Project Cam-A-Rok, Engaging Mechanical Engineering Freshman

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Introduction

This paper documents the implementation of many of the leading concepts into a successful freshman design course. There are many different forms that a freshman introductory engineering design course can take, and many examples shared through publication that describe what has worked. The experience outlined combines benefits of both a team-centric as well as an individual centric course. It contains both project driven aspects as well as short term homework style assignments. And the course completes the design work through both a virtual implementation in a solid modeling environment as well as a hands-on fabrication of the final design. Although this implementation involved model rockets as the basis of the project, the course could easily be adapted to other projects of a similar size.

Background

Taking advantage of the pedagogical work that has been done in exploring the freshman engineering design experience, this course was developed by implementing aspects and techniques that have been shown to enhance engineering student's learning as well as reinforces their interest and excitement. Sheppard and Jenison documented a strategy for describing the Organizational Framework of a course by identifying the skill (content) and process (how) of what is to be learned. (1) Four quadrants were described: Individual Content, Team Content, Individual Process, Team Process and how they differ in the learning process. Sheppard and Jenison then applied their Organizational Framework to study freshman engineering courses at a number of different institutions. (2) Their key conclusion might be summarized as an institution should chose the quadrants for freshman learning based on what fits at that institution, but should work to insure that students experience learning in all 4 quadrants as they continue through their curriculum.

Drummond as well as Knight, et al, describe the value of Team Based Learning (TBL) in both in the classroom as well as outside. (3) (4) Work done by Ohland, et al, demonstrates the value of cultivating the team experience, especially with team member/peer feedback during the process. (5) Layton, et al, have further enhanced the process by developing a software based tool called CATME that effectively coordinates the peer feedback. (6)

The virtues of Problem Based Learning (PBL) in an engineering course have been described by Kellar, et al, though they do warn that PBL implementation requires great deal of coordinated time and effort. (7) Mills and Treagust further describe the difference between Problem Based Learning and Project based learning. (8) Simply put, a project can be thought of as the compilation of a number of smaller problems. So, Project Based Learning builds on Problem Based learning by assembling an overarching structure to help break the project down into workable problems.

Finally, Knight, et al, as well as Barr, et al, describe the ability for students to gain experience with their learning through hands on exercises. [4] [9] Knight, et al, describes where a number of different freshman projects that required the students to actually build their designs led to better retention of those students in their original course of study. Whereas Barr, et al, describe how a hands on Reverse Engineering project helped to their students to better understand the design process and the critical nature of assembling multiple parts into a whole system.

Basic Structure of the Course

The course developed is for an 11 week quarter that has a 1 hour lecture meeting twice each week and a 2 hour lab session each week. Within that structure, the students are learning principles of engineering design and developing solids modeling techniques. Based on the background work, it was decided that the course should incorporate both team content as well as individual content, and it should work to develop engineering design skills as well as foster the teaming process. In addition, the work should include a hands-on aspect, this may be implemented in the form of a reverse engineering aspect to a portion of the project, or may even include the fabrication of the final design.

This was achieved by implementing a course long project that is worked by student teams. In addition to the main project, there are a number of incremental problems to be solved, some take the form of individual homework problems, while others require the full teams attention. The teams were assigned during the first week using the CATME [6] software's survey feature that allows students to input information about their preferences. Team members were collocated in the classroom allowing them to work together on team specific assignments and to support each other on in class learning exercises. Team building exercises are included in the first couple of weeks, and teaming is fostered throughout the quarter by the nature of the class time. For example, when working on in-class learning exercises, team members are expected to seek insight from their team to answer a question before asking the course instructor. This simple task has helped make team members more likely to seek each other when issues arise in the process of solving more complex parts of the project.

Formative assessment includes individual as well as team homework problems, and individual quizzes throughout the quarter. Many of both the individual and team homework problems are pulled from aspects of the overall design project, giving them a "guided tour" of the design process as they work their way to a final design. Summative assessment takes the form of team presentations, a team design report and an individual final exam. In addition to the grades that are earned, there is usually a "fun" bonus aspect to the project for all the teams that complete incremental work as well as the final design.

