# Board 7: Work in Progress: Toy Adaptation as Engineering Outreach to Diverse High School Students

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Heather Feldner received her BS in Human Biology and Master's degree in Physical Therapy from Marquette University. She has been a practicing pediatric physical therapist for 16 years, and began teaching in the University of Illinois at Chicago's DPT program in 2010. She became a board certified pediatric clinical specialist in 2012, completed her Assistive Technology Certificate from UIC in 2015, and earned her PhD in Disability Studies from UIC in 2016. She joined the University of Washington's Department of Mechanical Engineering as a postdoctoral researcher in September of 2016. Heather has a special interest in user-centered design and participatory research, and has been a lab member of the GoBabyGo program, which creates custom safety and accessibility modifications to commercially available battery powered toy ride-on cars for children with disabilities, since 2012. Heather's research focuses on investigating the impact of traditional and alternative mobility technologies on the experiences of people with disabilities and their families, and the direct and indirect influences of physical and social environments, technology design, industry, and disability orientation on those experiences.

**Shawn Israel PT, DPT, University of Washington**

Shawn Israel, PT, DPT is a pediatric physical therapist and clinical teaching therapist at the University of Washington in the Division of Physical Therapy, Department of Rehabilitation Medicine. She has experience working with individuals with a wide variety of neurological diagnoses across their lifespan and feels strongly that everyone should have access to toys, mobility and their environment to enhance their play skills and social interactions.

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Dr. Anat Caspi is director of the Taskar Center for Accessible Technology housed by the Paul G. Allen School of Computer Science and Engineering at the University of Washington. Caspi received her PhD from the Joint Program in BioEngineering at University of California, Berkeley & UCSF. Her research interests are in the areas of ubiquitous computing and data science. Caspi is interested in ways by which collaborative commons and cooperation can challenge and transform computing disciplines.

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Dr. Steele is an assistant professor in mechanical engineering at the University of Washington. She received her BS in engineering from the Colorado School of Mines and MS and PhD in mechanical engineering from Stanford University. She is the head of the Ability & Innovation Lab, dedicated to designing new tools and techniques to improve human ability through engineering, and also a leader of AccessEngineering to enable individuals with disabilities to pursue careers in engineering. Dr. Steele previously worked in multiple hospitals as an engineer, including The Children's Hospital of Colorado, Lucille Packard Children's Hospital, and the Rehabilitation Institute of Chicago.

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Dr. Dianne Hendricks is a Lecturer in the Department of Human Centered Design & Engineering and the Director of the Engineering Communication Program at the University of Washington. She designs and teaches courses involving universal design, technical communication, ethics, and diversity, equity and inclusion. She co-founded HuskyADAPT (Accessible Design and Play Technology), where she mentors

UW students in design for local needs experts with disabilities. She also leads STEM outreach activities for the UW community and local K-12 students involving toy adaptation for children with disabilities. Dianne holds a PhD in Genetics from Duke University, and BS in Molecular Biology and BA in Psychology from the University of Texas at Austin.

# Toy Adaptation as Engineering Outreach to Diverse High School Students

## Introduction

The well-documented lack of diversity in engineering begs for the development of effective educational outreach tools that appeal to students from underrepresented groups in engineering - including females, racial/ethnic minorities, students with disabilities, and first-in-family college students. Although women constitute half of the college-educated workforce, 89% of working professionals in engineering jobs are male. In addition, while African Americans, Hispanics, and Native Americans collectively compose 27.9% of the US population, they make up only 8.1% of employed engineers [2]. Similarly, while 19% of the US population has a disability, less than 5% of engineers identify as having a disability [4].

Research has found that the potential to make a positive societal impact is especially important to underrepresented students in career selection [6, 7]. Additionally, engineering courses that include service learning commonly enroll a higher number of underrepresented students [8, 9]. Due to the effectiveness of service learning in enhancing learning and student retention [10-13], as well as its promise in engaging underrepresented students in engineering, *we believe that service learning in engineering K-12 outreach is a key tool to attract underrepresented students*.

Toy adaptation for children with diverse needs is one method of service learning that broadly encompasses concepts and skills used in engineering and its related fields, is engaging and fun for both students and adult learners alike, can be accomplished in a short amount of time with minimal training, and results in the production of inclusive and accessible toys that directly and immediately impact play environments for children. Toy adaptation is the modification of an electronic toy to make it more accessible to children with diverse abilities [5, 14]. This includes deconstructing a toy and soldering a universal activation port within the toy's circuitry such that a variety of alternative switches can be used to activate the toy, as shown in Figure 1. Because this process 1) involves hands-on engineering concepts and skills, 2) has a clear and immediate societal impact related to cognitive and physical development, 3) can be conducted in a short time frame (approximately 1.5 hours), 4) is relatively affordable (~$5/student), and 5) is portable/can be conducted in a variety of locations, we believe that toy adaptation is a feasible and promising outreach method to promote the engagement of underrepresented students in engineering.

