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Toy Adaptation for Children with Disabilities: A Translatable Means to Engage Engineering Students in Community Engaged Learning

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ABSTRACT

Community engaged learning has demonstrated educational benefits and is an especially promising method to engage a diverse group of students in engineering. In this work, we present toy adaptation for children with disabilities as a novel community engaged learning tool. According to students surveyed, this process is enjoyable, demonstrates the impact of engineering, and makes students feel more connected to engineering. Female students were especially impacted by toy adaptation, feeling more empowered by the experience, finding the experience more useful, and more often seeing the positive impact of engineering. Additionally, toy adaptation is highly translatable due to its short-term nature, low cost, and opportunity to leverage community connections through existing networks. Given the widespread need for adapted toys, the translatability of toy adaptation, and the overwhelmingly positive student feedback, we anticipate that toy adaptation will engage students in circuitry, inspire diverse students to pursue engineering, and provide developmentally essential toys to communities.

Key words: service learning, experiential learning, student diversity

INTRODUCTION

Incorporating community service into education provides opportunities for students to apply academic content while helping others. Community engaged learning, which grew out of general community service by universities, allows for bidirectional collaborations between the university and the community which are mutually beneficial (David J. Weerts and Lorilee R. Sandmann 2008; Roper and Hirth 2005). Research on service learning, which is typically discussed as a pedagogical approach to community engaged learning (Butin 2010), has found it enhances classroom learning (Eyler, Janet; Giles, Dwight E. 1999), student retention (Tinto 1987), community connections (Eyler, Janet; Giles, Dwight E. 1999), personal development (Eyler, Janet; Giles, Dwight E. 1999), and professional skills (Shelby et al. 2013) while also being a way to effectively deliver curricula (William Oakes et al. 2002; Duffy, Tsang, and Lord 2000). Further, this type of student engagement is a promising method to engage diverse students in engineering because societal impact has been shown to be especially important to diverse groups in career selection (Giddens et al. 2008), and service learning courses are particularly attractive to students from diverse groups (Davis et al. 2014; Rader et al. 2011).

In response to research on the benefits of community engaged learning, universities have created new engineering courses and have incorporated community engaged learning experiences into existing courses as early as the first-year (William Oakes et al. 2002). For example, Louisiana State University incorporated service learning into a first-year engineering course by tasking students with playground design and construction. This project provided an engaging method for teaching engineering standards and safety codes while providing a new playground for local children (Ropers-huilman, Carwile, and Lima 2005). Similarly, the University of Colorado included service learning in optional first-year design courses by integrating design-build projects for community members with disabilities (Piket-May and Avery 1997, 1996). Programs like EPICS at Purdue University start in the first year and can expand throughout the students' undergraduate education (W. Oakes and Spencer 2005). These experiences have yielded many of the positive benefits of community engaged learning and been valuable to both students and their communities (Ropers-huilman, Carwile, and Lima 2005; Piket-May and Avery 1997, 1996; W. Oakes and Spencer 2005).

While there are many benefits to community engaged learning, there are also challenges. Specific challenges for adoption for many of these projects include their long-term nature, coordination with clients, and balance of student learning. Long-term projects that by nature require time commitments of numerous weeks, an entire term, or multiple terms can be challenging to adopt at other institutions because they would require large curricular changes to a course or series of courses. An additional challenge of many approaches includes coordination with clients and synchronization of student and client schedules. Picket-May and Avery describe that the "effort required to get projects coordinated with the clients is enormous" (Piket-May and Avery 1997) and coordination of clients must be completed regularly before each term.

In this paper, we present toy adaptation for children with disabilities as a short-term (~60 minute), easily translatable approach to incorporate community engaged learning into an engineering classroom as early as the first year. Toy adaptation can be conducted during class time and uses existing networks to distribute toys such as partnerships with local clinics, schools, non-profit organizations, libraries, etc. While every toy is unique and requires a unique adaptation approach, toy adaptation universally teaches circuitry, soldering, use of basic hand tools, and concepts of universal design and reverse engineering. In summary, toy adaptation is a short-term community engaged learning opportunity that can be implemented in a variety of classes with relatively low client coordination efforts and relatively consistent student learning outcomes.

