Modeling Real-World Objects:

Connecting SolidWorks to Toy Adaptation

Olga M. Stavridis, Rachel L. Kajfez
Department of Engineering Education
The Ohio State University
Columbus, OH, USA
Stavridis.2@osu.edu, Kajfez.2@osu.edu

Elizabeth A. Riter, Molly Y. Mollica
College of Engineering
The Ohio State University
Columbus, OH, USA
Riter.7@osu.edu, Mollica.15@osu.edu

***Abstract*—Classroom activities that are based in the real-world are known to be impactful. Similarly, activities that relate to social good have been found to be engaging and meaningful for students especially to those from underrepresented groups. Many times, these activities tend to be design based projects, and while meaningful, activities of that nature may not be suitable for every class. In this innovative practice paper, we will describe an approach to modeling real-world objects in SolidWorks. The goal of the modeling is to test students' technical and spatial abilities while connecting the modeling to the greater good. The SolidWorks modeling takes place in a 4000-level (senior) SolidWorks elective course where students become certified at the SolidWorks Associates Level. Team members from the Toy Adaptation Program (TAP) at The Ohio State University came into the class to discuss the purpose of their program and their work, which includes adapting toys for children with special needs. This need served as the background for a semester-long modeling project. Through the partnership, students now model toys that are adapted by the TAP. This activity brings awareness to the need for adapted toys and allows the students to use their modeling skills to create real-world objects while satisfying course requirements.**

Keywords—SolidWorks; accessibility; service

I. Introduction

Engineering courses teaching parametric modeling using a CAD package, such as SolidWorks, often integrate a multi-week project for students to complete along with typical homework exercises and exams. Many times, these projects are based in Project Based Learning (PBL) pedagogy. Dym, Agogino, Eris, Frey, and Leifer [1], who paraphrased Bransford, Brown, and Cocking [2], claim that PBL, "addresses one of the key issues in the cognitive sciences, transfer, which may be defined as the ability to extend what has been learned in one context to other, new contexts." Providing an open-ended, team project for undergraduate engineering students, allows for students to make the connection between classroom theory and real-world application aiding in their transfer of knowledge and skills. This addresses the issue recognized by Enderle, Ropella, Kelso and Halowell [3] in that undergraduate engineering students, specifically in the biomedical field, are not prepared to tackle real-world engineering problems upon graduation. Determining what topic or object the project should focus on can be challenging when trying to ensure that the learning experience is both valuable and at the right level of difficulty for the entire class. Because modeling projects like this often incorporate reverse engineering, other factors should also be taken into consideration when choosing the topic including the tangibility, accessibility and complexity of the object [4]. Instructors in this area have explored varying project topics or objects to have students model so that they are able to apply multiple concepts learned in SolidWorks in the course (e.g. feature based modeling, creating assemblies, and Finite Element Analysis) while understanding how these skills can be used when working as an engineer in industry. This idea of centering a project around a real-world product or object has been implemented successfully at several universities, including Oakland University in having mechanical engineering students design and create their own toy in a capstone course [5] and also at the University of Aveiro, Portugal in mechanical engineering [6]. Our paper discusses an innovative practice project that teaches students the concept of reverse engineering as well as the societal impact engineers can have on their community, by creating a holistically meaningful and worthwhile project experience based on a real-world topic.

The project topic being introduced in this paper is modeling an electronic toy. This toy is just one part of a much larger program at The Ohio State University (OSU) called the Toy Adaptation Program (TAP) [7]. This is a program in which undergraduate engineering students modify electronic toys so that children with disabilities can use them. In the course, student teams purchase a toy and have the opportunity to take it apart and figure out how it works, also known as reverse engineering or the disassemble/analyze/assemble (DAA) process [8]. It is believed that engineering students are "tinkerers" [9]; this project allows them to do just that in dissecting the toy to examine how it works. Students then model parts of the toy in a group setting and compile their work to create a final project. According to Lamancusa [9] who referenced Felder and Silverman [10] "many engineers are in reality 'visual learners', much better served by active, visual and tactile teaching methods." This theory aligns with the current Maker Movement, which emphasizes using both "tinkering" and tactile, hands-on experiences to learn how to do or make something [11]. Following completion of this project, students donate the toys to the TAP. Many engineering students, particularly those in underrepresented groups, tend to support projects that have societal impact [12-14]. Therefore, trusting these beliefs to be paramount for an effective project topic/object for a CAD modeling engineering course, the concept of centering the semester-long project on students modeling toys that would be donated to the TAP seemed like an ideal opportunity.