Previous studies from other groups have found that toy adaptation is a useful method to increase first-year engineering students' understanding of the field of engineering, and the connection between engineering and society [14]. Additionally, our previous work found that extracurricular toy adaptation is impactful to students, community members, and physical therapists [5], further highlighting the broad interdisciplinary connections and interests that may be fostered through this type of activity.

In this paper, we describe the impact of toy adaptation as a novel educational outreach approach for high school students by examining student engagement in underrepresented groups in STEM including females, racial and ethnic minorities, students with disabilities, and first-in-family college students. We present data from high school outreach experiences in three different contexts: 1) on-campus event for students from a local high school with high underrepresented minority (URM) enrollment who are mentored by University of Washington (UW) undergraduates, 2) on-campus event for students enrolled in a summer camp targeting underrepresented high school students held by the UW College of Engineering, and 3) event held in classroom of local high school where the teacher is leading a 6-week universal design module in a junior-senior elective course in technology and design.

We find that high school students enjoy toy adaptation and find toy adaptation valuable. Additionally, toy adaptation helps students see how engineering can have a direct impact on people and toy adaptation helps high school students feel more connected to engineering. Trends seen in the responses of underrepresented students within these STEM contexts demonstrated high positivity responses, similar to their majority peers.

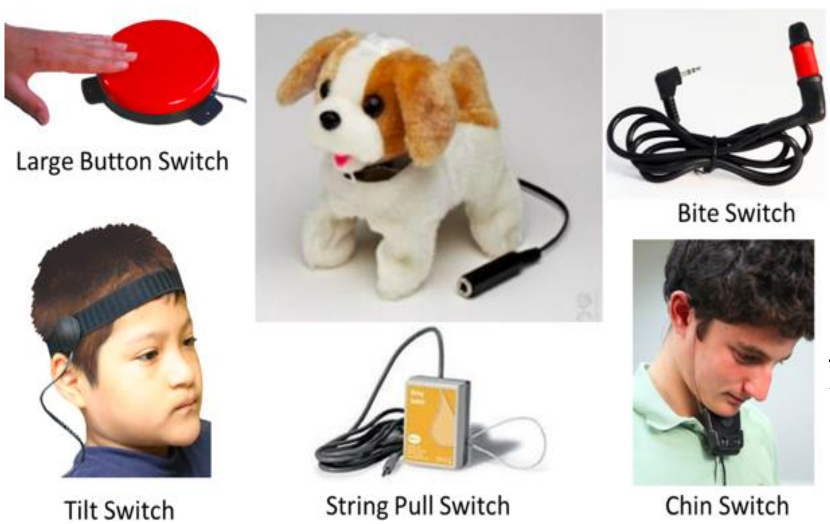


Figure 1: Adapted toy and sample activation switches: The dog is an example of an adapted toy with an additional female jack universal switch. This adapted toy can be activated by a variety of alternative activation movements including pushing a large button, tilting one's head, pulling a string, biting, or pushing one's jaw downward. I*mages from Enabling Devices [1] and Ablenet [3]*. This figure is from our previous work [5].

In addition to its novelty as the first report of using toy adaptation for high school educational outreach, our work is novel in that it evaluates the experiences reported by the high school participants themselves. Most reports of service learning outreach focus on the experience of undergraduate and graduate student volunteers, including recent studies of efforts to recruit women [15, 16]. Other studies involving K-12 outreach do not address effectiveness of specific materials in engaging underrepresented students, but instead focus on general best practices, program development, or assessment [17-20]. Additionally, groundbreaking studies involving best practices in teaching engineering to K-12 students have not been within the context of outreach, but instead have focused on formal classroom teaching approaches in general such as problem-, inquiry- and project-based approaches [21]. One program that evaluates feedback from high school students who are the participants in educational outreach is the Engineering Projects in Community Service learning (EPICS) Program at Purdue University, which began as an undergraduate program but has been implemented successfully in high schools for over a decade

[22]. In contrast to our work presented here, EPICS is a large-scale program involving longer-scale projects such as design teams. This contrasts with our work in that toy adaptation can be conducted in one session as a 1.5 or 2 hour activity without the required resources, infrastructure, and partnerships needed to facilitate high school design team initiatives, making toy adaptation a more feasible addition to existing or smaller-scale outreach efforts.