BACKGROUND

Play is the primary occupation of childhood due to its importance in childhood development (Dominguez, Ziviani, and Rodger 2006; Missiuna and Pollock 1991; Miller and Reid 2004). Toys play a significant developmental role because they present children with the opportunity to learn important concepts (e.g., letters or numbers) and have fundamental experiences (e.g., observe cause and effect when a button is pushed and the toy moves). Toys also assist in the improvement of motor skills, development of communication skills, and increase of independence (Missiuna and Pollock 1991; Ginsburg et al. 2007; Bhat and Galloway 2006). However, children with disabilities often cannot use a toy as it is originally designed, limiting access to the developmental benefits of play (Missiuna and Pollock 1991). In this paper, we will present toy adaptation for children with disabilities as a translatable means to engage engineering students in community engaged learning while also increasing availability of accessible, developmentally important toys.

Adapted Toys

An adapted toy is different from the aforementioned off-the-shelf toys because it is an electronic toy with an added female mono jack, as shown in Figure 1. This mono jack is a universal port in which a variety of alternative activation switches can be attached, allowing the toy to be activated, for example, by pulling a string with one finger, grasping a nearby button, or pushing a pedal with a hand or foot (see Figure 1 for examples of different switches). Adapted toys are available from several online retailers (“Enabling Devices,” n.d.; “Adaptive Tech Solutions,” n.d.; “Rehabmart.Com - Medical Supplies, Discount Medical Products.,” n.d.); however, these toys are expensive, generally two to five times the cost of the unadapted version of the toy. In addition, it can be challenging to assess how usable and engaging a toy will be from an online image, without in-person examination before purchasing. For some families already facing numerous financial demands, purchasing a $50 adapted toy that may not meet their child’s needs is simply not an option.

Figure 1. Adapted toys have an added mono jack that allows for a variety of alternative switches to activate the toy.

In response to the need for affordable and available adapted toys, non-profit organizations have been founded, often by the parents of children with limited access to adapted toys. For example, Santa's Little Hackers is a non-profit in Westminster, Colorado that accepts adapted toy requests and ships more than 500 toys across the country and world each winter (Ogden 2016). Additionally, Replay for Kids is a non-profit in Medina, Ohio that adapts, repairs, designs, and donates a total of 1,800 toys per year ("Replay for Kids," n.d.). Despite the existence and impactful efforts of non-profits such as these, the need for affordable, accessible toys still exists. For example, Santa's Little Hackers reported receiving four times the number of requests that they could fill in 2016 (Ogden 2016). Additionally, more than twenty states have no adapted toy libraries from which caregivers can borrow adapted toys and/or alternative activation switches ("USA Toy Library Association: Toy Library Locations," n.d.). Ultimately, the need for adapted toys exists everywhere, yet access is geographically and financially limited.

Toy Adaptation Process

Adapting a toy takes approximately one hour and uses consumable materials (mono jack, wire, and solder) costing approximately $1 per toy. Generally, toy adaptation includes opening the toy to find its circuit (Figure 2A), examining the circuit to determine how to activate the toy (Figure 2B), soldering in a mono jack in parallel for alternate activation (Figure 2B-D), and then closing the toy

