RELALATING TOY EVALUATION TO ENGINEERING FUNDAMENTALS IN A FRESHMAN ENGINEERING DESIGN COURSE

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Abstract

Toys can be used as a powerful yet less intimidating means for teaching engineering design elements and allows for students the opportunity to directly apply their knowledge to a hands-on project early on in their academic careers. In a freshman engineering design course, small groups of students used toys as a vehicle to learn fundamental engineering principles in studying complex toy design. The gender neutral toys allowed students the ability to setup and execute experiments for mechanistic evaluation with emphasis placed on generating, testing and implementing technical solutions to the toy design. Topics such as manufacturing, safety, cost analysis, materials selection, and marketing were directed from lecture portion of the class and applied to the toy analysis. From the observations and mechanistic evaluation of the toys, students were capable to design and fabricate a working prototype to a technical challenge. This paper describes a case study project demonstrating the process of relating toy evaluation to engineering fundamentals and reports feedback from faculty and students. Observations are also offered on the manner in which traditional age and adult students approached and executed the toy analysis project.

Introduction

Over the past decade, engineering colleges and the National Science Foundation have placed greater emphasis on integrating engineering design into the curriculum, emphasizing hands-on projects, teamwork and greater student to student collaborations. The introduction to engineering course taught at The Pennsylvania State University for first year level engineering students focuses on these areas of emphasis along with the goals of student recruitment, retention, and engineering development throughout the four-year curriculum [1]. Through this course, students are exposed to a lecture/laboratory setting in which many of the lecture topics are used as tools to solve a technically challenging project that students work on throughout the semester in small groups. This introduction to engineering course is offered at most of Penn State’s 24 locations and offers a wide assortment of project possibilities, faculty and student expertise and perspectives that can be used to compare and contrast project planning and execution. The coalition of commonwealth campuses (locations other then University Park) attracts more than 600 first year students who declare engineering as their preferred major.

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Approximately one-third remain in engineering after two years, one-third pursue other science, technology, engineering or mathematics (STEM) fields and the remaining one-third drop out altogether. These numbers present challenges in the coalition campuses to continue supporting engineering majors at the main University Park campus. Examining the data at Penn State, it appears that once students enter a major within their first two years, the likelihood of them completing that major is very high. Therefore, the critical period to enhance student retention is during the first two years of the degree; see Fig. 1 for Penn State retention data. One strategy to advance and improve the retention performance from the coalition campuses is an interdisciplinary approach following active, collaborative projects based on first year courses. These courses have been shown to be successful in retaining students, especially women and underrepresented students throughout their first two years and help to promote design fundamentals and problem solving teamwork elements at an early stage of the students' academic career [2-5].