In the past, for this team project, students could model things that were not tangible to bring to class and relied on dimensions viewed either from the online source from which the idea came or from a job site from which a team member may have worked. Modeling a toy from a pre-approved list, students have the actual object available to bring to class during work sessions. Members of the TAP are able to come to the classroom to support the students by providing specialized tools to help in taking apart the toy and to explain to the teams how the toy would likely be adapted for the disabled children. It is believed that this piece of the collaboration helps the engineering students working on their project to realize the end goal and understand the real-world application.

In the following sections, we discuss in more detail the TAP, the course and project, the current and future collaboration with the TAP, as well as results from a survey given to students in the class about their toy modeling experience.

II. The Toy Adaptation Program (TAP)

The Toy Adaptation Program (TAP) unofficially began in April of 2013. An engineering student participated in a toy adaptation workshop held by RePlay for Kids near Cleveland, Ohio. During this workshop, students were led through the process of taking apart an electronic toy, assessing the circuitry, and adding in a parallel circuit, to allow for activation of the toy through a capability switch. These switches are used by children with profound physical and/or developmental disabilities who would otherwise not be able to use many of these electronic toys without the adaptation process and capability switch. Having had such an impactful experience helping others while applying her engineering skills, this student brought the idea back to OSU.

Since then, the TAP has held at least one workshop each semester allowing hundreds of OSU engineering students and volunteers to adapt hundreds of toys, which have been donated to local toy-lending libraries or directly to families with special needs children. This experience has evolved over the past three years in that the TAP has integrated this into the classroom as a lab experience through development of curriculum. The TAP has also done workshops for industry professionals as a way to give back to the community and network with OSU students. The TAP has found that adapting toys is valuable to many different members of the community, including families, educators, occupational therapists, engineers, and more, and in a variety of ways.

For the past two years, Engineering (ENGR) 4410.02 has allowed students to model an electronic toy for their class project, instead of a random object, in the hopes that after modeling this in the course, students would then donate the toy to the TAP to be adapted and donated to children with special needs. TAP team members have visited the class to explain the program and its purpose so that students can connect their modeling experience with the overall mission of toy adaptation and recognize the impact their donation will have on local families. This partnership has not only enabled us to raise awareness of the need for adapted toys and receive donations from students, but it has allowed engineering students to contribute to a real-world problem by applying their technical skills. We plan to continue to grow this partnership with the goal of providing additional educational and societal benefits to everyone involved.

III. Engineering (ENGR) 4410.02

Through this collaborative partnership between the OSU TAP and ENGR 4410.02, we are able to create a meaningful in-class activity for our students that tests their technical skills. Below we describe the course and then the specific project related to toy modeling.

A. The Course

ENGR 4410.02 (Computer Graphics Using SolidWorks) is a two credit hour course offered as a technical elective for several engineering disciplines and is a required course for students pursuing a degree in Food, Agriculture, or Biological Engineering. Typically, 36 students are enrolled in the course each term. Objectives of the course, as stated on the syllabus include:

- Gaining a solid grasp of the fundamentals of solid modeling and developing an ability to use it to model complex parts and assemblies (using SolidWorks).
- Simulating the motion of a model and applying advanced analysis tools (e.g. Finite Element Analysis).
- Learning the fundamentals of geometric modeling-representation and manipulation of complex curves and surfaces and developing an ability to apply them to real-world examples.
- Learning how to create representations and manipulations of complex curves and surfaces.
- Reviewing good dimensioning practices.

During the class periods that meet for 80 minutes twice each week, a short lecture is given to review new topics within SolidWorks and then students work on in-class assignments. While working on assignments, the instructor and two teaching assistants (TAs) are available to help students. Also, homework is assigned and collected at the start of the following class. While gaining more experience with SolidWorks modeling, students are directed to create teams of four to begin a semester-long team project.

B. The Final Project

The final project is worth 25% of the course grade. This project requires students to model a complex assembly in SolidWorks. The complex assembly is an electronic or battery-operated toy selected from a list supplied by the TAP. Students work in teams of four, and the assembly that is created must be complex enough such that each team member is responsible for six to eight different parts.