Ultimately, toy adaptation is a unique service learning opportunity that can be conducted in a short time frame (90 minutes), is relevant in all locations (since individuals with disabilities live everywhere), is affordable (~$5/student), and can be conducted locations without advanced engineering equipment. Because of these factors, we believe that toy adaptation is a promising high school outreach tool to engage students in hands-on service learning.

## Methods

This is a descriptive study of our outreach and service-learning approach to toy adaptation from within an engineering framework, and our data collected at three events which specifically targeted underrepresented students in engineering. The study was conducted with ethical approval from the authors' institution.

**Subjects.** We present data from high school outreach experiences for students in three different contexts: extracurricular club focused on science and engineering, curricular (in-classroom), and engineering summer camp.

*Group 1: Extracurricular outreach event at UW*

Students (n = 15) from Highline High School, which has approximately 62% and 59% URM enrollment and students who qualify for free lunch, respectively [23] who are mentored by UW undergraduates visited the Department of Bioengineering for an all-day event. In the morning session, students spent 3 hours adapting toys and then had lunch with an interactive panel of undergraduates who talked about their path to college. In the afternoon, the students engaged in 3 hands-on activities involving biomedical engineering applications: in addition to toy adaptation, this included demonstration and exploration of real prosthetic implants including heart valve replacements, knee and hip implants, and vascular stents; extracting DNA from strawberries; and a simulated surgery activity where students learned to tie surgeon's knots. The survey about toy adaptation was administered at the end of the all-day event.

*Group 2: Curricular outreach event at high school*

A toy adaptation event was held in a technology and design elective course at Inglemoor High School, a public high school with approximately 15% and 14% URM enrollment and students who qualify for free lunch, respectively [23]. These 11-12th grade students (n = 17) adapted toys to begin a 6-week universal design module.

*Group 3: Summer camp at UW*

The UW Math Academy is a four-week UW College of Engineering residential summer camp targeting high-achieving underrepresented students, and aims to prepare students for college-level math and engineering through courses taught by UW faculty [24]. Toy adaptation was conducted with 28 students on one day for a 90 minute period and the survey was administered immediately after the toy adaptation event.

**Toy adaptation session structure**

At the beginning of each event, a short (~10 minute) introduction including an undergraduate or graduate student explaining to the room of students: 1) why is play developmentally important?, 2) what is an adapted toy?, and 3) what is the toy adaptation process? Additionally, this introduction included basic soldering iron safety rules. Students worked in groups of three: two high school students with one trained undergraduate or graduate student. These three students adapted one toy together, with the trained undergraduate or graduate student guiding the process but allowing the high school students to do the hands-on work and problem solve through the process.

**Definition of racial and ethnic minority groups**

In regards to the definition of URM in high school enrollment (as listed above for two high schools), the Washington State Office of Superintendent of Public Instruction identifies Hispanic/Latino of any race(s), American Indian/Alaskan Native, Black/African American, and Native Hawaiian/Other Pacific Islander [23]. Additionally, the Math Academy summer camp that targets underrepresented minorities in engineering defines URM as including African American, Latino, Native American, Pacific Islander and female students [24].

**Assessment methods**

Using methodology that was determined to be exempt by the UW's Institutional Review Board for Human Subjects Research, assessment includes both qualitative and quantitative self-reported data obtained by surveys after outreach events. These events occurred both during the academic year as well as in summer programs, and they primarily focused on underrepresented students in engineering at high school level. Quantitative data included a Likert scale from 1 = strongly disagree to 5 = strongly agree. Statistical significance was tested with a Mann-Whitney U Test. Qualitative data was transcribed verbatim from the free response section of the survey. A sample survey form is included as Appendix A.

## Results & Discussion

Anonymous survey data were received from a total of 59 participants at the three events. Demographic information was left blank for six of the participants. Of the remaining 53 participants, 3.8% (n=2) of the participants identified as African American, 32.1% (n=17) of the participants identified as Asian, 20.8% (n=11) of participants identified as Hispanic or Latino, 3.8% (n=2) of the participants identified as Native Hawaiian or other Pacific Islander, 30.2% (n=16) identified as White, and 9.4% (n=5) identified as multiple options or "Other." Additionally, 39.6% of participants (n=21) identified as female while 60.4% (n=32) identified as male. Some surveys included questions about whether other family members had attended college. Out of the 9 responses received, 67% (n = 6) would be first-in-family to attend college and 33% (n=3) would not be first-in-family to attend college. Finally, some surveys included questions about disability status. Of the students that answered this question, 97.7% (n=43) identified as "Non-Disabled," 0% identified as "Disabled," and 2.27% (n=1) identified as "Other." The surveys did not ask participants to indicate their disability, if any.

