ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016

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Paper ID #17452

Open-Ended Design Projects in a Rapid Prototyping Course

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Open-Ended Design Projects in a Rapid Prototyping Course

Abstract

In this manufacturing engineering program, the Rapid prototyping and Reverse Engineering course has become even more popular due to public interest and hype driven by both, the Maker and Rep-Rap movements. The course has been taught over the years with the challenge of constant update needs to its content. In addition to the major subject updates to the content, the instructor is employing preparation of short papers on newest developments while channeling students to conduct research, in case they are not actively following the area. Interesting projects and content are found and shared with the class.

Over the years, the course has had two small projects, one addressing the reverse engineering side and other for rapid prototyping. Usually the student teams worked on reverse engineering a simple toy, and the rapid prototyping projects aimed assisting handicapped people with improving quality of life or gaining employment. Designing toys was also employed in corporation with the former Infinitoy Company. In the past, student teams developed ZOOB concept designs and prototyped them for the company. To give students an opportunity for being creative, the construction toy project was brought back. This paper will focus on the open-ended construction toy design project by documenting every step of it. Various assessment processes including outcomes assessment will be included in the conclusion of the paper.

Background

This paper documents the experience of open-ended design projects in this Rapid Prototyping and Reverse Engineering course. The author has brought back the objective of toy design and development after utilizing projects addressing helping handicapped people for a few years. The idea of helping people was driven by the original NISH (National Institute of the Severely Handicapped) and NEXT competitions. This noble cause was discontinued due to relocating the course to the Fall Semester while the competitions were held in the Spring Semester. On the other hand, reapplying toy design and development posed an interesting and fun concept to the instructor and students.

Earlier rapid prototyping projects from a decade ago involved toy design and development. In addition, students re-engineered existing commercial ZOOB designs for the former Infinitoy Company. An example Re-engineering Proposal by Martin Pabian, then a BS Manufacturing Engineering major can be found below[1]:

ZOOB Reverse Engineering Project Proposal

by Martin Pabian

Rapid Prototyping and Reverse Engineering

Background: Citroid System is the organic technology behind ZOOB brand toys. The open-ended, ergonomic design has the potential for a wide array of applications far beyond toys, from complex mathematical modeling to character animation. The Citroid (ball structured with 61-fold symmetry) captures the classic geometries found in nature allowing the articulation of artistic, anatomical and molecular structures. This advanced 3-D operating system, combined with the revolutionary Orbit Design, connects in over 20 different ways capturing movement in both Cartesian and Polar coordinates.

Project Proposal: The project is to consist of reverse engineering the five unique pieces of ZOOB. These will be modeled using conventional 3D rendering such as SolidWorks or Inventor, or the Digitizer may be used. Secondly, the redesign or design of a new piece will be construed. If needed, these pieces will be presented for introduction into production. The third part of this project will employ the design of a motorized ZOOB piece. The design may be able to interact with every piece in the current ZOOB set, or may be limited to a new piece or only specific pieces. Lastly, the ability to simulate Atomic Modules will be taken into consideration.

Figure 1. Non-motorized ZOOB Vehicle Construction

In addition to the reverse and re-engineering proposal above, the same student prepared a rapid prototyping project where the students were asked to design motorized components, later on became the basis for the ZOOB Motor Company. The following concept was developed by Martin Pabian[2] in response to the project requirements.

ZOOB Rapid Prototyping Project – Design Concept

by Martin Pabian

Rapid Prototyping and Reverse Engineering

The motorized is ZOOB is simple in design and can be implemented in all but one of the pieces. It involves placing a motor inside the ZOOB piece. In this case, the shaft of the motor will stick out of the ZOOB piece. The wire can travel out through the middle of the body. The ZOOB piece can then snap into the accepting ZOOB wheel which was now redesigned with a hole in the center to accept the shaft. The shaft and hole can mate using a friction joint. That way the shaft can actually transfer power to the wheel.