The project contains four phases. The first phase is the Project Proposal (one per group, 5 points) which must include:

- A hand sketch, photograph, or drawing that shows the object to the group plans to model in SolidWorks.
- A list of each (different) part that each group member plans to model in SolidWorks.
- A rough idea or breakdown of what each team member plans to do for this project during the remaining weeks of the semester (Timeline or Gantt Chart showing timeline).

The second phase of the project is the Project Status Report (one per group, 20 points) which must include:

- The status of where each part is as far as completion (have not started, a percentage of completion, completed, etc.).
- An update of remaining work, who will do it, and when it will be done (Updated Timeline).

The third phase is the Final Project Requirements (one per group, 100 points) which must include:

- Hard copies of:
  - Isometric of the assembly
  - Bill of materials for assembly including exploded view and balloons
  - Detailed dimensioned drawings (including centerlines, hidden lines, section views) of four to five parts
  - Isometric drawings of other relevant complex parts (one to two for each team member)
  - Site sources of downloaded files (if any)
  - Paragraph on how the team worked together and any teamwork issues encountered (and how they were resolved)
  - An analysis of one or more parts using a SolidWorks application such as Simulation or Flow or other SolidWorks application
  - PhotoView 360 rendering
- Electronic copies of:
  - Assembly and part files
  - Animation file

Additionally, each team member must email the course instructor during the last week of the class regarding their opinion of each team members' contribution to the project based on percentage. If each team member contributed equally, the percentage for each member would be 25%.

The final phase is the Group Project Presentation (50 points). During the last week, each group presents their project to the class. The presentation lasts eight to ten minutes and includes such items as the overall assembly, animation, and an advanced concept (e.g. advanced mate or analysis).

IV. Examples of the Project

In the following figures, we have included example images of one group's project. This team chose to model a Fubbles Bump-n-Bubble Robot® bubble maker. The two figures show a simple part located within the toy and then a more complex mechanism with multiple parts.

Fig. 1. Simple Parts in Bubble Maker (left – arm; right – back)

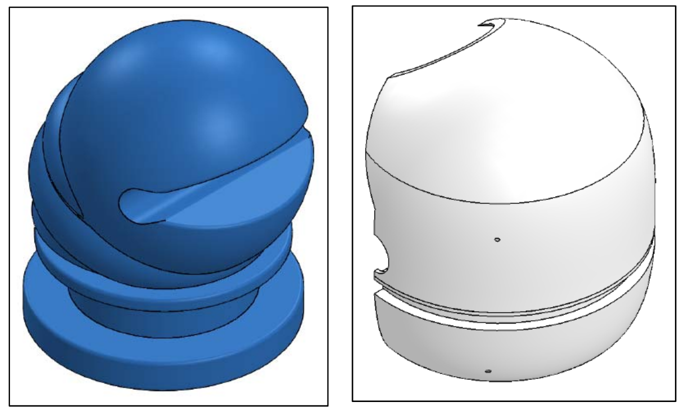
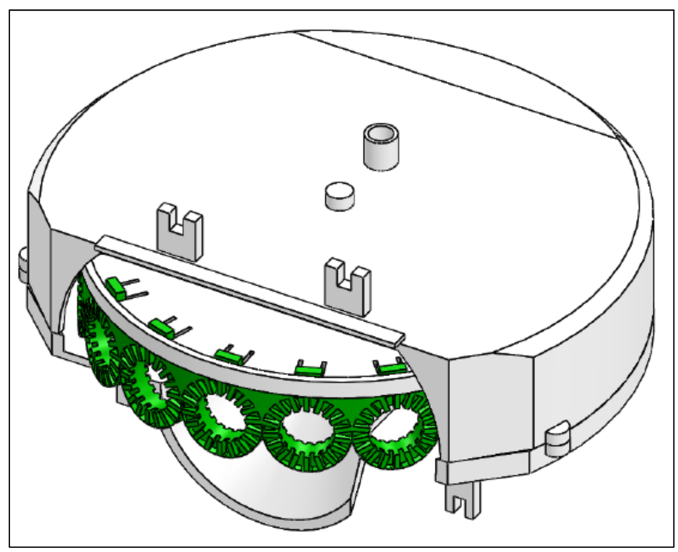


Fig. 2. Complex Mechanism in Bubble Maker



V. The Assessment

To assess the effectiveness of the project and to determine students' views towards the project in general, we conducted a survey about the experience. Under IRB approval, the survey was administered in class through the online course management system, and students had 10 minutes to complete the assessment. The assessment had three components: demographic questions, open-ended responses, and closed-ended responses. Each component has been detailed in the following sections.