Project "Cam-A-Rok" the Selected Design Project

A project was needed that would lend itself to 10 weeks of student team effort, give opportunity to demonstrate the engineering design process, allow for solids modeling assignments, be enhanced by teaming studies and require hands-on interaction in both a reverse engineering aspect as well as in design fabrication. The project selected was Project "Cam-A-Rok"; a project to design a payload module that would carry a digital camera on a model rocket allowing for in-flight filming of video.

The identified need for this device was stated as:

> "A model rocket company needs a payload module that can carry a specific digital camera on a model rocket in a way that will allow the camera to film the ground beneath the rocket as it flies skyward." (Figure 1)

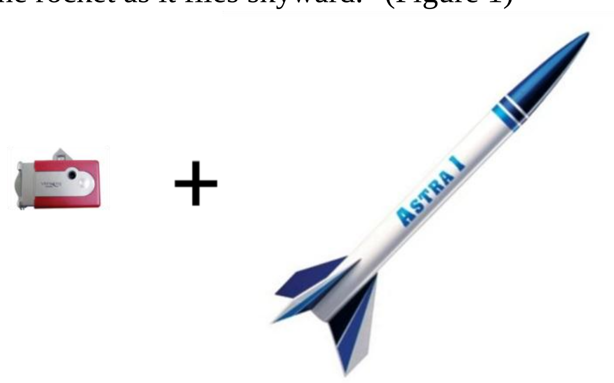

Figure 1 Concept for "Cam-A-Rok" Project

Subject to the constraints:

- Must not alter the camera in any way.
- Must be capable of filming (video) looking down past the tail of the rocket as it flies.
- Must allow the camera to be easily removed and reinserted.
- Must allow for the activation of the mode button, the shutter release button and view of the LCD display for mode confirmation while on the launch rod.
- Must be such that together all of the parts of the payload module will fit within a 3.5 x 3.5 x 7 inch volume (total rapid prototype volume available for each team).
- Must be safe for a typical college student to operate.

Each team was supplied with a "Design Support Kit" that included all the materials and equipment necessary for the reverse engineering of the rocket as well as the fabrication of the Cam-A-Rok system. The components included in the Design Support Kit are listed in Table 1 and can be seen in Figure 2.

Table 1 Design Project Support Kit Parts List

Item No.	Description
1	Project Case

<table>
<tr><td>2</td><td>Camera Kit<table>
<tr><th></th><th>Item No.</th><th>Description</th></tr>
<tr><td>☐</td><td>2.1</td><td>Digital Camera – VistaQuest VQ1005</td></tr>
<tr><td>☐</td><td>2.2</td><td>SD Memory Card – Lexar 512 MB</td></tr>
<tr><td>☐</td><td>2.3</td><td>AAA Battery</td></tr>
<tr><td>☐</td><td>2.4</td><td>Camera Specification Card</td></tr>
<tr><td>☐</td><td>2.5</td><td>Camera Quick Start Guide</td></tr>
<tr><td>☐</td><td>2.6</td><td>Large Mirror Tile – 0.75 in. x 0.75 in.</td></tr>
<tr><td>☐</td><td>2.7</td><td>Small Mirror Tile – 0.375 in. x 0.375 in.</td></tr>
</table></td></tr>
<tr><td>3</td><td>Model Rocket Kit – ModelRockets.us Centauri</td></tr>
<tr><td>4</td><td>Digital Caliper – Fowler Model #54-101-150</td></tr>
<tr><td>5</td><td>Execl Hobby Knife</td></tr>
<tr><td>6</td><td>12” Stainless Steel Ruler</td></tr>
<tr><td>7</td><td>9 in. x 12 in. Self-healing Cutting Mat</td></tr>
</table>