In response Likert scale questions, as shown in Figure 2, students responded positively to the toy adaptation experience. In response to "I enjoyed toy adaptation," most students selected "Strongly Agree" and all others selected "Agree," leading to an average value of 4.76. Additionally, students overwhelmingly agreed that "Toy adaptation is valuable" resulting in an average value of 4.56. Students also responded positively to "Toy adaptation helped me see how engineering can have a direct impact on people" and "Toy adaptation helped me feel more connected to the field of engineering" with average values of 4.54 and 4.43, respectively. One question with more variety in response included "Toy adaptation is challenging." This was the only question that received responses from "Strongly Disagree" to "Strongly Agree," which was anticipated given that students have varying level of experience related to technical skills (soldering, use of hand tools, etc.) as well as experience with electronics.

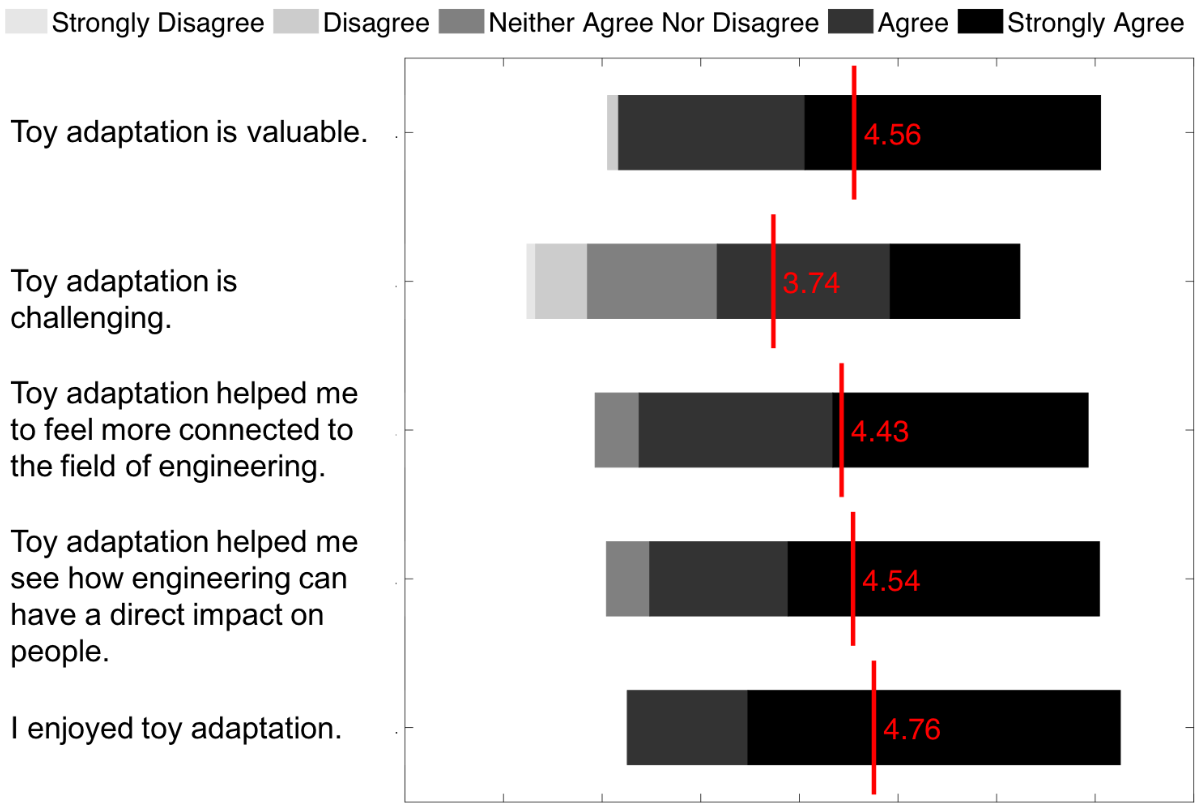


Figure 2: Responses from all high school students. In this floating bar chart, "Strongly Disagree" is indicated in light gray and "Strongly Agree" is indicated in black. Responses are centered around their average such that bars shifted to the right have higher averages than bars shifted to the left. The average of each bar is indicated by the vertical red line and numerical value. Standard deviations can be visualized in the graph by examining the quantity of answers for each respective Likert option. Numerically, from top to bottom, they are: 0.62, 1.02, 0.66, 0.66, 0.43.