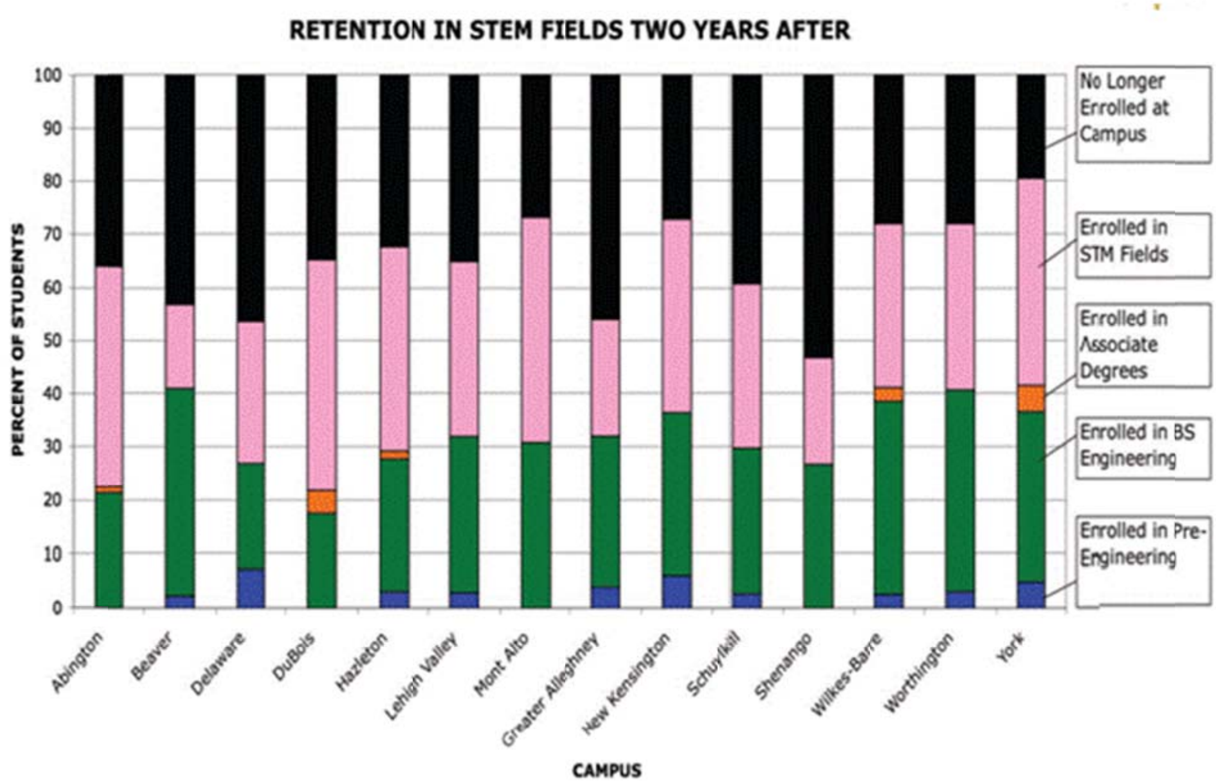

Fig. 1: Retention data of freshman engineering students in STEM fields two years after admission to coalition commonwealth campuses.

This strategy is sponsored by a "Toys N More" Fundamentals project across the coalition campuses designed to introduce engineering design and prototyping through the use of toys that have universal appeal to students various experiences and of both genders. The idea is that a toy can capture the imagination and interaction of students in the broad spectrum of STEM fields and add a level of comfort for the students to perform hands-on learning. Each of the coalition campuses has implemented this project to fit degree requirements with a separate stand alone course or a linked engineering design course. The Penn State DuBois campus has utilized its popular introduction to engineering design course that is required by all Penn State engineering majors and has incorporated the toys evaluation project as an active learning component to compliment course lecture topics. This paper describes the implemented toy evaluation assignment and takes a look at student-student and student-instructor interactions as a baseline observation and project detail.

Project Overview

The overall goal of the project is to focus a hands-on approach to teaching the principles of engineering design using toys as the media. Students have the opportunity to see the importance of their engineering education up front in their academic career through demonstration of design considerations and through working on a design project from concept through prototyping. The project is worked into an existing course of introduction to engineering design which is a 6 hour per week lecture/laboratory course covering the fundamentals of engineering design. In the past, the course has worked mainly through paper projects and thought experiments to validate engineering design principles applying basic engineering and math fundamentals to solve real world technical challenges. Many students find this a very difficult way to learn the necessary engineering they need as they progress through their academic career and to carry these skills into the workforce. Also many students are discouraged by the paper projects as another form of busy work with nothing “tangible” at the end of the semester to present to their instructors or peers. With the Toys N More initiative, the goal is to give students the opportunity to see design projects (toy evaluations) in a tangible manner and have a “product” to present at the end of the course to disseminate skills and knowledge learned and enhance student retention in the STEM fields through their first two years of education.

At the Penn State DuBois campus a total of 48 students participated in the introduction to engineering course with roughly 35% of the students characterized as an adult learner and 50% of the remaining students as a first in the family to attend college student. The adult learners were predominately from a manufacturing background with various industrial experiences. An assessment plan has been established using a mixed method quasi-experimental design to evaluate the impact of the Toys N More strategy and to determine overall success of the projects compared to other coalition campuses [6, 7].

The projects chosen consisted of gender neutral toys with elements (marketing, mechanical, electrical etc) that could be evaluated as a design project while meeting the requirements of the introductory design course while also meeting the goals of increasing student retention. The students were placed into teams of 4 members consisting of diversified member background, i.e.

adult learners were placed with members of traditional aged students. The teams were assigned a separate toy to evaluate and given a design rubric that outlined specific areas of interest to investigate during the evaluation. Students were given 3-4 weeks to complete the project with a total of 18-20 hours of in-class time devoted to the practical aspect of the project. At the end of the project students demonstrated their findings pertaining to the design rubric, a working prototype of their redesigned toy and a presentation to the campus community that highlighted their projects.

