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A Re-Design of the OneCar: A Project Based Learning Assignment for First Year Engineering Students

Dr. Matt Caputo, Penn State Shenango

Matt Caputo is an Assistant Teaching Professor of Engineering at Penn State Shenango. His research interests involve Additive Manufacturing, Shape Memory Alloys, Sintering and Engineering Education.

Prof. Georgia Macris, Penn State University
Dr. Daudi R Waryoba, Pennsylvania State University, DuBois Campus

Dr. Waryoba is a Program Coordinator for the B.S. Engineering, Applied Materials at Penn State DuBois. His research interests include thermo-mechanical processing, synthesis, and characterization of metallic materials, and the relationships between the structure, properties, processing, and performance of these materials; experimental and numerical modeling methods to investigate and elucidate the mechanics occurring during plastic deformation, recrystallization, and grain growth, and factors and mechanisms responsible for the formation and development of deformation and recrystallization texture, microstructure, and grain boundary structure; and the optimization of properties in additively manufactured and sintered powdered metals.

Work in Progress (WIP): A Re-Design of the OneCar: A Project Based Learning Assignment for First Year Engineering Students

Matthew P. Caputo[1], Georgia Macris[2], Daudi R. Waryoba[3]

[1]Engineering Department, Pennsylvania State University, 147 Shenango Ave, Sharon, PA 16146, USA
[2]Business Department, Pennsylvania State University, 147 Shenango Ave, Sharon, PA 16146, USA
[3]Engineering, Applied Materials, Pennsylvania State University, College Place, Dubois, PA, 15801, USA

Abstract
This work focuses on the beneficial educational characteristics of a project based learning assignment, introduced to first year engineering students during their introduction to engineering design course. This project tasks students with re-designing and manufacturing the Onecar™. The Onecar™ is a commercially available comprehensive Science Technology Engineering & Mathematics (STEM) kit that utilizes fundamental concepts of mechanics and energy to produce motion in a simple chassis. From this kit, students explore various energy sources (used to power electric motors that produce rotational motion), such as solar panels, capacitors, batteries, as well as chemical reactions, compressed air, and elastic potential energy; in order to produce a displacement. Each energy source is based on a scientific principle; such as force and motion, electricity, renewable energy etc. Students are assigned to a group of 3 - 4 to work as a "team" of engineers that test the current designs of the Onecar™ and evaluate their functionality based on velocity. Afterwards, students are asked to identify four of the top motion-generating energy sources and rank the performances. Students then design and fabricate new cars with the goal of increasing the velocity. The results of product testing, product re-design, prototyping, and prototype evaluation from the groups will be presented in this work. Additionally, the models and design approaches taken by the students will be highlighted and discussed. Responses from students' feedback suggests that they benefited from the project and collectively agree that this work helped them gain awareness into how to manage time, communicate, and collaborate in the group setting.

Introduction
Cornerstone engineering design (EDSGN 100) is a required 3-credit course for most engineering majors at Pennsylvania State University, typically taken by freshmen students. EDSGN 100 explores methods of project based learning (PBL) that emphasize three areas of instruction: [1]The engineering design process, [2]Design communication methods (such as graphical, verbal, written), and [3]Methods, and decision making using team design projects. PBL has shown to improve engineering curricula such that graduates have displayed increased skills in areas of multidisciplinary teamwork, project management, communications, ethics, and economics of engineering; which are catalyzed by student driven motivation and ownership of the assignment/project [1]–[3]. This PBL assignment seeks to address the abovementioned educationally beneficial characteristics as well as introduce fundamental scientific principles such as force and motion, electricity, renewable energy, among others. Research suggests that engineering students benefit from having knowledge of these scientific topics [4]. This work

shows how scientific concepts taught in physics and chemistry courses can be seamlessly integrated into a freshmen level engineering course through PBL methods. Herewith, the authors discuss the project framework and report a few examples from this PBL assignment.

Project Framework and Methodology

The structure of this PBL assignment has been categorized into five components: product testing, product re-design, prototyping, prototype testing, and presentation of results. To begin, students in the freshmen engineering course were gathered into groups of 3 - 4 students. Each group was provided with a OneCar^{TM} STEM kit which contains unassembled components of a simple vehicle including wheels, axles, chassis along with eight different energy sources, Figure 1 (a). The energy sources include battery, solar, wind, compressed air, capacitor, chemical, elastics, and mousetrap, and were utilized to produce motion in the cars. These energy sources were classified into two groups by the students: direct drive assembly (DDA) and thrust assembly (TA). DAA motion occurred when source energy was converted into rotational energy through gears mounted on the axle, whereas TA relies on a propulsive force from the sudden disruption of localized fluid. Rotational energy for DDA was converted from either elastic potential energy or an electric motor.