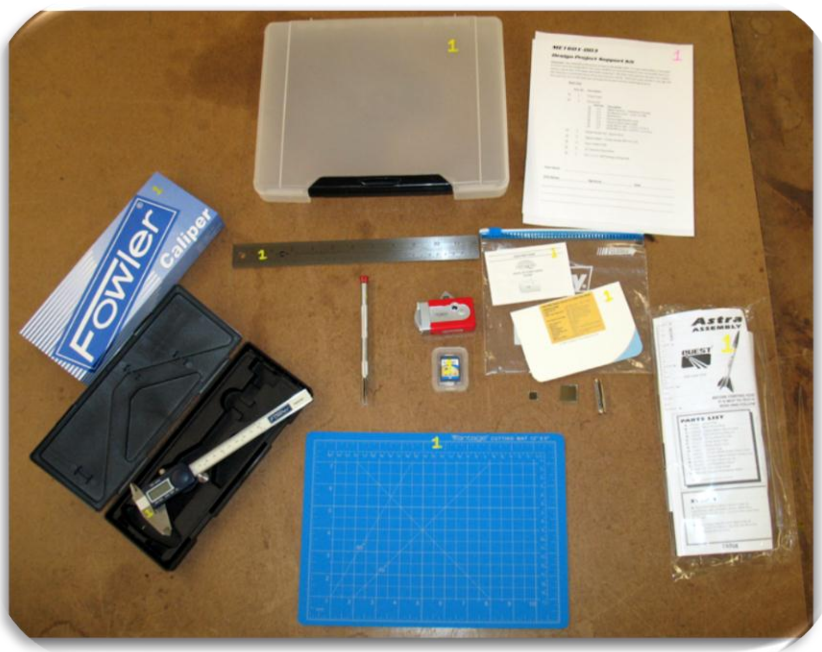

Figure 2 Design Project Support Kit Contents

Along the way, individual assignments concentrated more on developing the students’ skills with the solids modeling software, while the team assignments aligned with the design process.

Individual assignments included:

- Simple orthographic and perspective engineering sketching
- Various techniques for generating parts in the solids modeling software

- Generating flat drawings with correct dimensioning and tolerancing from the solid models
- Assembling the solid model parts into assemblies
- Simple reverse engineering strategies implemented on the model rocket kit and the exterior of the digital camera

The team assignments involved:

- Thoroughly identifying the problem need, the constraints and design criteria.
- Brainstorming possible solutions to the problem
- Evaluating the solution ideas
- Implementing the selected solution idea as a solid model with tolerances required to allow for Additive Manufacturing Rapid Prototyping techniques.
- Presenting their teams "trek" through the design process to the class
- Fabricating their rocket, finishing their model returned from the Rapid Prototyping Process, and testing its ability to allow the camera to function
- Formal Presentation to class on the team's final design result and its functionality
- Design report and portfolio documenting all the work done throughout design process

The final aspect to the project, the "fun" bonus for completing all the incremental work required by the design process, was the chance to "fly" their rocket and put their design to the test. "Launch Day" for the teams that had all the work completed and turned in was the last Saturday before final exams. With the assistance of a couple of upperclassmen, we all went out to the athletic fields and one by one flew all of the designs.