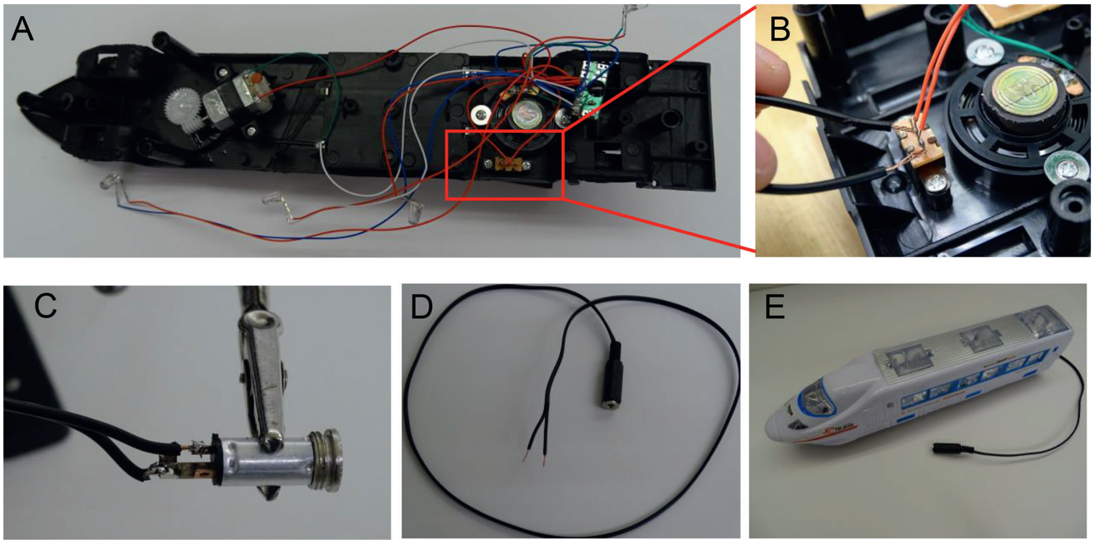

Figure 2. The toy adaptation process involves opening the toy and determining the two spots that complete the circuit (A and blown up in B.) One end of a wire is then soldered to a mono jack (C and D) and the other end is soldered to the points that complete the circuit. The toy is then closed (E) such that the jack can be accessed from the outside of the toy.

(Figure 2E). The toys are returned to their original packaging after adaptation and donated directly to families or community partners, such as non-profit organizations, hospitals, schools, and libraries (West, Kajfez, and Riter 2017).

Educational Opportunities in Toy Adaptation

The process of adapting a toy provides an experiential learning opportunity for students in the areas of circuitry concepts and components, reverse engineering, and universal design. Related to circuitry concepts, the mono jack must be added in parallel to the existing switch mechanism such that the alternative activation switch can be used to trigger the toy independently of the original mechanism. This contrasts with adding the mono jack in series, in which both the alternative activation switch and the original switch would need to be pushed to activate the toy. This simple circuits concept is one example of the content that can be learned through a toy adaptation experience. Toy adaptation also provides experiential learning with the measurement of voltage, resistance, and current using a digital multimeter. In addition to circuitry concepts, students actively learn about circuitry components by examining the toy circuit, which generally includes switches, batteries, LEDs, speakers, DC motors, resistors, etc.

In addition to delivering circuitry content, toy adaptation presents an opportunity to teach concepts such as reverse engineering (deconstructing an object to duplicate or enhance its function) and universal design (designing to enhance accessibility). It also teaches students the use of basic hand tools (screwdrivers, files, drills, etc.) and other technical skills such as soldering. Finally, and perhaps most importantly, toy adaptation tangibly demonstrates that engineers can employ their education to impact their community. While students are taking introductory courses such as calculus and chemistry, this experience shows students an application of their knowledge that has a direct benefit to their community.

METHODS

Toy adaptation was implemented with engineering students (Mollica et al. 2016; Stavridis et al. 2016; West, Kajfez, and Riter 2017) at The Ohio State University in the Department of Engineering Education. Students in the Fundamentals of Engineering courses (introductory engineering class for first-semester engineering students) participated in toy adaptation as a lab experience. In order to implement toy adaptation in the lab setting, the instructional teams (instructor, graduate teaching assistant, and undergraduate teaching assistants) attended a two-hour training session to familiarize themselves with the need for adapted toys and the toy adaption process. The instructional team then implemented toy adaptation into one of their laboratory sessions with students. The students were given preparation material prior to the lab, which included documentation on the procedure to adapt a toy and two videos covering the basics of soldering. At the beginning of class, students were shown an introduction video in which our community partners explained the real-world impact of toy adaptation on the community. The students then worked in teams of two to four and were given approximately one hour to adapt one toy. Students then completed a post-lab report in which they responded both to technical and reflective questions about toy adaptation.