A. Demographic Questions

These questions were answered to establish a better understanding on the population. The items in parentheses were the available responses for each question. Specifically we asked:

- What term were you admitted? (Fall 2011/Spring 2012/…/Spring 2016/Other_____)
- Why are you taking this course? Select all that apply. (Required for Major/Elective for Major/Interest in Computer Graphics using SolidWorks/Other_____)
- What is your sex? (Male/Female/Prefer Not to Answer)
- What is your ethnicity origin (or Race)? (White/Hispanic or Latino/Black or African American/ Native American or American Indian/Asian or Pacific Islander/Other/Prefer Not to Answer)
- Are you a first-generation college student? (Yes/No)
- What is your major/intended major? (drop down with all engineering majors and other)
- Was this your first toy adaptation experience? (Yes/No)
- Would you be interested in participating in a future toy adaptation experience? (Yes/No/Maybe)

B. Open-Ended Responses

These questions were included to assess students' perceptions of the project in general and to provide ideas for future enhancements to the project. Specifically, we asked students provide a well thought-out, two to five sentence response, for each question below:

- While modeling your toy, what went well?
- While modeling your toy, what did not go well, and how would you change things in the future to improve it?
- What else could have been provided (tools, instruction, etc.) to help you with modeling this toy?

C. Closed-Ended Responses

Finally, we asked closed-ended questions related to the project. Specifically, we asked students to respond to each of the questions below as they relate to their toy adaptation experience using the scale provided (strongly disagree to strongly agree – five point scale):

1. Participation in this experience helped me to feel more connected to the field of engineering.
2. This experience solidified my choice of studying engineering.
3. This experience helped me see how engineering can have a direct, positive impact on people.
4. I will use the skills I gained in this experience in the future.
5. I enjoyed this experience.
6. This experience taught me about reverse engineering.

Additionally, a set of the closed-ended items were also designed to ask questions related to the MUSIC Model of Academic Motivation [14]. The MUSIC model is designed to consider empowerment, usefulness, success, interest, and caring as it relates to the educational environment or an educational experience.

M. I felt empowered as a result of this experience. *(eMpowerment)*

U. This experience was useful. *(useful)*

S. While completing the experience, I felt like I could be successful. *(success)*

I. I found this experience to be interesting. *(interest)*

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

The survey concluded with the following question: In the space below, please provide any other comments you have about your toy modeling experience.

VI. The Results and Discussion

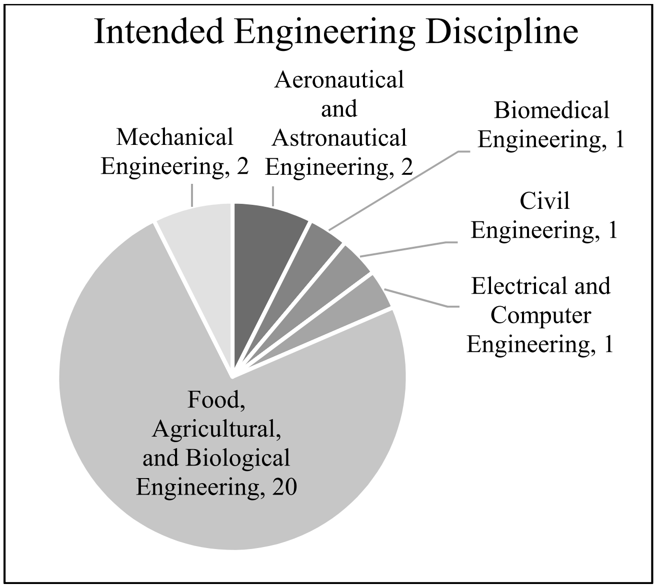
The results below are discussed in reference to the course, the project, and the TAP. The results provide insight into the impacts of the project and areas for future work.

