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Engagement in Practice: Deconstructing – Reconstructing Toys in a Design Context for Children with motor-impairments

Prof. Amanda R. Lowery, Vanderbilt University

Amanda Lowery is a Professor of Practice at Vanderbilt University Department of Biomedical Engineering. She has been working in the field of accessibility and service learning for 9 years. Her specific interests are in early childhood mobility and toy accessibility.

Eric Spivey, Vanderbilt University

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background

Service-learning experiences provide a rich platform for students to refine their technical skills while addressing real-world challenges, particularly in the area of assistive technology for children with disabilities. Engineering students often seek practical, hands-on experiences that not only enhance their technical competencies but also connect them to impactful projects within their communities, thereby enriching the educational experience and fostering empathy among future engineers [1-2]. Organizations such as Tikkun Olam Makers and Makers Making Change match people with assistive technology needs with makers in the community. Student chapters of these organizations have been established on many campuses [3-4]. The relatively quick project completion allows students and the end-user to see the immediate effect of the project. As a sub-set of accessibility design, the post-market modification of toys for children with disabilities has been used inside and outside of engineering courses at the high school level to college to teach practical application of engineering skills and problem solving [5]. The Go Baby Go project, started at the University of Delaware [6] and focused on modification of ride-on toys for use by children with mobility-impairments, exemplifies the value of this approach. The program has been locally adopted by affiliated groups at numerous universities, including Wichita State [7], University of Central Florida [8], University of Washington, Seattle [9], Oregan State University [10], and Indiana University, Indianapolis [11]. Beyond both the valuable pedagogy provided, and the benefit to the community, Mollica, et al. demonstrated that toy modification made students feel more connected to the engineering discipline [12-13].

This paper discusses the incorporation of the toy modifications in two required BME courses to teach aspects of technical writing. In the first course, a sophomore level lab, students modify small electronic toys for donation to a state-run toy lending library. In the second course, a junior level lab, students tackle a larger collaborative, cross-disciplinary, custom modification of a powered ride-on toy car for a specific individual. For both courses the students communicate their research, design, process, and outcomes in a design report. Conversations with students indicate this is a positive experience where they see value in the skills they are learning, and participants comment on the increased community inclusion they feel as a result of this project.

partnership development

This project is a collaboration between the Biomedical Engineering (BME) undergraduate program at one institution and the Occupational Therapy (OT) graduate program at a second institution. The two schools are located within walking distance of each other (< 1.5 miles apart), which helps facilitate student interactions. The two programs were connected through Go Baby Go in 2016. Go Baby Go is a non-profit organization that adapts battery operated ride-on toys for children with disabilities. The OT program already had an established Go Baby Go project and BME was able to use the framework to bring the program to its home institution. In 2022, BME moved the car modification project from an elective course to a required junior level lab course and added a smaller toy modification project to the sophomore level required lab course. The administration of the BME Department and School of Engineering has been very supportive of the project, providing visibility of the program to both prospective students and to school/department stakeholders at large. They also provide funding for the program, both from departmental funds, and as part of state educational grants.

project design and execution

Beginning in 2022, BME added two service-learning projects, one to the sophomore lab and one to junior lab, specifically to incorporate more industry-style design report writing.

In sophomore lab, the students increase the accessibility of electronic, button activated toys by making post-market modifications to purchased toys. Parallel to learning about this need, the students are learning to write an industry-style design reports documenting their modifications. The project extends over 6 lab sessions that meet for 3 hours once per week. The approximate schedule can be seen in Figure 1. The design report structure is introduced in the first week. Each week as the students progress through the physical toy modification, they draft corresponding pieces of the design report (Figure 2).

Singing-Dancing Toy Modification Schedule

Week 1: Structure of the Design Report
Week 2: Background/ Problem Definition/Document toy operation
Week 3: Learn basic lab skills and safety protocols
Week 4: Plan and circuit diagram
Week 5: Work time
Week 6: Design evaluation and recommendations
Week 7: Present toys to TTAP/ Reflection

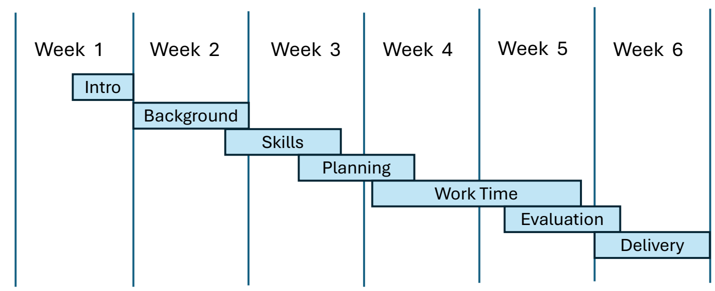

Figure 1. Approximate timeline of toy modification project in the sophomore lab class.

