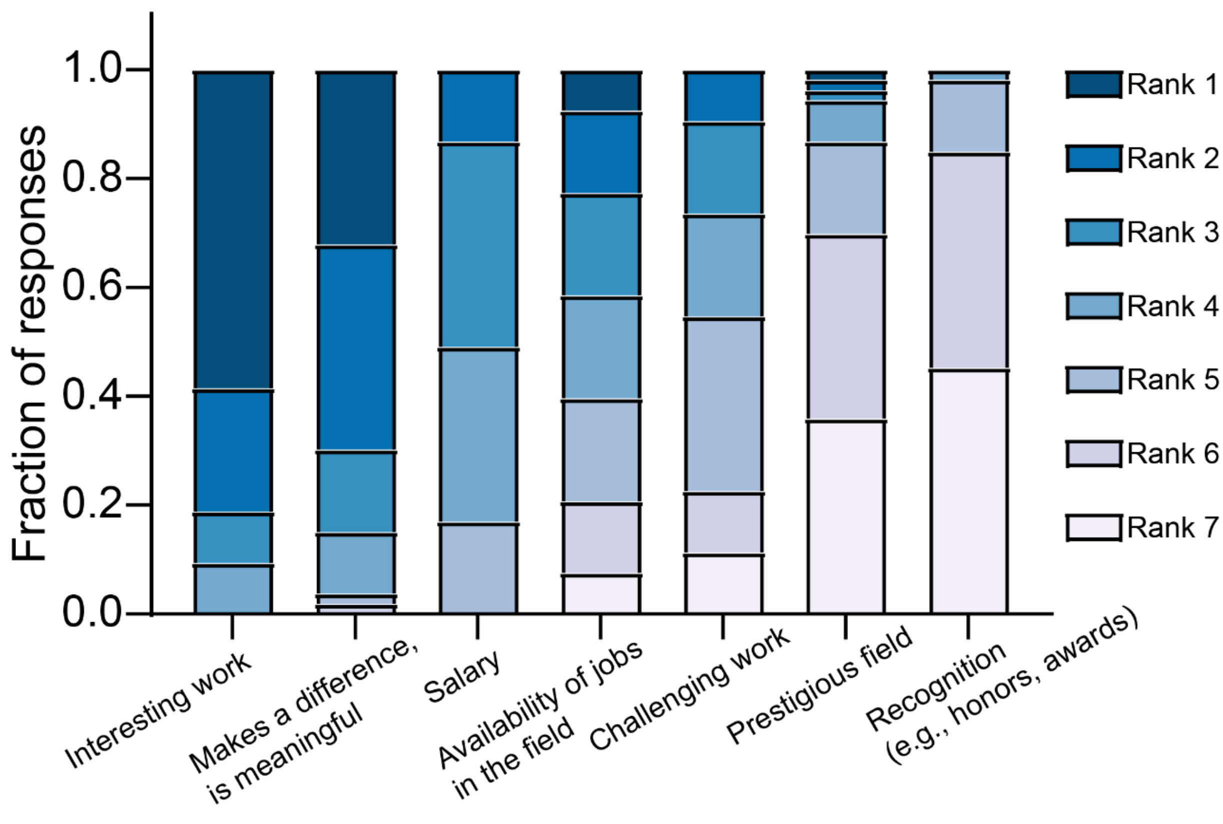

Figure 5. Student ranking of factors important in career considerations. Participants were asked to rank career considerations in order of relative importance on a scale from most important (rank 1, dark blue) to least important (rank 7, white). Responses were plotted in order of their average ranking.

Additionally, when asked to rank what they enjoyed the most about toy adaptation, 62% of students selected “doing something impactful that helps people”, 17% picked “learning how to solder”, 17% selected “taking apart the toy and experimenting with the circuit”, and 4% picked “working with my teammates to reach a goal” (Figure 6). These four options were selected based on enjoyable aspects commonly mentioned in open-ended sections of previous post-toy adaptation surveys. “Working with my teammates to reach a goal” was ranked fourth, which was surprising given that in previous work [8], this was a common response to the open-ended question about what participants enjoyed most. Students in this course work with the same team each week, so ranking this aspect last could be due to it being the least unique part of the toy adaptation experience.