A. Demographic Questions

27 students, including 18 males and nine females, responded to the survey. This correlates to a 75% response rate (27 out of 36). 6 of these students were first generation college students and 21 were not. The majority of students, 21 out of 27, identified their ethnic origin or race as white, while two identified as Hispanic or Latino, two as Black or African American, and two as Asian or Pacific Islander. This demographic information is similar to the overall demographic information for the College of Engineering at this institution. We present this information to contextualize the findings, not to evaluate the results across various demographic groups. Due to the innovative practice nature of this work and our limited sample, these types of comparisons are beyond the scope of this work.

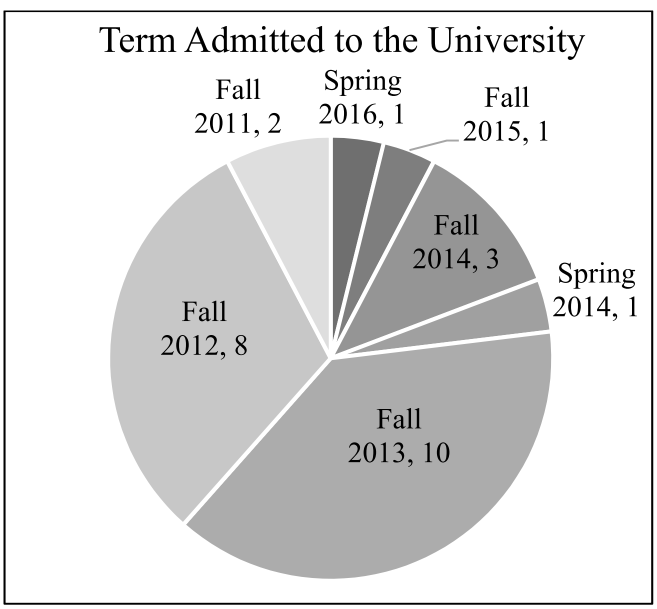
The survey responders included six different academic majors with the majority of students intending to study Food, Agricultural, and Biological Engineering (FABE), as indicated in Figure 3. FABE is represented so strongly in this course because it is required for some of the students in that degree program, depending on their chosen track.

Fig. 3. Intended Major



As shown in Figure 4, the course was composed mostly of third-year and fourth-year students based on the term and year they were admitted to the university. Given that this is a 4000-level course, this was expected. "Term admitted" is a better measure of experience at the university compared to "year in a program" given the high number of students entering OSU with previously earned credit, as well as the high number of students who switch degree programs at OSU.

Fig. 4. Term Admitted to the University



Finally, while only four students had previously had a toy adaptation experience, twenty indicated that they would be interested or would maybe be interested in a future toy adaptation experience. This is promising for the TAP as there are many plans for expansion.

B. Open-Ended Responeses

In response about what went well when modeling the toy, the most frequent response, mentioned by eight students, described that some components of the toy were relatively simple and easy to model. For example, one student said, "when modeling the toy, there were many pieces that were simple in terms of geometry, or repeated shapes. These were easy to model based on the tools that were included in SolidWorks and what we learned." Another common response, stated by seven students, was that the team worked well together as each member measured and created the models.

When asked to comment about what did not go well and what could be changed in the future to improve it, the most common response, mentioned by 18 students, included that the toy contained complex parts with curvatures that were difficult to measure and that assembling parts was difficult. One student stated, "It was difficult for all of the dimensions to match up since each person measured their own parts. It would have been better if we had organized the parts so that each person could make a sub-assembly from their parts or one person measured all of the parts so there was more consistency."

In response to additional materials that could be provided, students commented on the need for additional calipers and instruction on measuring irregular shapes. It is also notable that throughout the survey, there were four comments about the students enjoying the real-world application. One student said "It was fun applying the functions we learned in class to real world scenarios." Another student stated, "I learned how to use a lot of useful features while making the parts."

C. Closed-Ended Respones

Student responses to the numbered (#1-6 in the assessment section above) closed-ended questions above are shown in Figure 5. Notably, 78% of students indicated that they "strongly agree" or "agree" that this experience helped them see how engineering can have a direct, positive impact on people and that they will use the skills they gained from this experience in the future. This is particularly relevant when we consider the calls for a more diverse engineering workforce [16] and that underrepresented groups in engineering are drawn to engineering activities that are socially focused [12-14]. This activity may be a way to teach relevant technical knowledge that can appeal to a diverse student body.