Participants

The Ohio State University (OSU) is a large, public, land-grant institution located in Columbus, Ohio. The Ohio State University College of Engineering is composed of over 8,000 undergraduate students, of which over 1,500 are first-year engineering students (“The Ohio State University College of Engineering: 2016 Annual Statistical Report,” n.d.). Toy adaptation was implemented into Fundamentals of Engineering courses for two cohorts: a scholars cohort and an honors cohort.

The scholars cohort included students within a living-learning community that provides co-curricular engineering experiences to high-achieving students. The cohort has separate Fundamentals of Engineering class sections from non-scholars engineering students. Toy adaptation was facilitated in three scholars course sections with approximately 72 first-year students in each section. In this implementation, toy adaptation was paired with a basic circuits lab that is designed so that students can:

- recognize and assemble series and parallel circuits,
- construct electric circuits using a breadboard,
- develop techniques to measure voltage, current, and resistance,
- articulate the concepts and applications of reverse engineering,
- adapt a toy to be utilized by a child with a disability,
- understand the importance of engineering in adapting existing technology to be used in different ways, and
- safely and effectively solder and use basic tools.

The honors cohort included students in an accelerated introductory engineering class for academically high achieving first-semester students. The cohort has separate sections and curriculum from non-honors Fundamentals of Engineering class sections. Toy adaptation was facilitated in thirteen honors course sections with approximately 36 students in each section. In this implementation, toy adaptation was paired with a digital logic lab that is designed so that students can:

- articulate the concepts and uses underpinning reverse engineering,
- build logic circuits using transistors and NAND gates, and
- adapt a toy for children with disabilities.

Survey

Following implementation of toy adaptation in both engineering scholars and honors labs in the fall of 2016, data was collected through a voluntary online survey distributed to the students. The potential survey participants included all 676 students who completed the toy adaptation experience. This survey was sent to students one week after they completed the lab, with a follow up reminder about the survey sent two weeks after the lab.

The survey consisted of both Likert-scaled response questions and short answer response questions. These questions focused on the learning objectives of the lab along with the five elements of the MUSIC (eMpowerment, Usefulness, Success, Interest, and Caring) Model of Academic Motivation (Jones and Skaggs 2016). A brief series of demographic questions was followed by questions concerning their toy adaptation experience, which asked the students to rate statements related to toy adaptation on a five-point scale from strongly disagree to strongly agree. Example questions related to the toy adaptation experience include: “Did the experience show you how engineering can have a positive impact on others?” and “Did the experience solidify your choice of engineering as a career?” See Appendix A for the full survey. The survey received 35 responses from first-year scholars students (out of 209, 16%) and 105 responses from first-year honors students (out of 467, 22%). We recognize that the response rates for this survey are relatively low and therefore limits the scope of our findings.

Analysis

Student responses to all Likert-scaled questions were averaged and plotted on a floating bar chart. Each mean is marked with a vertical line and number. In order to investigate responses from male students (n=79) and female students (n=60), their responses were compared with a Mann-Whitney *U* test. Differences between other demographics were not examined due to small sample sizes from other diverse groups. This includes race or ethnicity responses in which 123 participants identified as white while 9 identified as Asian or Pacific Islander, 1 identified as Black or African American, and 1 identified as Hispanic or Latino. In addition, only a small fraction of students identified as first-generation college students (n=14).

RESULTS

The results from the survey given after the two implementations are presented qualitatively in this section and quantitatively in Figures 3 and 4. We use this information to provide a basic understanding of the student experience. In the discussion section, we will provide more understanding as it relates to the findings.

The Likert-scale question (5 = strongly agree to 1 = strongly disagree) with the highest average was "This experience helped me see how engineering can have a direct, positive impact on people" with an average of 4.63 (94 participants that strongly agreed, 37 agreed, 3 neither agreed nor disagreed, 1 disagreed, and 1 strongly disagreed). Conversely, the question with the lowest average was "This experience solidified my choice of studying engineering" with an average of 3.80 due to responses in which 40 participants strongly agreed, 40 agreed, 45 neither agreed nor disagreed, 8 disagreed, and 2 strongly disagreed. All questions from the survey, along with a bar showing summary and mean of response, are shown in Figure 3.