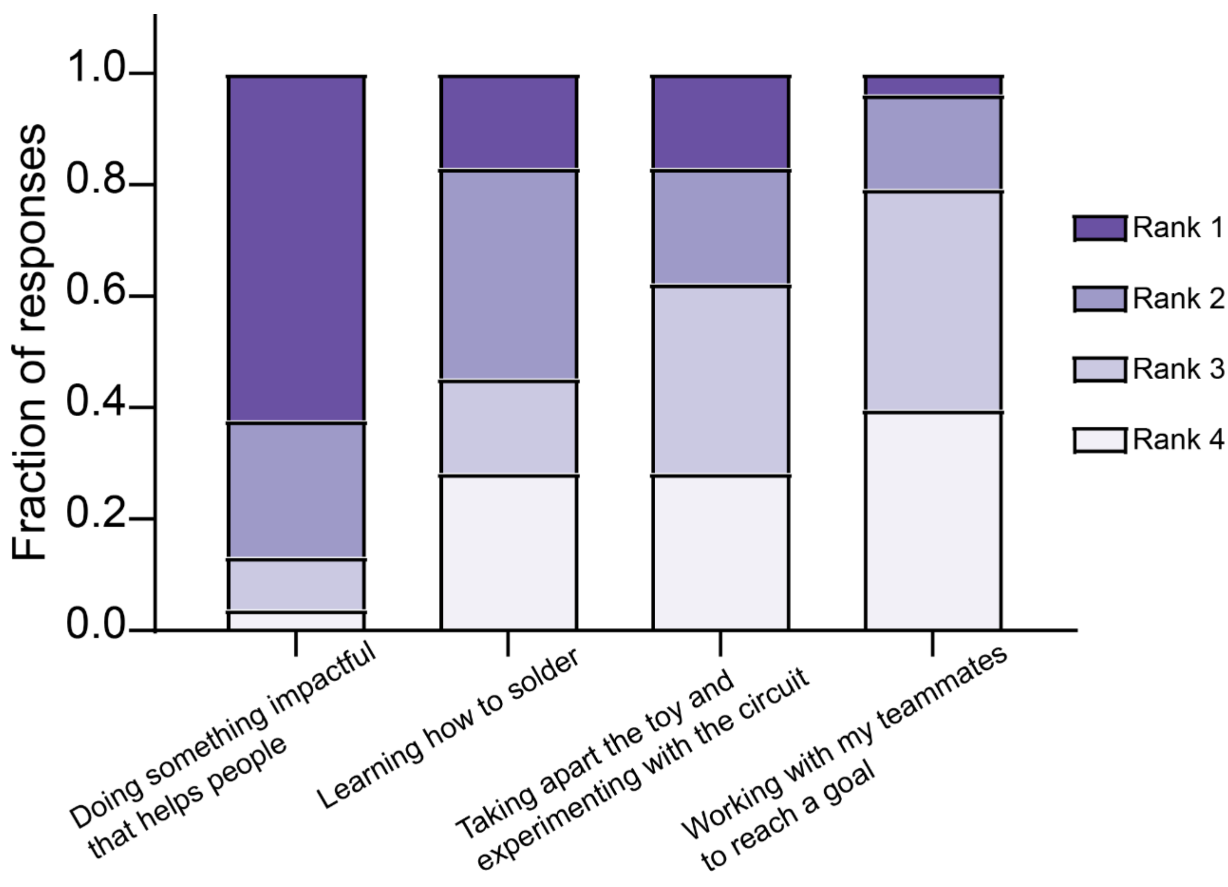

Figure 6. Student ranking of aspects they enjoyed the most in the lab module. Participants (n= 53) were asked to rank what they enjoyed the most about toy adaptation on a scale of most enjoyable (rank 1, dark purple) to least enjoyable (rank 4, white).

Career and Laboratory Interests of First-Generation College Students and Pell-Eligible Students

We also investigated whether career considerations vary between women and men, first-generation college students versus non-first-generation college students, and Pell-eligible students versus non-Pell-eligible students. There were no statistically significant differences in career considerations between men and women (not graphed), but we did observe significant differences by first-generation status and Pell-eligibility (Figures 7 and 8).

While all groups most commonly selected "interesting work" as the most important career consideration, non-Pell-eligible students ranked "interesting work" significantly higher (p-value = 0.031 by a Mann-Whitney U test) (Figure 8). Additionally, both Pell-eligible students and first-generation college students ranked "jobs in the field" as significantly more important in career selection than non-Pell-eligible and non-first-generation students ($p = 0.049$ and $p = 0.033$, respectively, by Mann-Whitney U test) (Figures 8 and 7, respectively). Further, non-first-generation college students ranked "salary" significantly higher than first-generation college students ($p = 0.046$ by Mann-Whitney U test) (Figure 7).

Steady employment is an important factor for many first-generation students; prior studies have found that 66% of first-generation students were employed during college, and these students worked more hours than their non-first-generation peers [14]. First-generation students commonly face financial pressure, with about 27% of first-generation students coming from households making $20,000 or less, compared to 6% of non-first-generation students [15]. In addition, a recent study indicates that even with identical credentials, first-generation graduates have more challenges with their post-graduation job search, including approaching the process with less confidence and knowledge than their peers [16], supporting our findings that the first-generation group of students was significantly more concerned with job availability. Prior studies have also shown that first-generation students accept offers more quickly [16] and earn less money than continuing-generation students [17]; the reasons for these disparities are multi-faceted but in our work, we noted a lower prioritization of "salary" by our first-generation students.