A Case Study: Engineering Principles from a Smurf® Toy Evaluation

This case study pertains to a project of a talking Smurf plush toy. The team consisted of first year engineering male students containing 2 adult and 2 traditional aged students. The plush toy was purchased at a local retail store with funds provided by the Toys N More initiative for approximately $17. Students were provided with a design rubric indicating 9 areas to investigate during the evaluation, Table 1. These areas were intended to be open ended guidelines to quickly establish discussion within the group and productive interactions with the instructor. The openness of the guidelines were deliberate to capture the imagination and interaction of students and especially to add a level of comfort in the broad spectrum of all the STEM students as each student could contribute based upon their educational and practical backgrounds.

Table 1: Open ended design rubric indicating 9 key areas of interest for toy analysis

1) dissecting the toy and observing the manner of the stitching, stuffing, lining of the button senor and microphone box
2) a critical look at the manufacturing process defining downstream processes
3) identification and evaluation of electrical components and other materials used, what was significant about the design
4) what special features does the toy present (safety, costs, toy purpose, ergonomics, packaging for transport and marketing, does the toy include all necessary components, and ease of manufacturing)
5) what is the power source and what advantages/disadvantages does this present
6) why were the materials chosen, any specific purpose of materials (non flammable etc) that must be considered
7) identify how and why the toy is pieced together
8) is this a good design, what are the strengths and weaknesses of the current toy design
9) how would your group improve upon the current design

<u>Toy Evaluation</u>

After the introduction of the toy and an overview of the design rubric the design team planned their toy evaluation dissection following the open ended guidelines of the rubric and plotted a timeline for completion of the project. The team was responsible to work in previously covered lectures topics into the rubric elements and had to show measureable deliverables at each step of the process. The group then dissected the Smurf toy to examine the design, fabrication process, safety features associated with the toy's electrical components and aligned their findings to the design rubric. Emphasis was placed on student-instructor collaboration at this point to help discussions within the group with a focus on the design purpose through cost metrics, materials concerns, toy function, target customer base, etc. This allowed for individual group specific topics to be covered to aid in identifying features of the toy and illuminating the current design. Students arranged and executed simple experiments to test features such as safety and mechanical properties of the toy components. In this case study project, students identified two potential tests for the safe use of the toy looking at the impact of the battery and microphone housing if thrown at a child and also the possibility of electrical shock from a sensor located in the hand of toy if placed in a child's mouth. Images of the student's experiments are found in Fig 2, showing how the students conducted the experiments in controlled surroundings and collected respective data.

(a) **(b)** **(c)**

Fig. 2: Student conducted experiments of safety and impact testing of a Smurf Toy (a) hand sensor submerged in water to simulate moisture and testing of conductivity, (b) impact testing on a mass balance scale and (c) images of battery and microphone housing that exhibited failure during impact

Pulling the data collected from the group's experiments and applying the lecture topics of customer needs, product specifications and with instructor interactions the group benchmarked the current design criteria and related their finding the design rubric.

<u>Design Refinement</u>

Once the group determined their toy's current design elements the group set forth to improve the design within the boundaries of costs, materials, safety elements, and marketing parameters they

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previously established. This allowed the students to consider technical challenges beyond current mechanistic fundamentals of the toy. The group working with the Smurf toy discovered a faulty mechanical hinge feature to the battery and microphone housing that exhibited weakness during their impact testing, Fig. 2. The hinge assembly was found to snap apart when a critical threshold of impact energy was imparted to the back side of the plush toy. The team set out to redesign the housing maintaining the inner workings as originally designed. With the use of computer aided design elements taught within the introduction to engineering course and a Dimension 3D rapid prototyping machine, the students were able to design and fabricate a working prototype that remedies the exhibited hinge weakness, Fig 3. With the design benchmark and redesign prototype, the group prepared a written report chronicling their evaluation methodology and design parameters. This culminated into a presentation in which students shared their findings and prototypes with the campus community. The campus event allowed the student group the ability to present a tangible skill and knowledge base to a public audience which could immediately relate to the project toys.