When comparing responses from male (n=79) and female (n=60) students, as shown in Figure 4, all questions except one yielded higher averages (more agreement) for responses from female students than male students. The only question that yielded a higher average result from male students was "This experience taught me about circuits," however this difference was not statistically significant when tested by a Mann-Whitney *U* test. Out of all of the remaining questions in which female responses yielded more agreement, three questions were significantly different. Female students (mean = 4.30) felt significantly more empowered by the toy adaptation experience than male students (mean = 3.84, $p = 0.00386$). In addition, female students more strongly agreed that toy adaptation helped them see how engineering can have a direct positive impact on people,

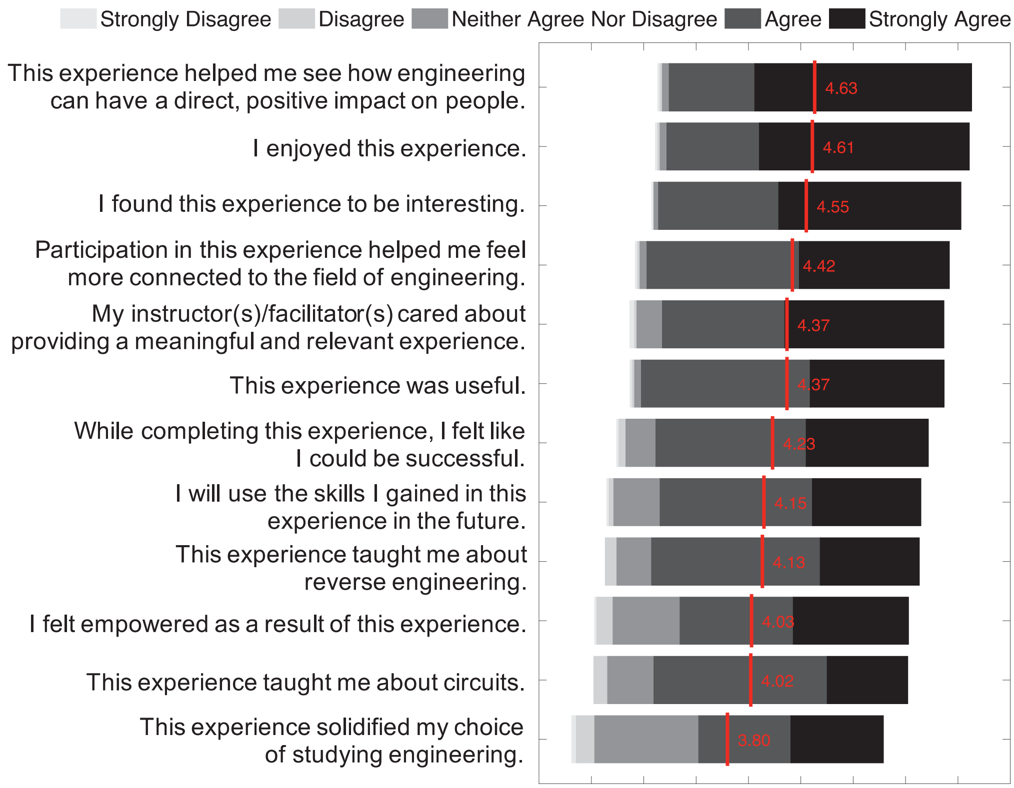

Figure 3. Results from all participants. Participants responded on a scale from 1 = Strongly Disagree to 5 = Strongly Agree. Mean values are indicated by the vertical line and number.

with female students averaging 4.74 while male students averaged 4.56 ($p = 0.022$). Finally, female students more so agreed that this experience was useful (mean = 4.51 vs. 4.27, $p = 0.046$).