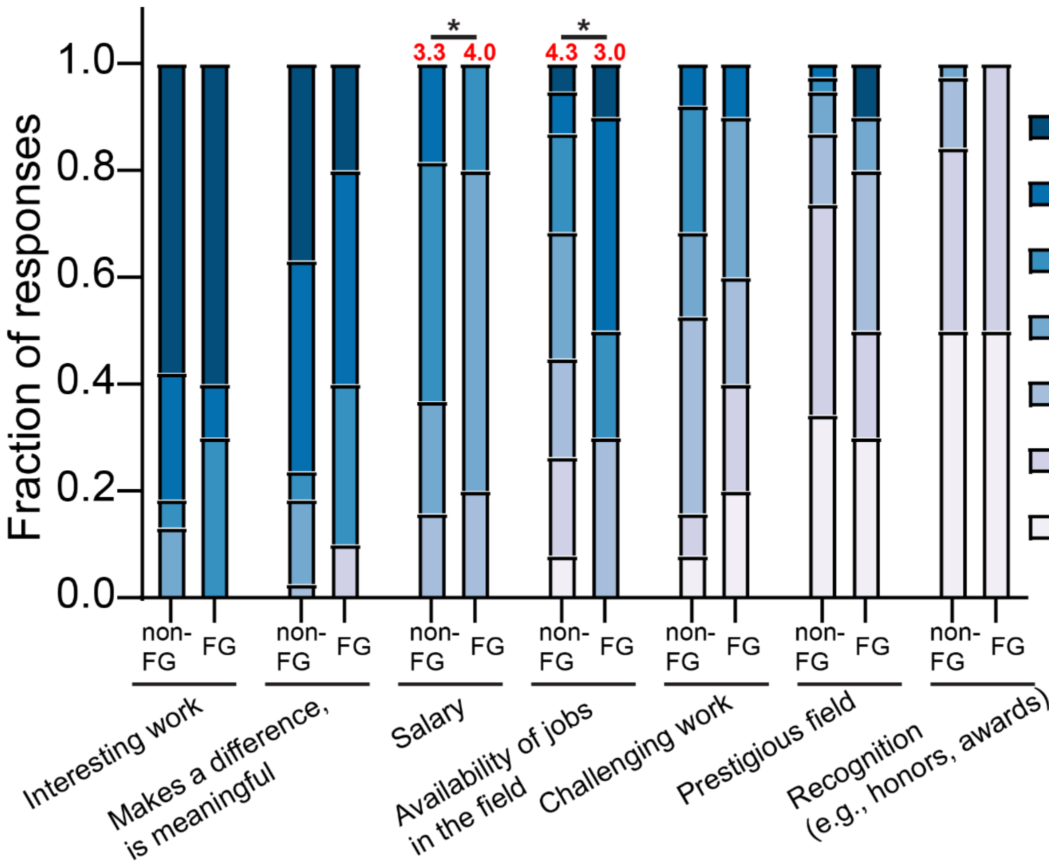

Figure 7. Ranking of factors important in career considerations by first-generation (FG) vs. non-first-generation students (non-FG). Participants were asked to rank career considerations in order of relative importance from most important (rank 1, dark blue) to least important (rank 7, white). First-generation college students ranked "availability of jobs in the field" significantly higher than non-FG students ($p = 0.033$). Additionally, FG students ranked "salary" significantly lower, on average, than non-FG students ($p = 0.046$). Red numbers indicate the average ranking (i.e., there is a red "4.0" above "salary" for FG students. This 4.0 indicates that on average, FG students ranked salary as fourth most important out of seven options.) This value was calculated by averaging FG students' rankings for salary: 20% (2 out of 10) ranked it third, 60% (6 out of 10) ranked it fourth, and 20% (2 out of 10) ranked it fifth. Statistical significance is indicted by the asterisk (*) and defined as $p < 0.05$ by a Mann-Whitney U test.

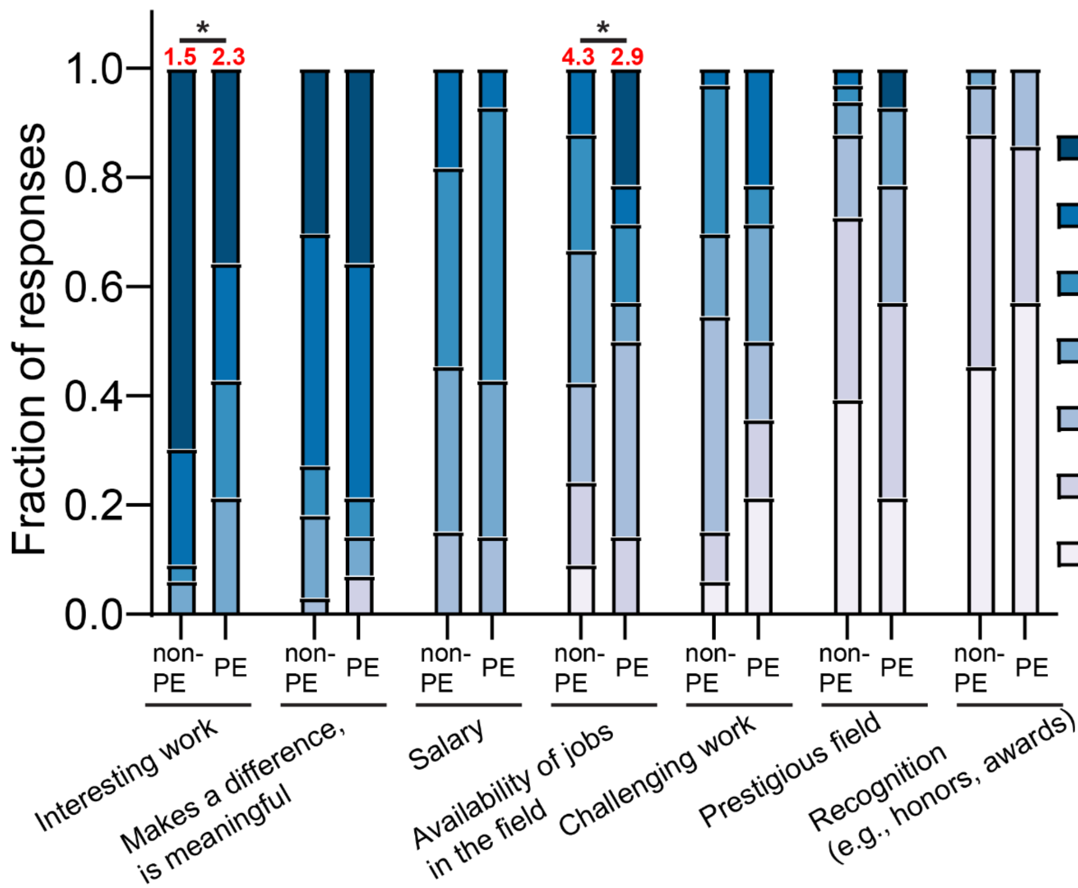

Figure 8. Student ranking of factors important in career considerations by Pell eligibility. Participants (PE = Pell-eligible, non-PE = non-Pell-eligible) were asked to rank career considerations in order of relative importance from most important (rank 1, dark blue) to least important (rank 7, white). Non-PE students ranked "interesting work" significantly higher than PE students ($p = 0.031$) as an important career consideration. Conversely, PE students ranked "availability of jobs in the field" significantly higher than non-PE students ($p = 0.049$). Red numbers indicate the mean ranking. Statistical significance is indicted by the asterisk (*) and defined as $p < 0.05$ by a Mann-Whitney U test.