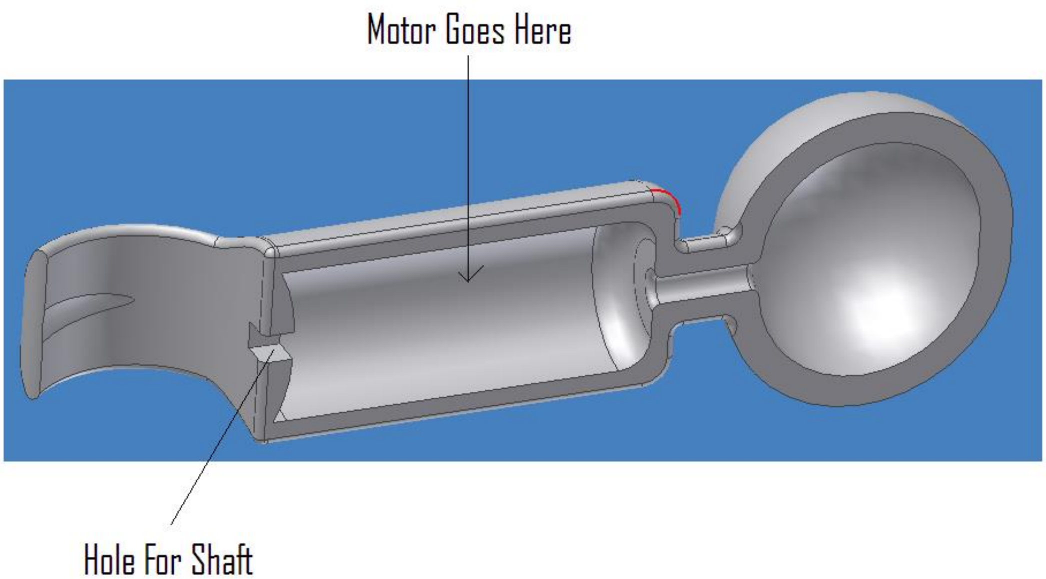

Figure 2. A ZOOB piece with motor housing

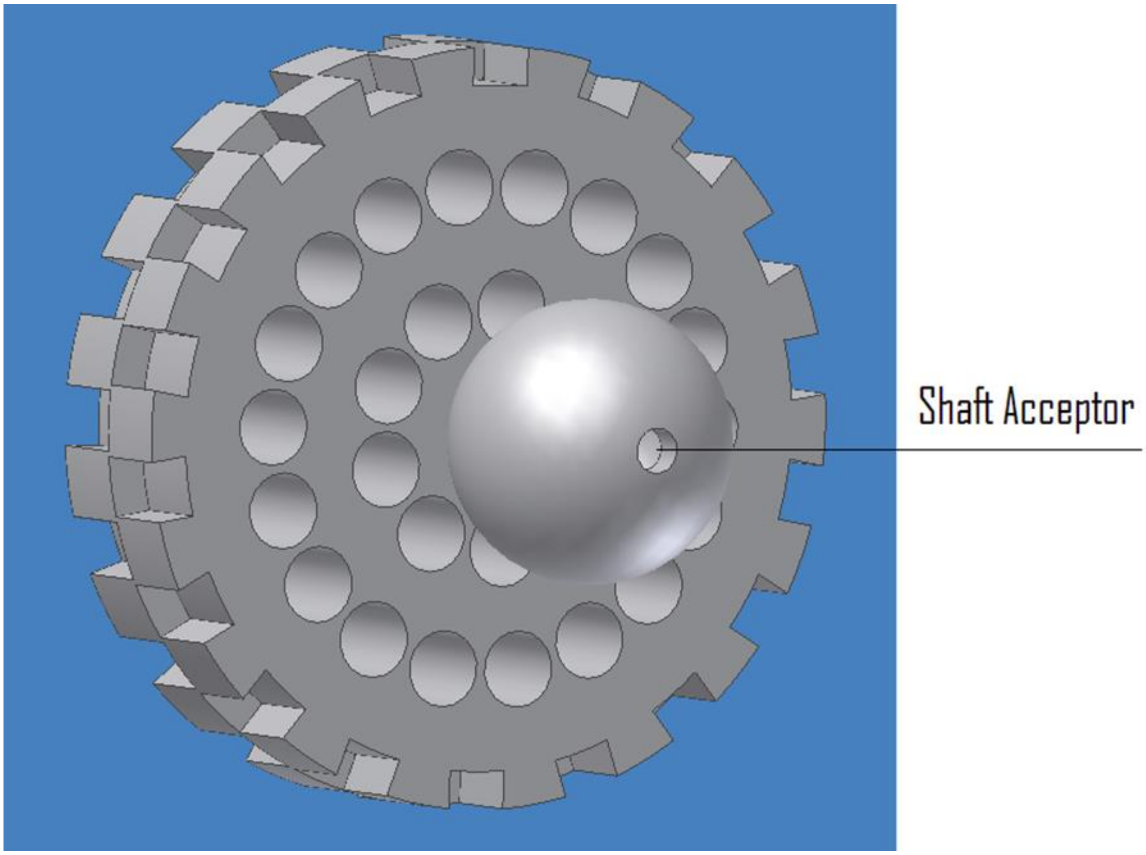

Figure 3. ZOOB wheel to be driven by a piece with a motor housing

These designs can be implemented on current ZOOB, if you can find a motor small enough. If not, you can create a larger ZOOB piece, with a tapered body so that all the current ZOOB pieces can attach to it.

Current Efforts

As indicated above, the previous toy design projects were based on a commercial toy, the ZOOB construction toys. The current toy design projects are open-ended and interdisciplinary team-based. The current projects include multiple critical requirements as defined below:

- Product Definition: It is a problem statement that encompasses selected concept designs and assemblies and is given in Figure 4. In this segment, student teams define the objective of the toy or its concept by demonstrating its design. They also need to apply the concept by using example assemblies. The latter indicates how the toys are used. Interesting concepts are developed while only small number of student teams tend to re-engineer existing toys.

- Materials and Manufacturing Process Selection: The teams need to determine the material to be used and the process associated in making the toy pieces. Manufacturing engineering students tend to do better in this segment.
- Ecological Analysis of the Materials and Manufacturing Processes Selected: The EcoAudit is an imperative segment of the project. It is done by using the CES Edupack Software. Students are also made aware of the Solidworks' Sustainability feature. Figure 5 illustrates an example analysis where the most of the CO_2 foot print generation and energy consumption belongs to the materials stage of the project.
- Engineering Analysis Method/Physical Testing: This step is used in virtual/physical testing of the design for a critical requirement. Besides Finite Element Analysis (FEA) teams can do testing, and this may include virtual testing such as drop tests as indicates in Figure 6. Mechanical engineering concentration students tend to do better in this segment.
- Cost Estimate: Each team is required to develop a cost estimate model. This segment usually reveals that some students are not able to tie the business content of their curriculum into their technical projects.
- Safety Features of the Design Concept: Teams are asked to develop safety features of their designs. Students usually employ existing toy safety features as references and do well in this segment.