In the open-ended response section, students were overwhelmingly positive about their experience. When asked what did not go well in an open-ended question, students commented on minor procedural issues such as trouble with soldering or not finishing a complicated toy. There were no other negative, salient comments. The responses were reviewed and two main themes surfaced. First, the toy adaptation experience had a real-world focus. Second, the experience encouraged positive and collaborative teamwork.

Regarding toy adaptation impact and real-world focus, one female biomedical engineering student said,

> "This experience was so beneficial for me. Up until this lab, I had been really doubting my interest in engineering; however, once I completed this lab, my interest for engineering was renewed, and I remembered why I chose to become an engineer in the first place."

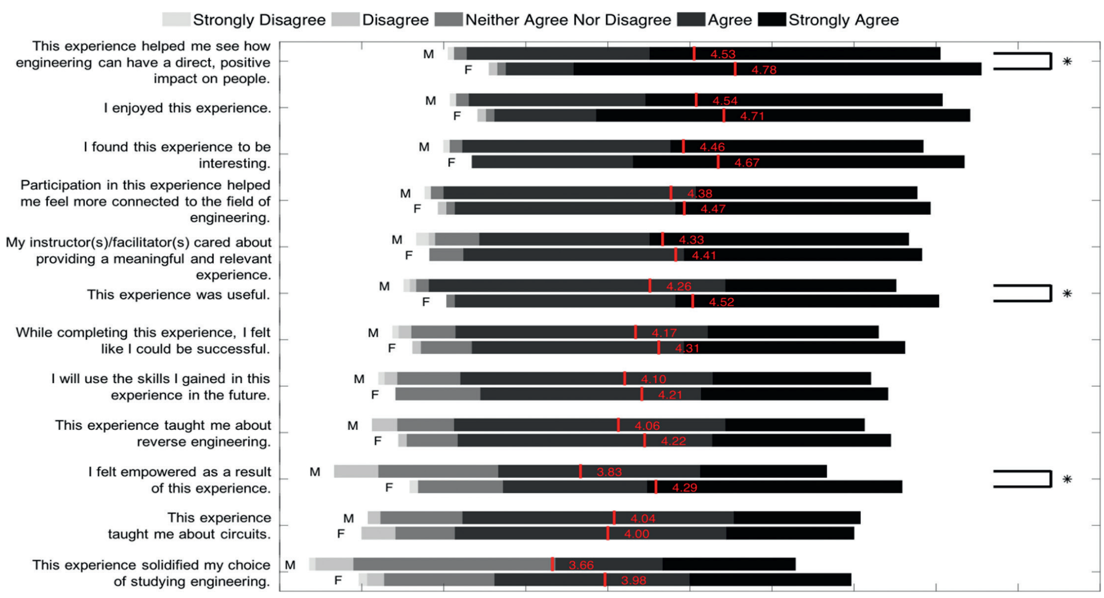

Figure 4. Results from male (indicated by M) versus female (indicated by F) participants. Statistical significance is indicated by the asterisk (*) and is defined as p < 0.05 when tested by a Mann-Whitney U test.

A male industrial systems engineering student said,

"The adjustment to college and being away from home is definitely a process and this lab meant a lot to me personally. It helped me understand that even though college is hard, in the end, if I can create these meaningful gifts, then the hardships I endure in college will be worth it without a doubt."

Another female biomedical engineering student commented,

"It made engineering rewarding and tangible in a format that was do-able for a first year. This lab will be hard to top!"

A male computer science and engineering student said,

"[It] felt great to help out a child. I could do this every day."

Finally, a female mechanical engineering student stated,

"I absolutely loved that this lab was able to impact people. I find a lot of what we are doing in this class to be very distanced from real life and pointless. I almost find that it's busy

> work. This lab allowed us to actually learn something while helping other people and that made me actually really enjoy this assignment. I strongly dislike learning things that have no purpose to them and I wish more in the class was like this lab."

From these comments, we see that students enjoyed the real-world focus and the impact of this lab. The experience was described as rewarding, tangible, beneficial, and purposeful. For at least one student, this experience inspired her to continue her engineering pursuit.