We also examined laboratory interests of first-generation versus non-first-generation college students (Figure 9) and Pell-eligible versus non-Pell-eligible students (Figure 10). All four groups most commonly selected "doing something impactful that helps people" as the most enjoyable part of toy adaptation, and we observed no statistically significant differences between groups.

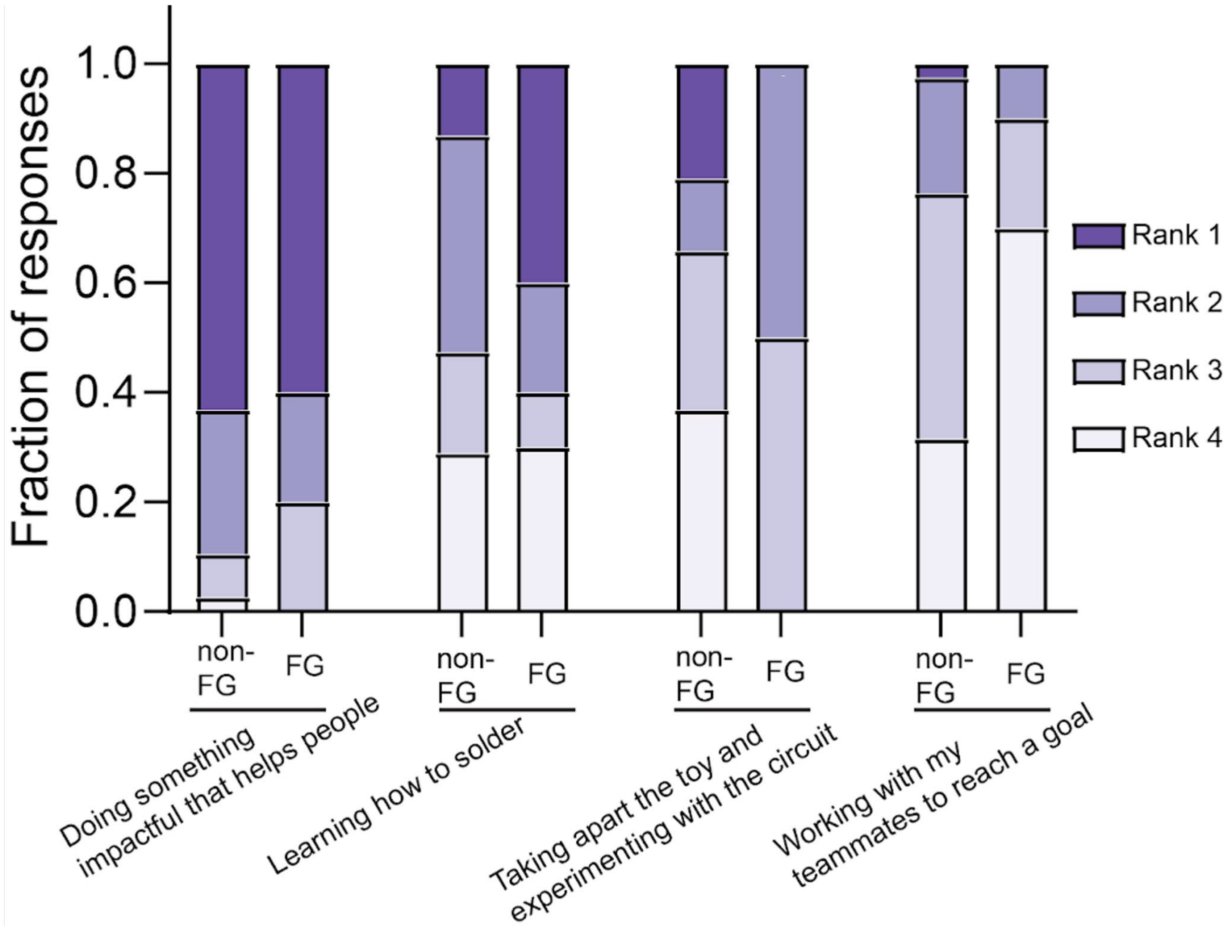

Figure 9. Ranking enjoyable aspects of toy adaptation by first-generation (FG) versus non-first-generation (non-FG). Participants were asked to rank what they enjoyed the most about toy adaptation on a scale of most enjoyable (rank 1, dark purple) to least enjoyable (rank 4, white).