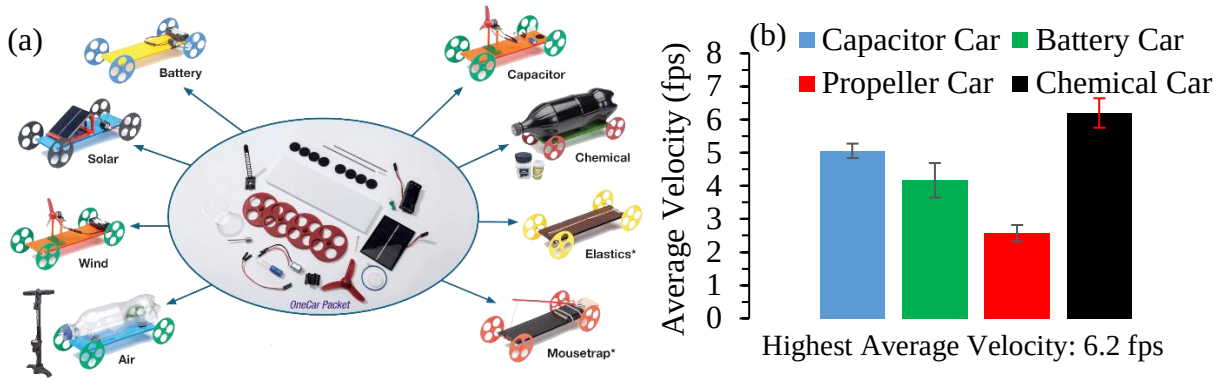

Figure 1: (a) Image of the OneCar^{TM} STEM kit displaying assembled cars with the respective eight energy sources, and other components. (b) Results of initial product performance displaying average velocity (in feet per second) for the capacitor, battery, propeller and chemical energy sources.

The first year engineering students were then tasked with testing and evaluating each cars functionality based on each energy source. No constraints were imposed on the students for the testing conditions of the cars; and was left intentionally ambiguous as to encourage the students to create a design of experiments (DOE). However, it is worth noting, all groups selected to evaluate the velocity of each car by measuring the time required to travel a known distance. After performance evaluations, students were then assigned to re-design a car (chassis, axle, and wheels) while retaining the top four energy sources, based on initial performance tests. One constraint was enforced during the re-design of the car, for which at least one component of the modified car be produced using additive manufacturing technology (3D printing). Next, the groups of students designed (via 2D sketching and 3D CAD design, taught to all students), manufactured (using subtractive and additive manufacturing methods) and assembled the re-designed cars, and then re-evaluated these cars using original testing criteria. Finally, each group was required to make a formal presentation and design report that overviewed the project including initial testing results, the approach towards the re-design, and final results.

Results and Discussion

Groups assembled the eight cars and began initial product performance testing by measuring the amount of time each car took to travel a distance of 25 ft. The results obtained from initial testing indicated that the capacitor, battery, propeller and chemical energy sources (citric acid + sodium bicarbonate + water) produced the highest average velocities, Figure 1 (b). It is worth noting, some groups designed their performance criteria based exclusively on average velocities; while other groups considered factors such as "ease of assembly" and "preliminary indicators of performance" during the evaluations. Groups distinguished several problems with the initial designs of the OneCar including "a distinct issue with staying straight" as well as "weight reduction" being another area for potential improvement. Additionally, in other groups reported a lack of friction between the wheels and ground as an integral problem; which caused slipping resulting in loss of motion. These undesirable characteristics, among others, were key considerations for the groups during the re-design process. To address the flaws identified during the product evaluation, groups sought to improve the chassis, wheels, and position/mounting of the energy source. In one group, the chassis of the chemical energy source car was re-designed with mounting supports attached and 3D printed with a supported frame structure to reduce the weight, Figure 2 (a). Additionally, the wheels were designed with a "pizza cutter" tapper, figure 2 (b), with the intent of improving one-directional motion. Figure 2 (c) shows the fully assembled re-design of the chemical energy source car.

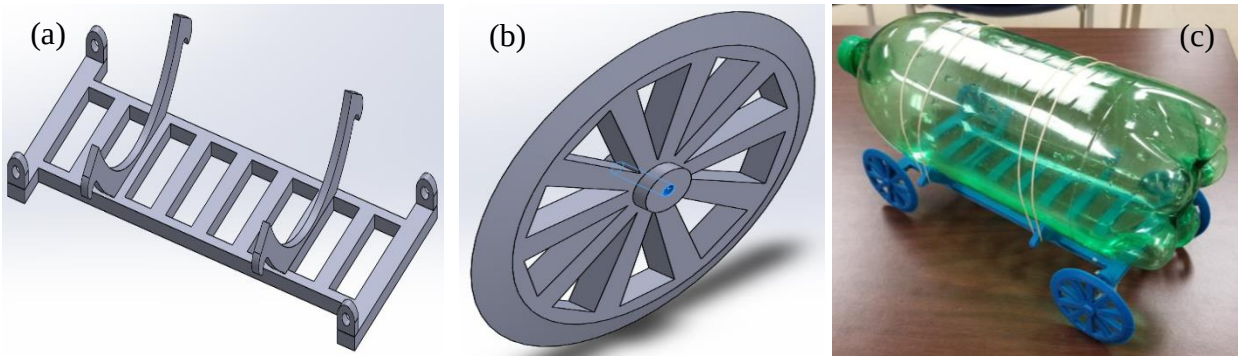

Figure 2: 3-dimensional CAD design of a modified (a) chassis, (b) wheel and (c) re-designed assembly of 3D printed chassis and wheels.

Conclusion and Future Work

To conclude, this work reports on the initial observations of a PBL assignment that incorporates scientific principles into an engineering design course. The PBL assignment challenges students to evaluate the OneCar™ and then redesign, manufacture and assemble a modified design. In future work, this project is envisioned to be expanded to consider student feedback in an attempt to evaluate project effectiveness.

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