To support the background section of the project, the students learn about the need for toys that are accessible to children with special physical needs, and they hear from a biomedical engineer working for a statewide program that assists residents in obtaining assistive technology devices and services. The students then begin defining the problem by reflecting on the stakeholders and their goals / needs in providing accessible toys. After a small market analysis of current solutions, they draft a problem statement and identify constraints that will be requirements in the new solution. A few engineering standards (from ASTM F963-17) are pre-identified for the students to include in the requirements. For example, two of the engineering standards that must be met include: wire strain relief and strangulation prevention for toys.

By the third week the students are ready to begin planning their modifications, but do not yet have the hard skills to fully scope possible modifications. One week is spent on skills development. During this time, the students practice skills such as: stripping wires, soldering, using heat shrink, sewing, adding wire strain relief, understanding switch function, drill and power tool safety, and more.

Once the skills have been acquired, the students begin the Design Description by planning the circuitry and physical changes to be made. Most of the toys we purchase are activated by a single momentary switch embedded in the soft fabric of a plush toy. The modification plan should include the removal of the small embedded button and replacement with a large external button with the same function. A casing must be constructed for the new button and the engineering standards must be met. Additionally, a few more complicated toys with multiple functions are available to modify, for students who come into the class with more advanced skills. These more complicated toys have been welcomed by the state because older clients appreciate the added complexity of the toys, and there are fewer market solutions for complex toys.

Design Report Sections

- Background/Motivation
- Problem Definition (Needs and scope)
  - Identify stakeholders
  - Identify current solutions and shortcomings
  - Formulate a Problem Statement
  - Identify solution Requirements
  - Receive Pre-identified Standards
- Design Description
  - Schematics of original circuitry and new circuitry
  - Schematics of original physical structure and planned structure
- Design Evaluation
  - Evaluation of the Requirements and Standards
  - Results of functional test
  - Economic Analysis
- Recommendations/Conclusions:
- References:

Figure 2. Outline for generic design report writing project that accompanies the toy modification

When the design description is approved by the instructor, the students then modify the toys by replacing buttons. This typically occurs in week 4-5 of the project. They document the process and finish with the Design Evaluation. During this stage, they double check the function, requirements, standards, and conduct a cost analysis of the toy. The final report piece is to make recommendations for how toys could be modified in the future or how they personally would approach the project differently next time. The toys are then donated for distribution across the state.

In junior lab, students expand on the toy modification by working on the cross-disciplinary Go Baby Go project with OT. Early childhood mobility is important for development milestones [14]. Following a similar timeline and design report structure, the BME students learn about the lack of options available to families who have a child with motor skills delays, then make modifications to the toy car. Working in groups of 4 BME students and 2-10 OT students, teams are paired with an individual child with a mobility need.

Families and children are recruited through the pediatric occupational therapy clinics around the area. The selection criteria for participation include the weight limit of the toy; the family availability to participate in the assessment, fitting, and delivery of the car; and a willingness to work with the students. The students develop practical skills that are important to their disciplines. The OT students provide the clinical assessment and help identify the needs of the child. The BME students then design and install the modifications needed to make the toy operational by the child. These modifications typically include rewiring the “gas” pedal (an electrical switch activating the vehicle motors) from the foot position to a button located on the steering wheel, installing postural supports, and installing steering adaptations. All students are then part of the delivery of the cars to the children. Students participate in on-the-spot problem solving during the delivery and final fitting of the car with the child. Meeting the children receiving the cars provides very clear and strong motivation for the project as well.

Although they have the same design report sections, the junior lab students write reports that are more varied and specific than they were in sophomore lab. Each car design is unique to the child's physical and developmental needs, and the students are required to identify additional engineering standards beyond what was provided in the sophomore lab. This progression helps prepare them for the design reports they will write in senior design.

cost

The cost is covered by lab supply funds, department and school support, and state education grants. The age, size, and health condition of the child dictates the car that would best fit their needs. Typically, a 12-volt ride on toy car (average cost $150) is a good fit for children ages of two to four. Smaller 6-volt toys are cheaper (less than $100), but only appropriate for very young children. Likewise, older children require larger ride-on toys, costing more (over $200). Additional consumable supplies cost $50-100 depending on the types of modifications needed. The small toy modifications are less expensive with most of the cost being the toy itself. BME is spending approximately $60 per student for the car project and $40 per student for the smaller toys. The number of small toys and cars varies each semester between 20-60 toys and 4-8 cars. The combine total per semester cost for the projects is between $3000 - $4600. We can offset some costs by applying for internal grants and partnering with other external organizations.