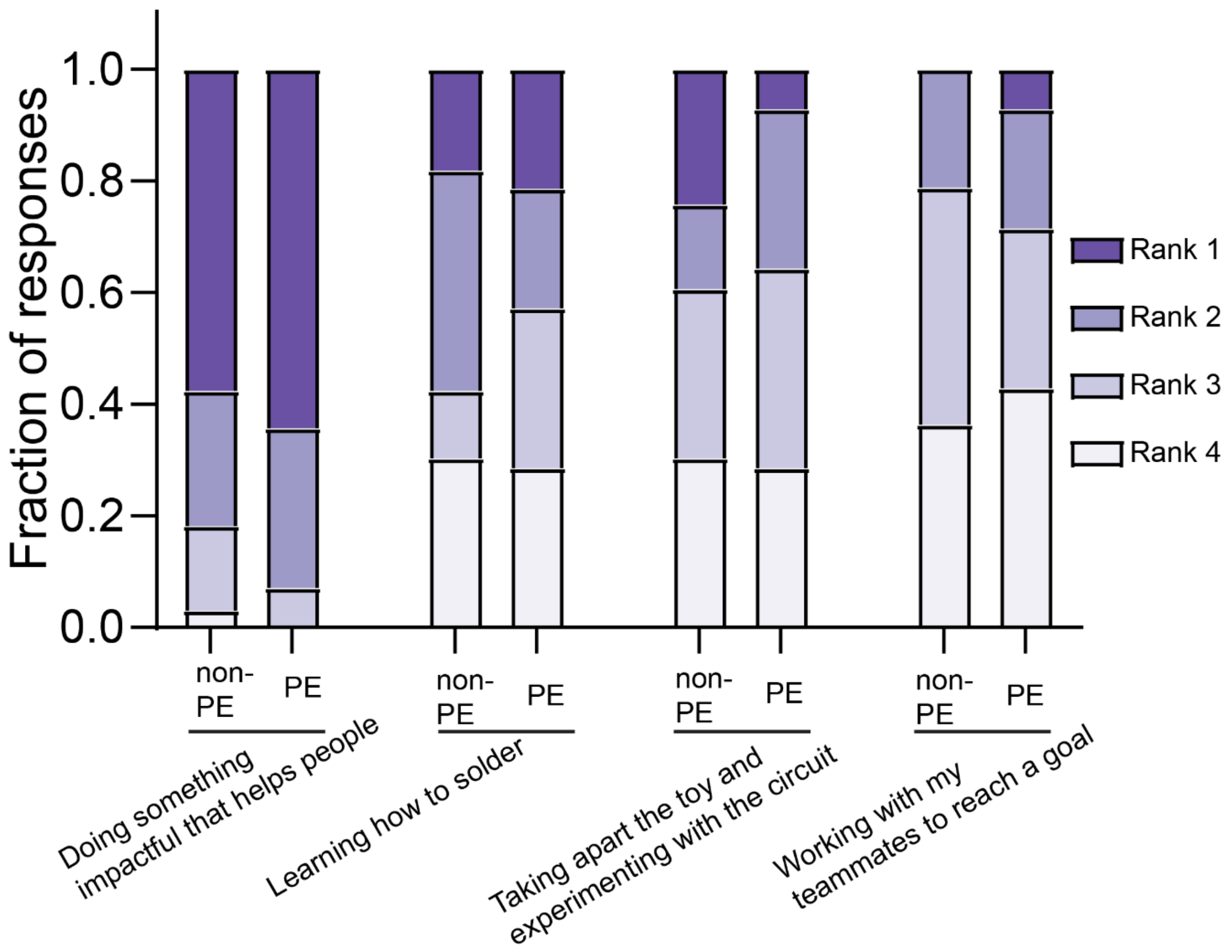

Figure 10. Ranking enjoyable aspects of toy adaptation by Pell-eligibility. PE indicates Pell-eligible while non-PE indicates not Pell-eligible. Participants were asked to rank what they enjoyed the most about toy adaptation on a scale of most enjoyable (rank 1, dark purple) to least enjoyable (rank 4, white).

Connection Between Laboratory Interests and Career Interests

Interestingly, there seemed to be a connection between career interests and laboratory interests. For students who selected the technical, hands-on aspects of toy adaptation (i.e., learning how to solder and taking apart the toy and experimenting with the circuit) as most enjoyable, 78.8% selected “interesting work” as their most important career consideration. Comparatively, of students who selected the impactful, people-oriented aspects (i.e., doing something impactful that helps people and working with my teammates to reach a goal) as most enjoyable, only 48.6% ranked “interesting work” as the most important career consideration. These proportions were significantly different ($p = 0.027$, one-tailed two-proportion z-test). Conversely, of students who selected the impactful, people-oriented aspects as most enjoyable, 40% selected “makes a difference, is meaningful” as the most important career consideration, compared to 16.7% for those who selected the technical, hands-on aspects of toy adaptation.

This difference was also statistically significant ($p = 0.043$, one-tailed two-proportion z-test). This demonstrates a clear connection between laboratory interests and career motivations.

Conclusions

In summary, toy adaptation was successfully added to a core undergraduate lab course, and student feedback indicates connections among student responses to the toy adaptation activity, career interests, and demographic/identity.

Student response to toy adaptation was overwhelmingly positive, including students agreeing that they enjoyed the experience, that it helped them see how engineering makes a positive impact, that it contributes to their sense of belonging in engineering, that it solidified their choice in studying engineering, that they felt empowered as a result of the experience, that it was useful, and that it helped them form connections with teammates. In particular, women agreed significantly more that they felt empowered as a result of the experience. Although the data indicate an overall enjoyment of toy adaptation by both first-generation and non-first-generation students, we noticed that first-generation students tended towards a lower average rating for most of the aspects of toy adaptation, except for its usefulness. In particular, we noted a relatively low rating for whether this module helped solidify their choice in studying engineering. Pell-eligible students also indicated less agreement that this toy adaptation experience solidified their choice of studying engineering, and this difference was significant.