In addition to the questions above, student responses to the MUSIC (labeled with M, U, S, I, C in the assessment section) model questions are shown in Figure 6. Notably, 81% of students indicated that they "strongly agree" or "agree" that they found this experience to be interesting and 78% indicated that they "strongly agree" or "agree" that they found this experience useful.

Fig. 5. Responses to Numbered Close-Ended Questions

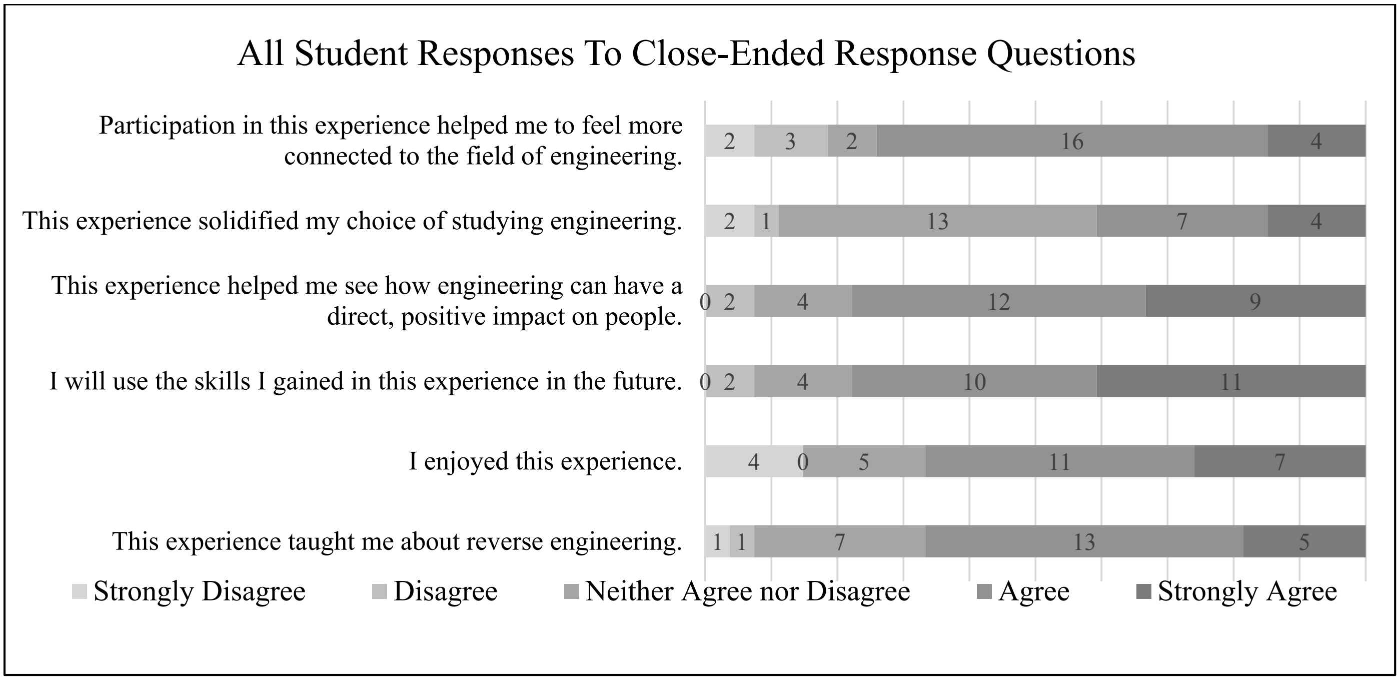
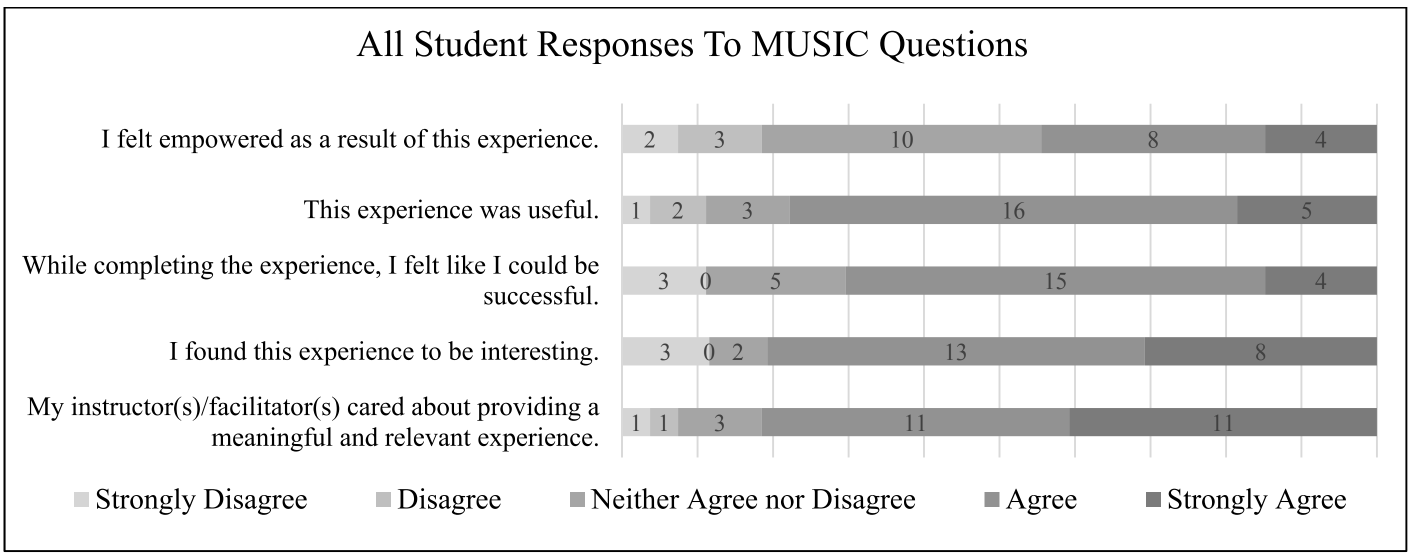