When high school student responses are compared by gender, as shown in Figure 3, female students reported higher averages in 4 out of 5 questions. For example, when responding to "Toy adaptation is valuable," responses from female students averaged 4.80 and male students averaged 4.41. However, although there was a trend toward females responding more positively, the average responses between males and females were statistically similar.

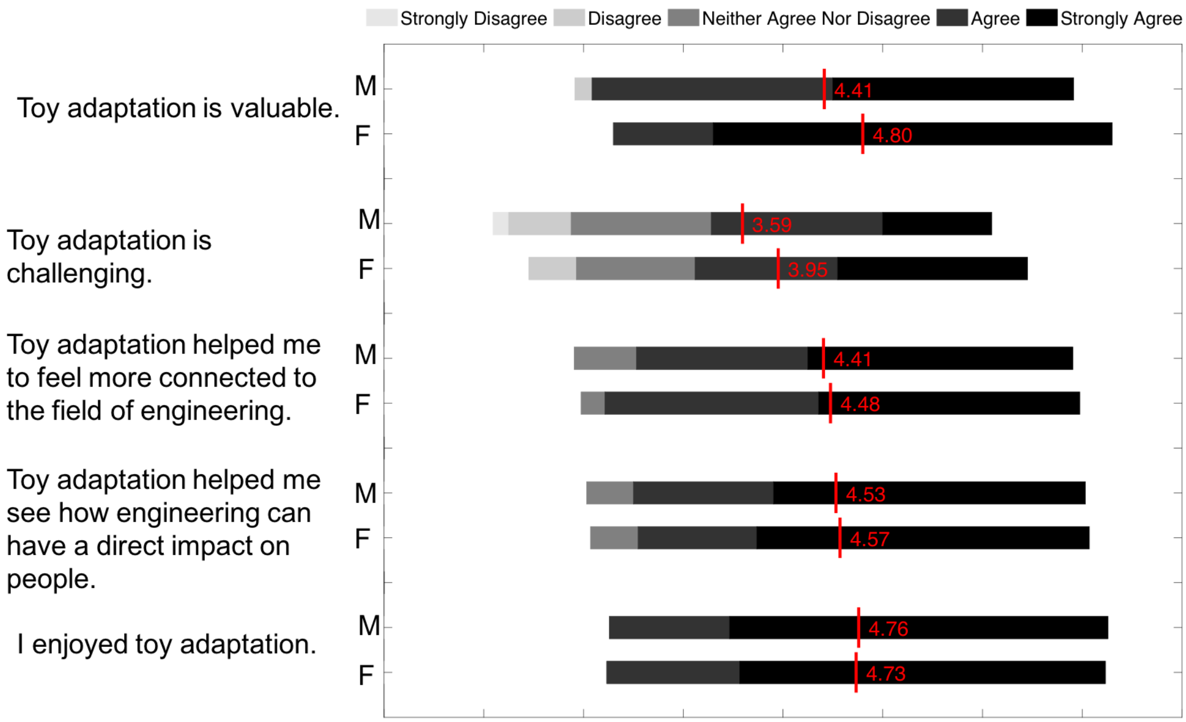


Figure 3: Responses separated by gender. In this image, "M" indicates responses from male students (n=32) and "F" indicates responses from female students (n=21). In this floating bar chart, "Strongly Disagree" is indicated in light gray and "Strongly Agree" is indicated in black. Responses are centered around their average such that bars shifted to the right have higher averages than bars shifted to the left. The average of each bar is indicated by the vertical red line and numerical value. Standard deviations can be visualized in the graph by examining the quantity of answers for each respective Likert option. Numerically, from top to bottom, they are: 0.68, 0.41, 1.07, 1.02, 0.71, 0.60, 0.67, 0.68, 0.44, 0.46.

When high school student responses are compared by race or ethnicity, as shown in Figure 4, students that are racial or ethnic underrepresented minorities in engineering consistently answered more positively (higher averages in 5 out of 5 questions). In this instance, those that identified as African American, Hispanic/Latino, or Native Hawaiian or other Pacific Islander are considered racial or ethnic underrepresented minorities (URM) while that identified as White or Asian are considered non-racial or ethnic URM. For example, when responding to "Toy adaptation helped me feel more connected to the field of engineering," responses from racial or ethnic URM students averaged 4.63 and responses from non-racial or ethnic URM students averaged 4.30. Although there was a trend toward URM students having a more positive response rate, the average responses between URM students and non-URM students were statistically similar.