We additionally observed statistically significant differences in career interests between first-generation students and non-first-generation students, wherein first-generation students ranked "availability of jobs in the field" as significantly more important and "salary" as significantly less important than their non-first-generation peers. Similarly, Pell-eligible students ranked "availability of jobs in the field" as significantly more important and "interesting work" as significantly less important than their non-Pell-eligible peers. This aligns with recent work demonstrating that college-educated workers from wealthier backgrounds were more likely to emphasize passion-seeking than those from working-class backgrounds, and an overall connection between passion-seeking in employment and socioeconomic privilege [18].

While we did not observe significant differences in laboratory interests between first-generation versus non-first-generation and Pell-eligible versus non-Pell-eligible, we did observe connections between laboratory and career interests. In particular, participants who selected the hands-on, technical aspects of toy adaptation as most enjoyable were significantly more likely to select "interesting work" as their most important career consideration. Similarly, participants who selected the impactful, people-oriented aspects of toy adaptation as most enjoyable were significantly more likely to select "makes a difference, is meaningful" as their most important career consideration.

First-generation engineering students can face complex challenges in their undergraduate career, including navigating a challenging STEM curriculum, role conflicts, financial constraints [19], and a lack of engineering role models that would provide them access to knowledge about engineering majors [20]. Given these challenges, our results of first-generation students indicating a comparatively lower level of enthusiasm for the experience is unfortunately not surprising. Historically, there has been a dearth in studying first-generation college students in undergraduate engineering [21], and our results lend further support to the significant need to increase our understanding of how to foster positive first-generation student experiences and success in pursuing engineering degrees.

Future Work

While this work examined the relationship between laboratory and career interests through a post-module survey, it does not provide insight into whether toy adaptation affected students' career and/or laboratory interests. In the future, implementing a pre- and post-survey could enable investigation on how this hands-on, impact-focused laboratory experience influences career and/or laboratory interests.

While this work examined toy adaptation experiences of students overall and by demographics including gender identity, first-generation college student status, and eligibility for a Federal Pell Grant, it did not examine responses by racial and ethnic identity, status as an international student, or disability identity. While the post-module survey did ask about these demographics, we did not examine results by these identities due to a small number of respondents from students of races and/or ethnicities historically excluded from engineering, who are international students, and who identify as disabled, respectively. Investigating how these identities relate student experience with toy adaptation as well as career and laboratory interests warrants future study. We aim to do this in collaboration with institutions with a student population that better matches the diversity of the country. Additionally, in future work, we plan to include an additional post-module demographic survey question: "Do you identify as a member of the LGBTQIA+ community? (Identities may include lesbian, gay, bisexual, transgender, queer, intersex, asexual, or other gender or sexuality identities not explicitly named)". The addition of this question would facilitate investigation of the impact of toy adaptation on engineering on LGBTQIA+ students, which is important given that LGBTQIA+ students face greater marginalization, devaluation, and health and wellness issues relative to their peers, and their experiences in their engineering programs contribute to these inequalities [22].

Student feedback was overwhelmingly positive and did not include major suggestions for changes for the next offering. Suggestions included spending additional class time discussing the importance of adapting toys and the role of bioengineering in addressing accessibility, so next offering we plan to spend longer in the lab section discussing these topics with students.

Ultimately, these suggested future studies build upon the work presented in this paper by engaging students in an impact-focused, accessible design experience and examining how this experience impacts students overall and students from groups historically excluded from engineering. Identifying curricular laboratory activities that are educational, engaging to all students, and meet students' career interests is valuable in supporting a positive engineering educational experience.

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Appendix A
Toy Adaptation Lab Handout

Module 2: Toy Adaptation

applying circuitry and problem solving skills for social impact

As you know from prior classes, a circuit is the path through which electrical current flows. Circuits control medical devices such as glucose meters (Figure 1 top) used to determine diabetic insulin needs, computed tomography scanners (Figure 1 bottom) used for diagnostic imaging, and pacemakers used to regulate cardiac contractions.

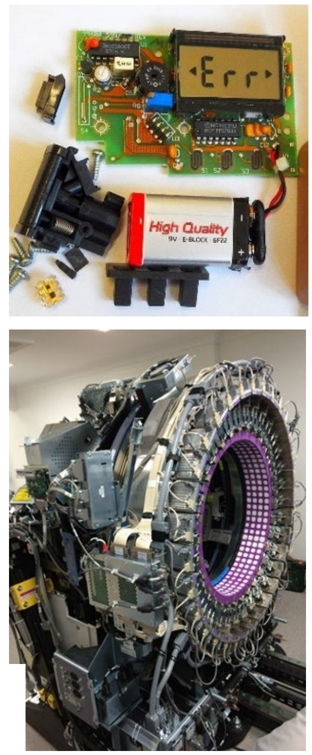

Figure 1: Circuits in medical devices. Circuits are used to power small, patient-used medical devices such as glucose meters (top) as well as large, hospital equipment such as computed tomography scanners (bottom.) Images (from top to bottom) from DiodeGoneWild and Meditegic

Some components of basic circuits include a voltage source (such as a battery), resistors that limit current flow, and light emitting diodes (LEDs) that emit light. We can combine these three components together in a circuit diagram, as shown in Figure 2. Voltage, current, and resistance in this circuit can be measured with a digital multimeter (DMM). Current flows in a circle from the positive end of the battery, through the resistor, and then through the LED. In the system shown in Figure 2, the resistor and the LED are in series, which means that current flows through one, then the other.