Fig. 6. Responses to MUSIC Close-Ended Questions



In addition, although it is difficult to make assessments about significant differences with this sample size, when examining responses between more advanced students (admit year 2012 or earlier) compared to less advanced students (admit year 2013 or later), it was noteworthy that the less advanced students more frequently strongly agreed or agreed with the closed-ended response questions. This was true on 10 out of the 11 closed-ended responses above. In the open-ended response section, one student described, “I am a senior…I think that this is good for those who have little to no experience in SolidWorks but for people like me, it is hard to get interested when we do modeling in a much higher level.”

VII. Conclusions and Limitations

Overall this project was a success based on our assessment data. The students enjoyed the experience and are interested in future opportunities to interface with the TAP. They also see the connection between the project and the real world which includes the societal impact. We believe that this project is a strong first attempt at connecting the TAP to a course in a new way based on technical knowledge. We hope to continue to develop additional partnerships with additional courses to strengthen students' understanding of the TAP and their ability to do engineering work that is socially relevant.

We acknowledge there are limitations to this work. Mainly, the sample is small because the class is small, which limits the transferability of the findings. Over time, we hope to collect additional data to be able to analyze the trends in a more rigorous and robust way. This will allow us to better understand the impact of this project and allow others to consider the results in the context of their courses and projects. Additionally, we may consider comparing the results to a control experience; however, since this paper is in the innovative practice category, we believe these limitations are within the allowable scope of this work.

VIII. Future Work

As the course is planned for next year, there are ideas for integrating the class project and the TAP more fully. Currently, students are given the project to create a complex SolidWorks part (model) and to then convert the SolidWorks part file to a 3D part file (.stl) so that the files can be 3D-printed. For the last several years, students have created a chess piece. The goal for creating a more integrated relationship between the students of this course and the TAP would be to have the 3D-printed part be one that can actually be used for the toy adaptation process. Items that could be designed by students in the course and 3D-printed include switches, panels and/or tools that aid in the adaptation of the toys. Also, during the next course offering, a class will be scheduled in the syllabus/schedule that includes a collaboration with the TAP to complete a workshop in the classroom. Expectations are that students will feel more closely connected to the organization and more motivated to perform well on their project(s) seeing the larger picture of how the toy will be adapted to serve the needs of children with disabilities. One method that enhances design education is engaging design coaches to help manage the contextualization of engineering design theory and practice [1]. It is believed that the TAP members would serve as the "design coaches" for student teams completing their modeling projects.

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