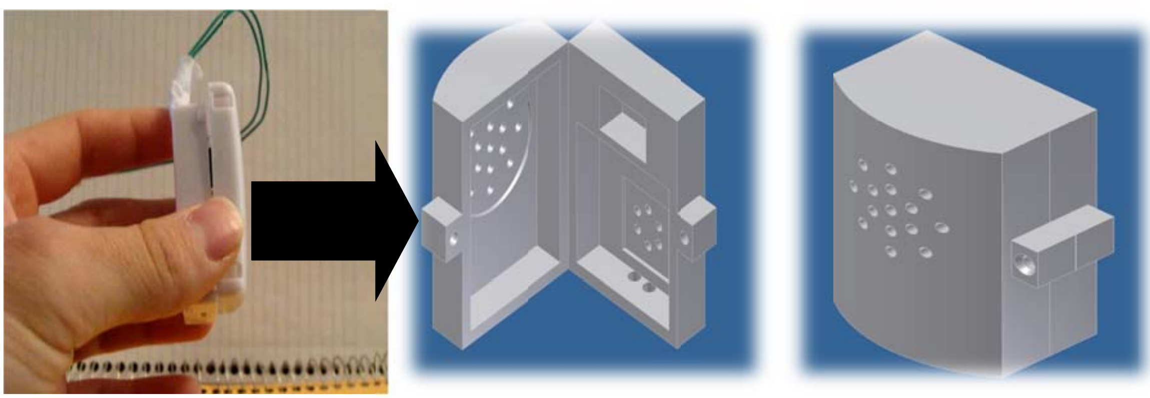

Fig. 3: Redesign battery and microphone housing of Smurf toy using computer aided design software and Dimension 3D rapid prototyping machine

Group Collaboration Observations

At the Penn State DuBois campus, the introductory engineering design course is taught as an "active learning" environment where students are given opportunity to apply and implement the fundamentals of engineering design process (from conceptualization to product development) through lectures taught in class to design and physically build a prototype that solves a particular technical challenge. Teaching the necessary content of the lectures is more easily met when using a medium that is comfortable and common to all the students (toys) and that the students can fall back upon previous experiences to aid in applying their new insight into the engineering design process.

The observed group interaction from the Smurf toy group was very similar to other groups where the adult learners immediately started to draft a timeline with deliverables and actionable tasks associated with each of the team members. Younger members of the group immediately opened the toy to examine it, investigating the toy workings and purpose. Teamwork and skill levels within the group worked together very well when 2 adults and 2 traditional students were paired. Adults were able to pull from their past industry experience and the traditional students were able to work on the more computer intensive side of the project allowing for complimenting skilled tasks to be set. A similar observation was also made when pairing technology students with engineering students where the technology students had more of a "this is how it is put together" understanding while the engineering students had a "this is how it works" understanding. The overall observation of the student-student interactions were documented with a follow up survey at the end of the semester discussing how the group dynamics evolved as the project continued. Common responses to the survey indicated that students enjoyed working with the toys and that they had an easier time relating to the lectures when they could apply the topic to the toy evaluation. Student feedback relating to the toy evaluation is reported below:

- The application of what we learned in class lectures helped to understand how the ideas are used in the real world. I think it is great when personal experiences can be incorporated with the lectures or projects so that we have an idea of what to expect and how to use what we learned later in our lives.
- The lectures incorporated with hands on engineering proved to be very informative and interesting.
- I think that the design projects (toys) and Solid Works classes helped a lot. It gave me a better feel for what engineers might have to go through. The lectures, although long, they really helped too. You had the experience and you know what's going on, which i think added to the overall idea.

Preliminary results across the Penn State system indicate increased student retention by ~13% under the Toys N More program over the previous 5 years of data. Although the data is preliminary, it appears that students are relating to the toy evaluations. There are also observable increases in 5 areas of engineering efficacy including communication, feeling of inclusion, teaming, technology and successful completion of engineering curriculum. These are very encouraging as the Toys N More program enters is third year.

Conclusions

The introductory engineering course at Penn State focuses on a hands-on learning objective of the engineering design principles through course projects. These projects help to enhance the student's perception of engineering through basic engineering principles in a project oriented manner. The students benefit from the grant through projects that are taken from conception through prototype to showcase design elements and evaluation findings. This opportunity lets students explain their design projects and take pride in their early knowledge of engineering and they are able to carry that pride throughout their academic careers. The process of allowing the students to first benchmark the current design and then redefine the design within the given elements proves very efficient at delivering home the ideas of design iteration and refinement. Working with a real entity such as a toy allows the students to examine and produce a product in which time was not spent on acquainting the students with the project but that students could jump right into the details of the engineering fundamentals.

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