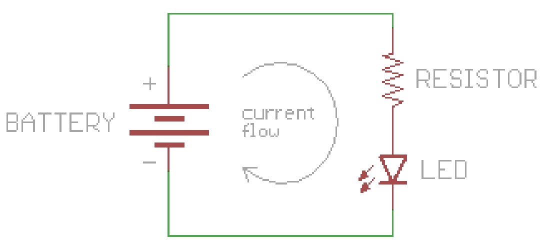

Figure 2: A basic circuit. This circuit contains a battery (voltage source), resistor (limits current flow), and an LED (emits light.) Image from Sparkfun.

Similarly, in Figure 3 left, the current flows from the positive end of the battery, through the resistor, through one LED, and through a second LED. In this system the two LEDs are in series. In contrast to circuitry components that are in series, circuitry components can be in parallel. This means that current flows through two components at the same time, rather than consecutively. For example, in Figure 3 right, the current flows from the positive end of the battery, through the resistor, and then splits and passes through the two LEDs simultaneously.

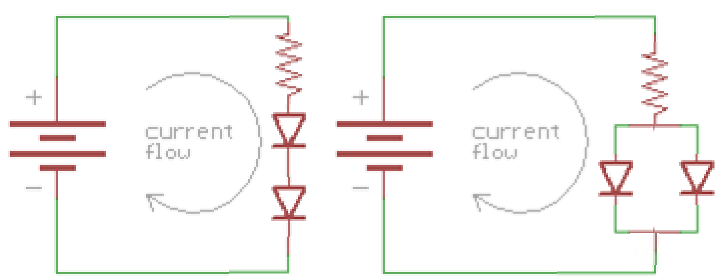

Figure 3: LEDs in series (left) versus in parallel (right.) Image modified from Sparkfun.

In this lab, you will examine and modify the circuit of an electronic toy in order to create a more accessible option for toy activation.

Introduction: the developmental importance of play & adapted toys

Play is important in cognitive and physical development as it teaches cause and effect, fosters independence, and develops motor skills. People with disabilities often cannot use toys as they were originally designed, limiting the ability to gain these developmental benefits. For example, spina bifida is a birth defect of the brain, spinal cord, or meninges and often results in muscle paralysis and neurological complications. These symptoms may limit the ability of an infant with spina bifida to reach out and push a small activation button to use the toy as it was originally designed. Cerebral palsy is another example of a disability which can impact motor function and the ability to maintain balance and posture. There can be limits in the dexterity of hands and limbs due to effects on muscle tone and coordination, creating the need for more accessible activation than what comes with a toy originally.

Figure 4: Adaptable toy example. This Olaf plush toy is normally activated by pushing the small buttons on his chest. The adapted version (shown here) has added universal female jacks for alternative activation switches. Image from Desktop Technology Services Limited

To increase the usability of toys by children with diverse abilities, adapted toys exist. An adapted toy, as shown in Figure 4, is a toy with one or more added universal headphone jacks. Dozens of alternative activation switches can be plugged into these universal jacks such that the toys can be activated by pushing a larger nearby button (Figure 5 left), moving a toe (Figure 5 middle), or tilting one's head (Figure 5 right).

Figure 5: Alternative activation switch examples. Alternative activation switches plug into the female jack on an adapted toy. This allows the toys to be activated by pushing a nearby large button (left), moving a toe (middle), or tilting one's head (right.) Images (from left to right) from Ablenet, Pattycare.org, and Enablemart.

Although adaptable toys exist and are available for purchase online, they are **often 3 to 5 times** the cost of unadapted toys. This means that a basic $20 off-the-shelf toy is often priced $60-$100 when adapted, limiting the financial accessibility of toys and their developmental benefits.

Documentation expectations:

You will submit a brief memo that documents the main steps of your procedure and your ultimate product. The emphasis will be on the experience vs. the write-up for this lab, but it will be a good idea to have documentation of this engaging project, for your own records too. Because the documentation for this lab is short, we ask that you also please fill out the survey on this module (google form to be posted on Canvas).

Documentation guidelines:

- Coordinate among your team members for picture-taking of key steps as outlined in the instructions below
- You can use your lab notebook to jot down notes and take photos of that, or use the white board to brainstorm and take photos of that and include it in your documentation.
- Only one memo per group is required.
- We don't need a recap of the procedural steps outlined in the toy adaptation instructions handout.
- Purple text below (also underlined) guides you through what we expect in your brief memo.

Toy adaptation lab procedures (please also refer to the **toy adaptation instructions handout** - it has a more visual depiction of key steps, including check-ins needed with teaching team)

1. Toy assessment: **Carefully remove the toy from its packaging.** Do not damage the packaging because you will repackage the toy after the adaptation for donation. Overall, we want to keep these toys in as polished condition as possible, so please handle toys and packaging with care. After removing the toy from its packaging and before taking the toy apart, take a picture of the toy for inclusion in your memo. Examine how the toy is activated (a button, remote, etc.) and what the activation does (sounds, lights, motion.) Note how the toy is activated and what it does upon activation. If the toy does not activate, try new batteries.

2. Toy disassembly. Take the necessary section of the toy apart to find the circuitry controlling the function. This typically involves unscrewing or seam ripping. In our case, it will mean unscrewing the toy. Be careful not to strip the screws. Do this carefully (do not lose screws or other parts) because you will need to put it back together. Note how parts are assembled so you can put it all back together at the end. We will have small plastic cups to store the screws.