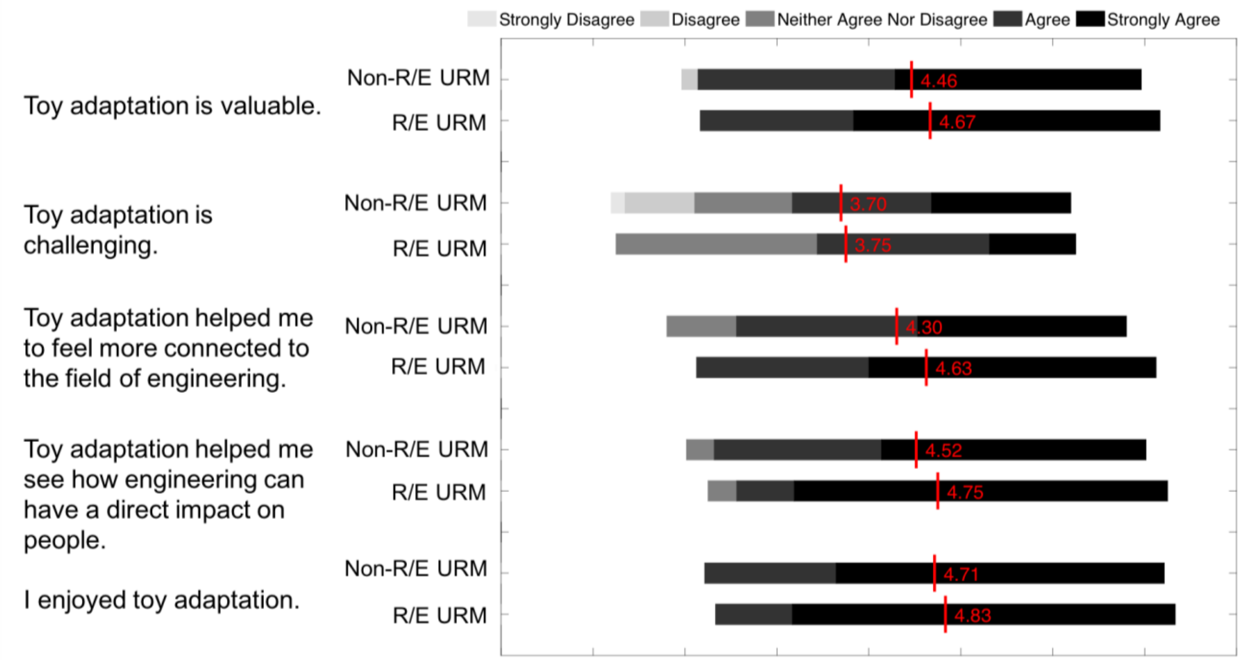


Figure 4: Responses separated by racial/ethnic underrepresented minorities (R/E URM). In this instance, those that identified as African American, Hispanic/Latino, or Native Hawaiian or other Pacific Islander (n=16) are considered R/E URM while those that identified as White or Asian (n=33) are considered non-R/E URM. In this floating bar chart, "Strongly Disagree" is indicated in light gray and "Strongly Agree" is indicated in black. Responses are centered around their average such that bars shifted to the right have higher averages than bars shifted to the left. The average of each bar is indicated by the vertical red line and numerical value. Standard deviations can be visualized in the graph by examining the quantity of answers for each respective Likert option. Numerically, from top to bottom, they are: 0.68, 0.49, 1.17, 0.77, 0.73, 0.50, 0.66, 0.58, 0.47, 0.39.

Because female gender and racial/ethnic minority status may intersect in underrepresented populations in engineering, we also considered these demographics in aggregate. When considering these interactions, as shown in Figure 5, students that are underrepresented consistently answered more positively (higher averages in 5 out of 5 questions). For example, when responding to "Toy adaptation helped me see how engineering can have a direct impact on people," responses from intersecting underrepresented minority students averaged 4.68 and responses from non-underrepresented minority students averaged 4.36. Although there was a trend toward underrepresented students responding more positively to toy adaptation, the average responses between underrepresented students and non-underrepresented students were statistically similar.