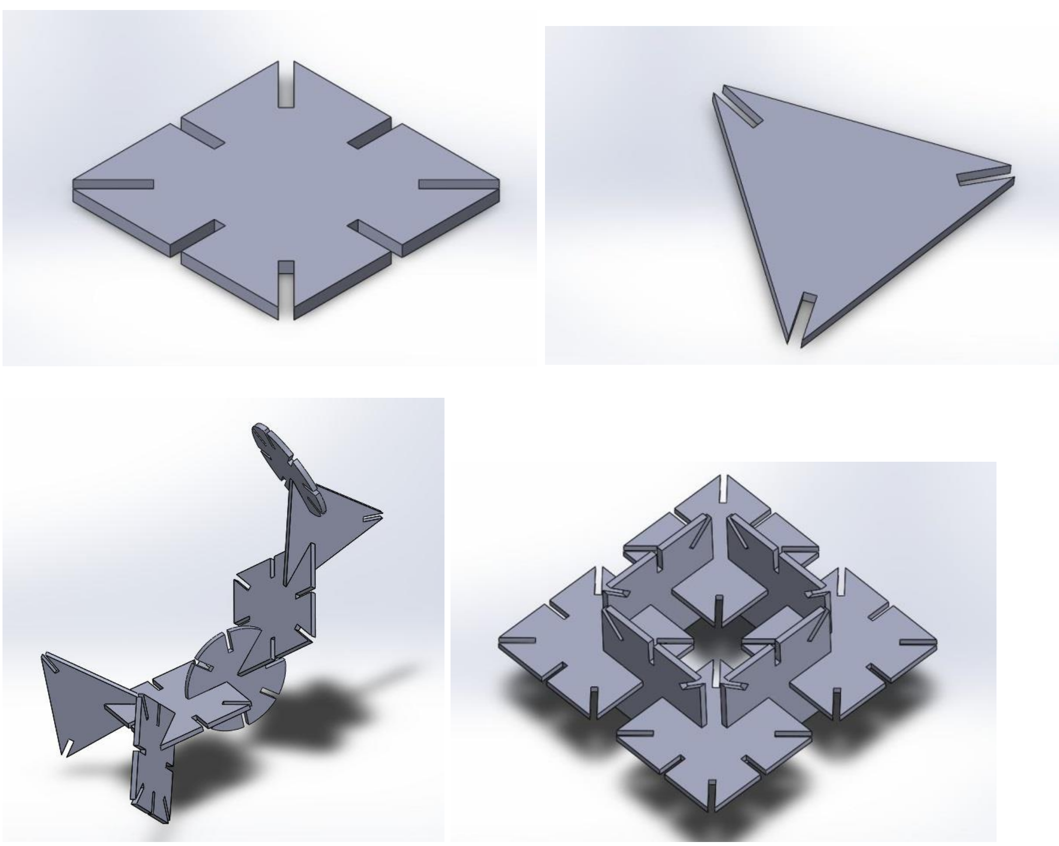

Figure 4. Concept Design of Construction Toy Pieces and Assemblies[3]

The project is evaluated based on the components listed above. Besides the creativity of the concept of the construction, cost, safety, and environmental impact of the design is studied along with material and manufacturing process selection. An engineering analysis/experiment type is required from each design team and varies. The examples attached above used a drop test as while other teams did burn testing of materials as they sought potential materials.

Conclusions

Besides forcing student creativity, an open-ended design project requires multiple elements to be successful. These have to be based on realistic constraints imposed by each team as prescribed in ABET student outcome c – where students design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability. The open-ended construction toy projects used in this Rapid Prototyping and Reverse Engineering course accomplishes this student outcome by incorporating the realistic constraints including the ones on economic, manufacturability, safety, environmental and sustainability. In these projects, ABET student outcomes a, b, d, e, g, h, and k are also addressed strongly. These open-ended construction

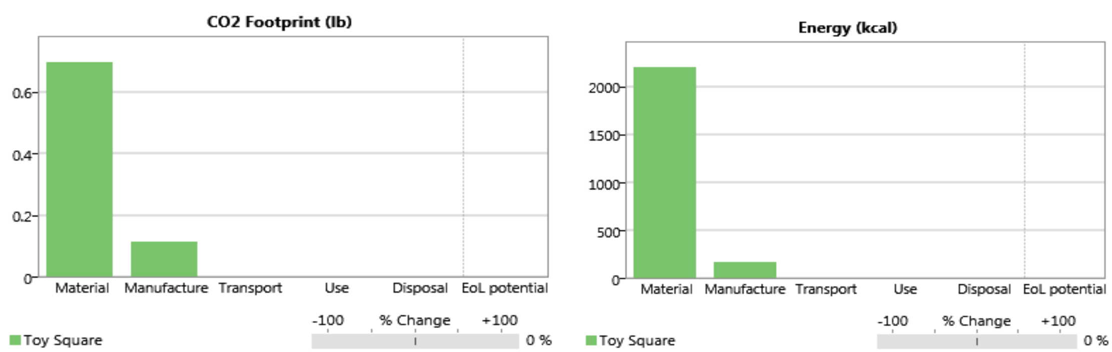

Figure 5. Ecological Analysis through CES Edupack Eco-Audit Tool[3]