In addition to commenting on their enjoyment of a lab with a real-world impact, several students commented on their team. One female, chemical engineering student said,

> "My team worked very well together, and it was fun determining how to adapt the toy and make it work."

A male, mechanical engineering student said,

> "Our group worked together well and we were all able to contribute to the adaptation."

Finally, another female student said,

> "My group communicated our ideas very well. We discussed the plan and how we would accomplish tasks before attempting to begin, that way everything was clear and minimal errors were made."

For these students, a major part of their experience included working effectively with their team to correctly adapt their toy. Students mentioned effective communication, working well together, and having fun.

DISCUSSION

Toy adaptation was included as a relatively short-term, translatable community engaged learning experience and taught to 676 first-semester engineering students of varying majors. Student responses were overwhelmingly positive in regards to showing students how engineering can have a direct and positive impact on people, students enjoying the experience, students finding the experience to be interesting, and all other Likert scale questions. The experience is especially impactful to female students, who answered significantly differently on several questions. This difference was statistically significant when related to female students feeling empowered by the experience, finding the experience useful, and seeing the positive impact that engineering can have. These results make toy adaptation a promising tool to engage a diverse group of students in engineering experiences, which supports results from other studies on community engaged learning (Davis et al. 2014; Rader et al. 2011). In addition, in the open-ended response section, students explained their appreciation for an impact-focused lab and multiple students mentioned that it increased their passion for pursuing engineering. Ultimately, this experience is enjoyable and impactful to students while it is also beneficial to the community.

Toy adaptation possesses an important distinction from many of the community engaged learning approaches in the literature. Not only does it provide a hands-on, technically-focused engineering experience, but students are able to successfully adapt a toy in approximately 60 minutes. This provides a significant advantage as it can be added to an existing course without necessitating a significant rework to the course content. Further, as toy adaptation is closely related to a variety of topics such as circuitry, reverse engineering, and universal design, it may be a suitable addition to a variety of courses. It also does not require a large time commitment to manage clients and student/client collaboration, as established infrastructure (schools, hospitals, and services for children with disabilities) can be utilized to reach families. All of these distinctions yield the ability to engage a large number of students (in the case of this work, 676 students in one semester.) In addition, the need for adapted toys exists everywhere because children with disabilities live in communities across the country and world. Finally, because toy adaptation only requires basic, inexpensive tools that colleges likely own, toy adaptation is feasible to add to a course at large or small institutions and the cost to add toy adaptation would be approximately $5 per student (this is calculated from the cost of an average toy and the consumable materials ($15) divided by a team of two to four students conducting the adaptation.) Despite these benefits, there are drawbacks to this style of community engaged learning. First, meaningful reflection is challenging on this scale (classrooms of ~36 or 72 students for a total of 676 students.) While students did reflect through questions in their post-lab report, due to limited time and class size, the teaching teams did not lead a reflective discussion. Additionally, because this is a shorter-term experience than other community engaged learning formats, it is possible that the long-term student impact is lesser than a semester-long community engaged learning experience. Finally, while the impact of this activity is relatively direct and tangible to students and while students did hear from community partners in the introductory video shown before toy adaptation, the students did not directly interact with the community partners (parents, toy users, etc.) These were concessions that were made to achieve the scale, community impact, and translatability of this toy adaptation approach.

In summary, due to the universal need for adapted toys, the translatability of toy adaptation to various courses and institutions, and the positive student feedback, we believe that toy adaptation has immense potential impact on engineering students and their communities. We envision a worldwide network of universities collaborating to engage students in experiential and community engaged learning, inspire future, diverse engineers who are interested in making an impact, and provide affordable, developmentally important toys to children of diverse abilities.