3. Circuit assessment.
    a. Examine the circuit. Identify the batteries, lights, motor, speaker, and other components.
    b. Take a picture of the unmodified circuit of your toy.
    c. Do your best to draw a circuit schematic including all aforementioned circuit components. This can be challenging, so just do your best to capture the key components, or feel free to create a simplified version.
    d. Use a test wire (small piece of wire) to find which two points complete the circuit to activate the toy. Indicate these spots on the circuit diagram. We will depict these points as parts of a switch.

e. Now, indicate where you will add your switch with a new, modified circuit diagram. Describe whether the jack you will add is in parallel or in series with the original activation button.
f. If interested in taking a deeper dive, use a digital multimeter to measure 1) voltage, 2) resistance, and 3) current in accessible areas of your circuit. Indicate these values on the circuit diagram.

4. Wire preparation. Using 1 foot of double stranded wire, separate one inch on each end of the wire. Strip ¼ inch of insulation off each wire on both ends. (we have found that the '1' setting has been working well).

5. Exit plan. Make a game plan for how the wire will exit the toy after it is soldered. This may mean that you need to file a notch or drill a hole in the toy. Keep in mind, the points that complete the circuit (determined in step 3) are the points to which you will solder one end of your wire (two junctions total). In this activity, we will be filing a notch for the exit for both toy versions.

6. Wire soldering. Remove batteries for soldering. Solder one end of the 1 foot wire to each of the two points that complete the circuit. Be sure to follow soldering safety protocols such as wearing safety glasses and being careful not to touch any metal components of the **soldering iron (they are hot!**). With one end soldered into the toy, touch the two wires on the opposite end together. The toy should activate. Reduce strain on the wire by circling or tying it around a sturdy component within the toy so that when the wire is moved/pulled, the soldering connection is not under unnecessary strain.

7. Jack soldering. Make sure you have **threaded the plastic case** for the jack onto the wire **before** you solder, because it will not fit over the other end of the jack!!! Solder the jack to the other end of the wire. One of the wires should be soldered to the bottom hole of the jack, and the other should be soldered to either of the top holes. Make sure the profile is low enough to be able to replace the plastic case over the jack in the end. After soldering your jack, test your toy with an alternative switch. Take a picture of your modified toy circuit for inclusion in your memo.

8. Toy reassembly. Close the toy as carefully as possible. After reassembling, test the toy with an alternative activation switch. Repackage the toy, making it look as new as possible. Explain how you know the jack you added either in parallel or series (did you verify?), and why it would be incorrect to add the jack in the other configuration option. How did your toy adaptation experience turn out? Is your adaptation complete, or does it need more work by a HuskyADAPT team member? (We will label the toys so we can keep track of this.) Please add any thoughts or reflections on the module here (optional).

9. Please fill out our google form survey when announced =) Thank you! Hope you had fun!

Thanks to Molly Mollica for toy adaptation instructional materials

Appendix B
Toy Adaptation Survey
The purpose of this survey is to obtain information about your experience in this module. Survey results will be used to evaluate the program, and results may be shared for educational purposes only. This google form survey is anonymous (including not collecting email addresses), and results will not be reviewed until after final course grades have been submitted. Choosing not to complete the survey will not affect your grade in this class. The confidentiality of information received from respondents to questionnaires shall be fully protected, and information will only be presented or discussed, in an anonymous fashion, for the purposes of educational improvement.
*Required

Have you previously done toy adaptation before?*
- Yes
- No

If yes, where?
[Short answer open-ended text response]

What did you think of the toy adaptation experience in BIOEN 337?*
[Long answer open-ended text response]

Please rank the following: #1 (enjoyed the most) to #4*
- Learning how to solder
- Doing something impactful that helps people
- Taking apart the toy and experimenting with the circuit
- Working with my teammates to reach a goal

Please rank the following from #1 to #7, where #1 = most important to you considering what type of career work to pursue, and #7 = least important to your consideration.*
- Interesting work
- Availability of jobs in the field
- Makes a difference, is meaningful
- Challenging work
- Salary
- Recognition (e.g. honors, awards)
- Prestigious field

What careers are you considering? Why?
[Long answer open-ended text response]

Please rate your level of agreement with the following from 5 (strongly agree) to 1 (strongly disagree):*

- I enjoyed the toy adaptation experience.
- Toy adaptation helped me appreciate how engineering can have a direct, positive impact on people.
- My experience in this lab module contributes to my sense of belonging in engineering.
- This experience solidified my choice of studying engineering.
- I felt empowered as a result of this experience.
- This experience was useful.
- This experience helped me form connections with my teammates.

Any additional comments regarding your experience with the toy adaptation module?
[Long answer open-ended text response]

As part of our interest in establishing an inclusive and welcoming environment, we would like to know if our students' experiences in this new lab module, as addressed in the prior questions of the survey, are different depending on various demographic factors and personal identities. If you are comfortable doing so, please answer the following demographic questions.

How do you currently describe your gender identity? Please specify, or indicate if you prefer not to answer.
[Short answer open-ended text response]

How do you currently describe your racial and ethnic identity? Please explain, or indicate if you prefer not to answer.
[Short answer open-ended text response]

Are you a first-generation college student?

- Yes
- No
- Prefer not to answer

Are you an international student?

- Yes
- No
- Prefer not to answer

Are you eligible for a Federal Pell Grant or State Need Grant?

- Yes

- No
- Prefer not to answer

Do you identify as having a disability?

- Yes, I identify as disabled
- No, I identify as non-disabled
- Prefer not to answer