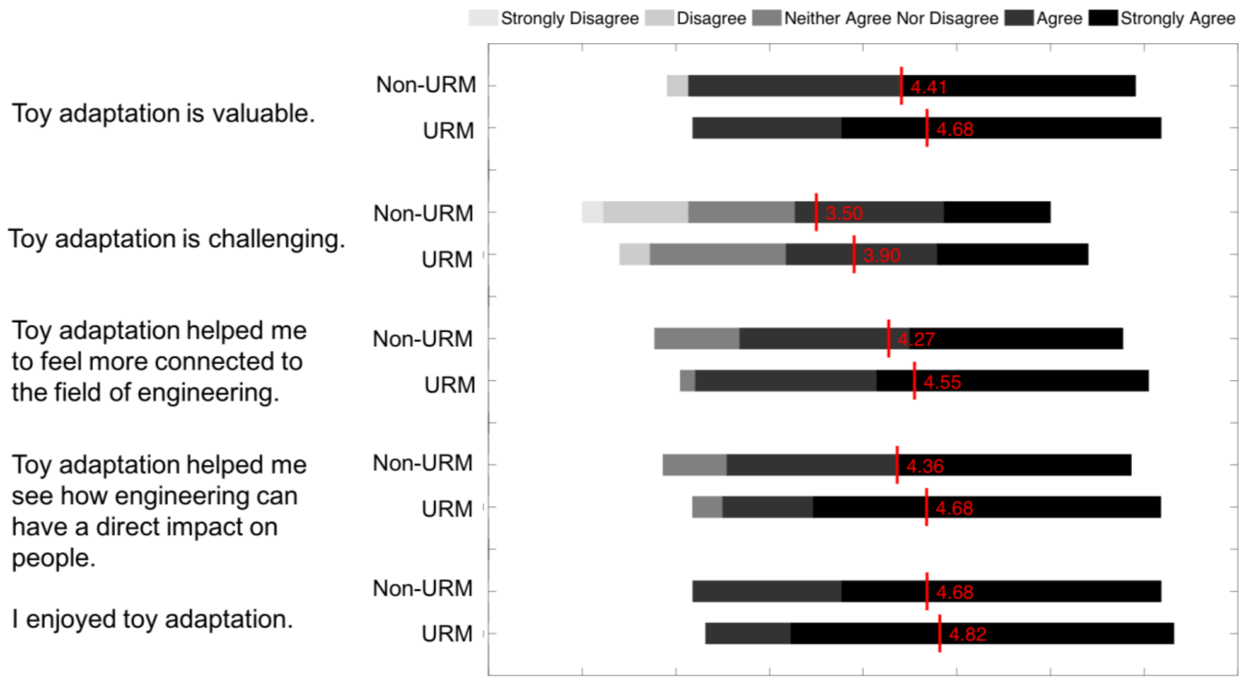


Figure 5: Responses separated by underrepresented minorities (URM) and non-URM. In this case, URM includes those that identified as female, African American, Hispanic/Latino, or Native Hawaiian or other Pacific Islander (n=31) and non-URM includes all other students (n=22). In this floating bar chart, "Strongly Disagree" is indicated in light gray and "Strongly Agree" is indicated in black. Responses are centered around their average such that bars shifted to the right have higher averages than bars shifted to the left. The average of each bar is indicated by the vertical red line and numerical value. Standard deviations can be visualized in the graph by examining the quantity of answers for each respective Likert option. Numerically, from top to bottom, they are: 0.73, 0.48, 1.19, 0.94, 0.77, 0.57, 0.73, 0.60, 0.48, 0.39.

In response to the qualitative, free-response questions, students often commented that their favorite part of toy adaptation was its hands-on aspects, as well as its application in helping people. For example, when asked "What did you like most about this event?," one 16 year old female student said, "The hands-on part of it was super fun! Also, knowing that we were helping people." In addition, one 17 year old male student said, "The hands-on application of engineering to create a product that will directly benefit people."

Some students mentioned that their favorite part was working with a current undergraduate or graduate student. For example, one 16 year old female student said that her favorite part was, "talking with the UW students about their interests and majors while learning more about how circuits work." An 18 year old male said that his favorite part was, "taking apart the toy, learning about the circuitry, and also working with the UW students. They're cool."

**Limitations to our study**

Similar to the findings of a previous study of the impact of engineering outreach involving project-based service learning on students in a 10th grade high school design course [25], our findings revealed statistically similar responses between underrepresented students and non-underrepresented students. However, as in the other study, this is not surprising because all students reported high Likert numbers and we had a relatively small sample size. Additionally, our survey design could be improved to better examine differences in how students receive toy adaptation. For example, asking students to agree/disagree with the statement “I enjoyed toy adaptation” is likely not the most optimal way to understand differences between students now that we have observed that every responding student either selected “agree” or “strongly agree,” yielding an average of 4.76. While it is promising that the activity is so enjoyable, a question that yields exclusively positive responses will make it challenging to assess any differences in how the activity is received. It may be more effective to assess what students found most meaningful about toy adaptation by asking students to rank options such as “its societal impact,” “soldering”, “working with current college students”, etc.