CONCLUSIONS

Toys are developmentally important, yet children with disabilities often cannot engage with toys off-the-shelf. Adapted toys increase usability, but access to them is financially and geographically limited nationwide. This work presents toy adaptation as a promising method to engage first-year engineering students in technical engineering while solving accessibility problems within the community. According to students who were surveyed after the inclusion of toy adaptation within a first-year engineering course, this process is enjoyable, demonstrates how engineering can have a direct, positive impact on a community, and makes students feel more connected to engineering. Female students were especially impacted by toy adaptation including feeling more empowered by the experience, finding the experience more useful, and more often seeing the positive impact that engineering can have on the world. In addition to positive responses from students, toy adaptation is highly translatable due to its short-term (60 minute) nature, low cost ($5/student), and opportunity to leverage community connections through existing networks (such as schools and hospitals.) Because this community engaged learning approach is readily translatable to other institutions, we envision a future network of universities effectively teaching course content while engaging with their communities, inspiring students, and providing developmentally essential toys to local children with disabilities.

Future Work

Toy adaptation efforts through our organization and others continue to grow and develop. As one example, we are currently expanding toy adaptation to involve students in middle and high schools by working with local libraries and teachers. This paper documents toy adaptation in the higher education engineering context, but workshops around this topic can be held for many different groups. Partnerships with those in K-12 is just one of the many expansions possible. Through these expansions, we hope to inspire future engineers who are interested in working in a field that makes a true impact. We also hope to encourage those who are non-engineers to engage in engineering experiences so they be ambassadors for the field as well.

Despite the growing nature of adapted toys and adapted technology in general, little is known about the educational impact of these experiences on developing engineers. Through our work, we hope to not only serve families in need but also research the broad impact of these experiences to better understand how they affect the motivation and identity of the participants. We are also interested in the short and long-term impacts of this experience along with other community engaged learning experiences. This information will ensure that the programs are beneficial socially and educationally.

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APPENDIX A

I participated in:

- Fundamentals of Engineering 1281 Lab
- Scholars 1181 Lab
- Other

What is your sex?

- Male
- Female
- Prefer Not to Answer

What is your ethnicity (or Race)?

- White
- Asian or Pacific Islander
- Black or African American
- Other
- Prefer Not to Answer

Are you a first-generation college student?

- No
- Yes
- Prefer Not to Answer

What is your major/intended major?

- Aeronautical and Astronautical Engineering
- Aviation
- Biomedical Engineering
- Chemical Engineering
- Civil Engineering
- Computer Science and Engineering
- Electrical Engineering
- Environmental Engineering
- Food, Agricultural, and Biological Engineering
- Industrial and Systems Engineering
- Materials Science and Engineering
- Mechanical Engineering
- Welding Engineering

Was this your first toy adaptation experience?

- Yes
- No

Extended response. Please provide a well thought-out, 2–5 sentence response for each question below.

When adapting your toy, what went well?

When adapting your toy, what did not go well, and how would you change this?

In the space, please provide any additional comments.

Why did you choose to be a toy adaptation mentor this year? (MENTORS ONLY)

If you participated in toy adaptation last year, why did you choose to participate then? How was your experience different this year (as a mentor)? How was it similar? (MENTORS ONLY)

Likert scale. Please respond to each of the questions below as they relate to your toy adaptation experience using the scale provided.

Participation in this experience helped me to feel more connected to the field of engineering.

This experience solidified my choice of studying engineering.

This experience helped me see how engineering can have a direct, positive impact on people.

I will use the skills I gained in this experience in the future.

I enjoyed this experience.

This experience taught me about reverse engineering.

This experience taught me about circuits.

I felt empowered as a result of this experience.

This experience was useful.

When completing this experience, I felt like I could be successful.

I found this experience to be interesting.

My instructor(s)/facilitator(s) cared about providing a meaningful and relevant experience.

This experience taught me about logic. (FEH ONLY)

This experience relates to the Honors & Scholars G.O.A.L.S. (SCHOLARS ONLY)

This experience relates to the Green Engineering Scholars themes of green engineering, innovation, and social responsibility. (SCHOLARS ONLY)

This experience gave me a sense of leadership. (MENTORS ONLY)

Serving as a toy adaptation mentor has inspired me to include engineering education and/or outreach in my future. (MENTORS ONLY)

I would like to participate in future workshops in my 3rd and/or 4th year as a toy adaptation mentor. (MENTORS ONLY)