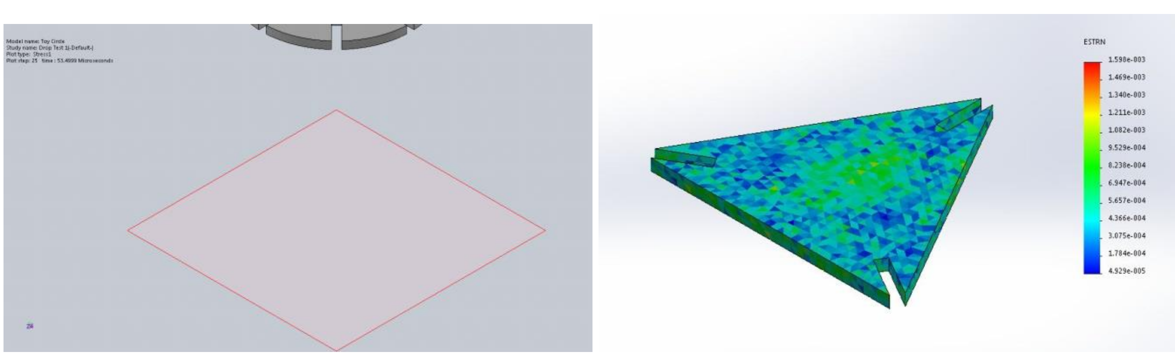

Figure 6. Drop Test for Engineering Analysis[3]

toy projects effectively address ABET students outcomes a and b due to use of math, science and engineering knowledge along with designing virtual and physical experiments in material selection or strength analysis. Design teams are made from students from multiple disciplines working on problem solving, thus adhering to ABET outcomes d and f. Communication requirement for the project includes written documents and making a Power Point Presentation (PPT) for the ABET outcome g. Safety of toys is also relevant in terms of ABET outcome h while students use modern tools for their concept presentation including Animations or 3D Printing.

This engineering program uses a vector analysis approach for its faculty outcomes assessment reports (FCARs) based on five levels described in Table 1 below[4]. The results of the last three years have been indicating a similar trend with students performing at "Excellent" and "Proficient" levels. Two of the last three years (2013 – 2014 AY) and (2014 – 2015 AY) is indicated below in Table 2. The 2015 - 2016 AY report is not completed at the moment when this paper was being written, but agrees with the previous data. In addition, the outcomes b, d, and f were brought back in the Fall Semester of 2015 to have more complete analysis.

Table 1 Vector Analysis Used in Outcomes Assessment[4]

Percentage of Students Getting 80%/B- or Better	**Conclusion**
90 - 100	Excellent
80 - 89	Proficient
70 - 79	Adequate
60 -69	Concern
<60	Weakness

Table 2 ENGR 4801 – Outcomes Data for 2013-2014 and 2014 – 2015 AY[4]

Course No.	**Course Name**	**a**	**b**	**c**	**d**	**e**	**f**	**g**	**h**	**i**	**j**	**k**
ENGR4801	Rapid Prototypin g & Rev. Engr.	E E		E E		E E		P E	P P	E E		E E

In addition, student interest and attitude towards the course subject and the projects have always been positive, other than the concern about the additional work-load required. That was the reason that the author went back to the toy design projects. The learning experience is similar to a capstone project where students need to start with a concept and follow through the engineering design and development process to reach the final prototyping stage.

While most of the teams attempt to be creative and develop a new concept, some teams resort to modifying or reengineering existing toy designs. The interdisciplinary make-up of the teams enhance the experience since mechanical engineering concentration students bring in their strength in CAE while manufacturing engineering students tend to do well in materials and manufacturing segments. Over the years, there have been issues in cost modeling segments of the projects where students have been missing important parts of their costs. As a future addition to the project, a competitive benchmarking segment will be employed in continuous improvements efforts.

References

[1] Pabian, M., Unpublished RP & RE ZOOB Reverse and Re-Engineering Project Proposal, 2006.

[2] Pabian, M. Unpublished RP & RE ZOOB Rapid Prototyping Project – Design Concept, 2006.

[3] Bach, J, Boff, B., Hervol, B., Rolaf, A., Unpublished Report for the Construction Toy Project, 2015.

[4] Unpublished ABET Self-Study Report.