Furthermore, there are several challenges in evaluating engagement of underrepresented students through service learning in educational outreach. Although there are myriad resources containing curricular content that can be deployed in outreach, such as TeachEngineering [26], we are not aware of any evidence in the literature for a direct effect of any single outreach activity in attracting underrepresented students. Gathering data on effectiveness is further complicated by issues in methodology, including data that is self-reported and tightly clustered – for example, all participants reporting high scores for enjoyment and perceived learning [27] as we found in our study. In addition, outreach initiatives targeting underrepresented students may be prone to failure for a variety of reasons, including absence of assessment and unintentional sabotage by volunteers who do not represent diverse groups or who lack awareness of cultural differences and their own implicit bias [20].

Finally, as we are continuously optimizing and developing our survey instrument, there are some slight inconsistencies in the surveys used in the three events described here. For example, all surveys did not include questions about whether the student’s parents attended college or how often the student interacts with individuals with disabilities.

Future research will use additional survey development and analysis methods with the aim of preventing a ceiling effect and extrapolating further similarities or differences between high school students. Additionally, we aim to explore how different approaches to engineering outreach and service learning may be compared and contrasted, including how these approaches are designed and implemented, how URM K-12 students are involved, how the varied approaches are perceived by K-12 students, and how the fiscal and logistical considerations are managed and supported.

## Conclusion

This study presents the novel use of toy adaptation, a process in which electronic toys are adapted to be accessible to children of diverse abilities, in the context of engineering educational outreach to underrepresented high school students. We found that both female high school students and racial or ethnic minority high school students generally responded more positively to questions about their toy adaptation experience than their male and non-racial or ethnic minority peers, respectively.

This work is novel in its focus on the participants (high school students) rather than the undergraduate volunteers who performed this service learning activity. In future work, we plan to examine high school and undergraduate students who are the first in their families to attend college, transfer students to UW from community colleges, and students with disabilities. Furthermore, we will continue our initial efforts to investigate the perceptions of toy adaptation and disability in students who have varying levels of interaction with individuals with disabilities [5]. The importance of further work involving disability in the field of engineering education is underscored by a recent literature review [28] that showed very few studies include disability as an identity among underrepresented groups in engineering.

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**Appendix A:** XXXX High School Toy Adaptation Event
DATE

The purpose of this survey is to obtain information about your experience at today's Bioengineering Outreach event. Survey results will be used to evaluate the program, and results may be shared for educational purposes only.

- This survey is voluntary. Choosing not to complete the survey will not affect your participation in this event.
- Your responses are anonymous and will not be reviewed until after the event ends.

**Please answer the following questions:**

1. What did you like MOST about this event?

2. Is there anything we could have done differently? Any other suggestions?

| | **Strongly Agree** | **Agree** | **Neutral/ Unsure** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| I enjoyed toy adaptation. | 5 | 4 | 3 | 2 | 1 |
| Toy adaptation helped me see how engineering can have a direct impact on people. | 5 | 4 | 3 | 2 | 1 |
| Toy adaptation helped me feel more connected to the field of engineering. | 5 | 4 | 3 | 2 | 1 |
| Toy adaptation is challenging. | 5 | 4 | 3 | 2 | 1 |
| Toy adaptation is valuable. | 5 | 4 | 3 | 2 | 1 |

(continued on next page)

The purpose of this survey is to obtain information about your experience at today's Bioengineering Outreach event. Survey results will be used to evaluate the program, and results may be shared for educational purposes only.

- This survey is voluntary. Choosing not to complete the survey will not affect your participation in this event.
- Your responses are anonymous and will not be reviewed until after the event ends.

**Please tell us about yourself!**

Age: _________________________ Gender: ______________________

What is the primary language spoken in your home? ____________________________

Please check your current grade:

_____ High school

_____ Undergraduate student

_____ Graduate student

_____ Other (please describe: ______________________________________________)

Please specify your disability identity:

_____ Disabled

_____ Non-Disabled

_____ Other (please describe: ______________________________________________)

Please check all that apply:

______ African American
______ Asian
______ Hispanic/Latino
______ Native American/Alaska Native
______ Native Hawaiian/Other Pacific Islander
______ White, non-Hispanic/Latino
______ Other (please describe: ________________________________)

How often do you interact with people with disabilities (please check one)?

______ Never
______ Less than once per year
______ 2-3 times per year
______ Once per month
______ 2-3 times per month
______ Once per week
______ 2-3 times per week

**Appendix B: Sample photos from outreach events with high school students**