student outcomes and evaluation

This project offers innumerable opportunities for complex problem solving, developing empathy, integration of skillsets across classes, and professional communication. Students gain the practical experiences of using hand tools, designing to constraints such as engineering standards, iterating those designs, and managing their time. The real application problem solving has an immediate impact on the students and the families involved. For the students, the openness of this project can be daunting, but the success of the students and children is very rewarding.

The engineering challenges encountered, and innovative solutions developed, especially in the car modifications and to a lesser extent in the toy project, help develop complex problem-solving skills critical to engineering. In the toy project, the students follow a standard approach, and the instructors guide them to a small subset of possible solutions. For example, the challenge of providing an actuation method that does not require gripping or pinching motions leads to the large external button as a solution. Within the sub-set of solutions, students make decisions on readily available momentary or locking switches and what best facilitates the function of the toy. In the car project, the number of competing constraints and possible solutions increases. One common issue is a child cannot reach the steering wheel where the "gas" button has been placed. Students can design a solution to bring the steering wheel closer to the child or bring the child closer to the steering wheel, but additional limitations on the child's abilities uniquely influence the design choices. Some confounding issues have included: asymmetric arm lengths, contractures limiting the ability to extend the arms, spasms, and inability to sit independently or hold their head up. These issues along with our limitation on supplies and time spur innovation. For the challenge of reaching the steering wheel, students have designed PVC pipe crossbars over the button, 3D printed steering column extensions, head-actuated buttons, and PVC pipe frames with kickboards to increase back support. Every year, the technology in the cars and the children in the program are changing, which creates a continual renewed need for innovation.

Students consistently comment on how this project makes them feel like "real engineers". They appreciate that it is meaningful work, not busy work. In job interviews, they discuss problem solving, planning, design, timing, and troubleshooting. The projects have even inspired some students to volunteer in future semesters of the course or to carry the project to extracurricular groups like TOM. One student commented "Participating in the Go Baby Go project was a unique opportunity to apply my engineering knowledge to improve the mobility of a child, which gave me an opportunity to make a meaningful difference. This experience strengthened my passion for biomedical engineering by allowing me to see the positive impacts I can make on my community." We are currently working on obtaining IRB approval to allow a more formal assessment of the projects' impact on students.

community impact and lessons learned

These projects have lasting impacts on the families involved as well. One mother from the Spring 2024 groups said, "The Go Baby Go car has been a blessing for Bailey. She is able to be included with her sisters when they play outside. They can ride bikes while she cruises, or [they] walk alongside and even control the car for her at times. She just wants to be one of the neighborhood kid gang, and she is now." Years after receiving a Go Baby Go car, another parent from the 2016 group told me her child used his car until he couldn't fit in it anymore. Now that child is active in wheelchair sports.

One of the key lessons learned from developing this program into a recurring course is that internal flexibility and external support are essential. Because the students, the client children and the toys themselves change from semester to semester, there can be no "answer key" to the project portion of the class. The need for flexibility is critical to adjust for extra design time and changes in material availability. Because of this, having a solid external support system in terms of funding, logistical support and clear (but general) parameters for success are equally important. The fluidity and the resulting "open-endedness" of the project, students must be responsible for imposing order and structure on their own project. Instructors must be prepared to help structure the project if needed, by providing clear check points, feedback, and a sense of support. In parallel, training students with the specific skills and tools used for toy modification is critical for giving them the perspective to properly plan the work.

conclusions and next steps

The Go Baby Go cars and small toy modification projects continue to grow. Students come into the courses eager to participate. Parents of children with disabilities contact the program asking to be added to our recruiting lists. Other faculty have reached out to be included as well. To help accommodate the growth of the projects, the new Department of Experiential Design at the collaborating institution joined the car project. In late Spring 2025, the three departments worked together to modify 12 cars in a single semester.

Currently, the feedback from the students and families is anecdotal. To better document the impact of this project on our students, we plan to develop a formal assessment through surveys. Similarly on the client side, we plan to have more follow-up with the families to understand how the toys and cars have impacted them. This data and dissemination of our process may be a resource for others in need of toy modifications.

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