Results – The Student Designs and Flights

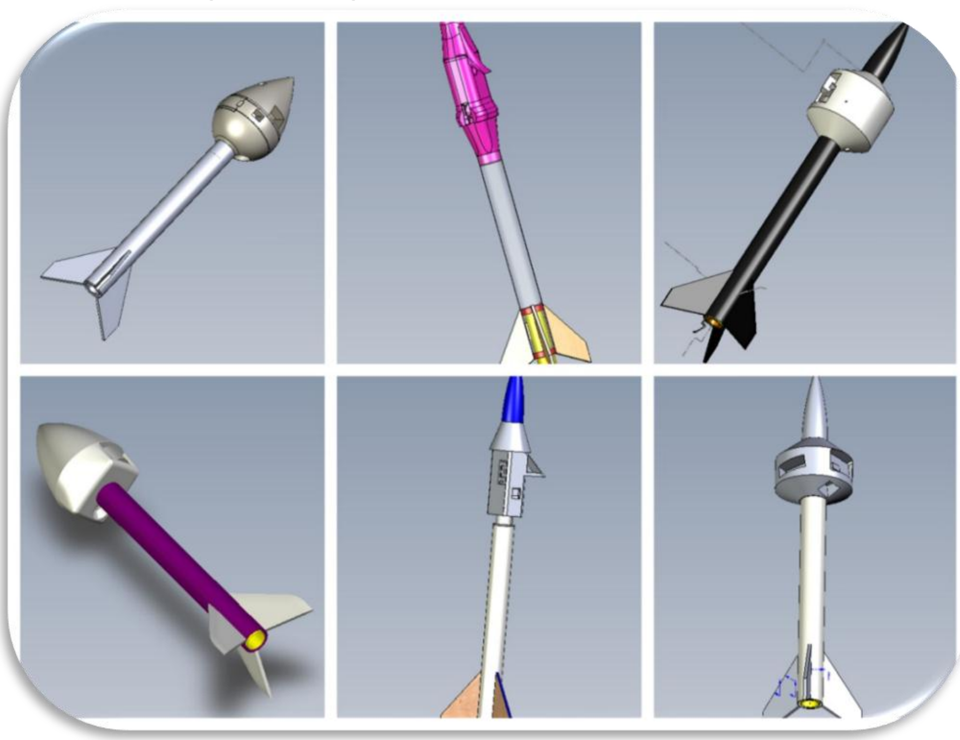

Figure 3 Examples of Design Teams' Resulting Solid Models

A sampling of the models resulting from the student teams is shown in

Figure 3. They took on two general configurations, a vertical orientation of the camera with the lens pointed to the side using a mirror to see downward, and a horizontal camera orientation with the lens pointed downward through a hole in the capsule.

All of the teams completed all of the incremental work required and were able to participate in the bonus Launch Day activity. An example of the launch and flight can be seen in Figure 4.

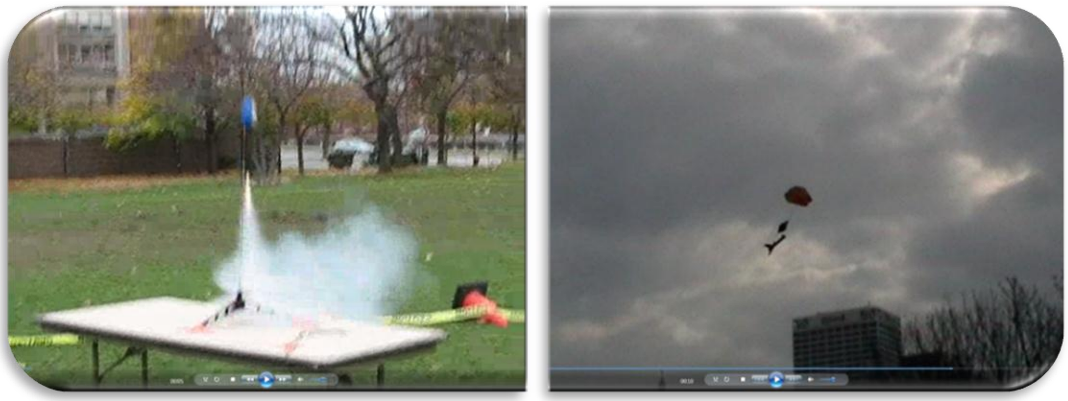

Figure 4 Rockets In Flight

A total of 12 teams with 4 students per team were involved with project. All 12 teams flew their rockets, with varying levels of success. The fabrication skills varied greatly across the teams resulting in a range of performance from some models that "jammed" on the guide rail during liftoff, to rockets that did not successfully deploy their parachutes to models that performed flawlessly returning with video footage of the flight. Of the 12 teams, 5 teams captured video, Figure 5 shows a sampling of still frames from some of the clearer video footage shot on the successful flights.

Conclusion

Neither the formative nor summative assessment showed significant improvement over previous courses, but even though the learning environment was much more relaxed the class was able to cover more material than it had in the past. Most of the teams developed a level of camaraderie usually seen in sports teams. Aspects that I plan to improve on in the future include allowing the students to use the CATME feedback surveys on two week intervals rather than four week intervals and to develop additional projects that would fit the same format.

Acknowledgments:

- Wisconsin Space Grant Consortium – Higher Education Incentives Seed Grant, that supported the purchase of the supplies used in the project.
- Milwaukee School of Engineering Rapid Prototype Consortium – Manufacturing the RP models pro bono.

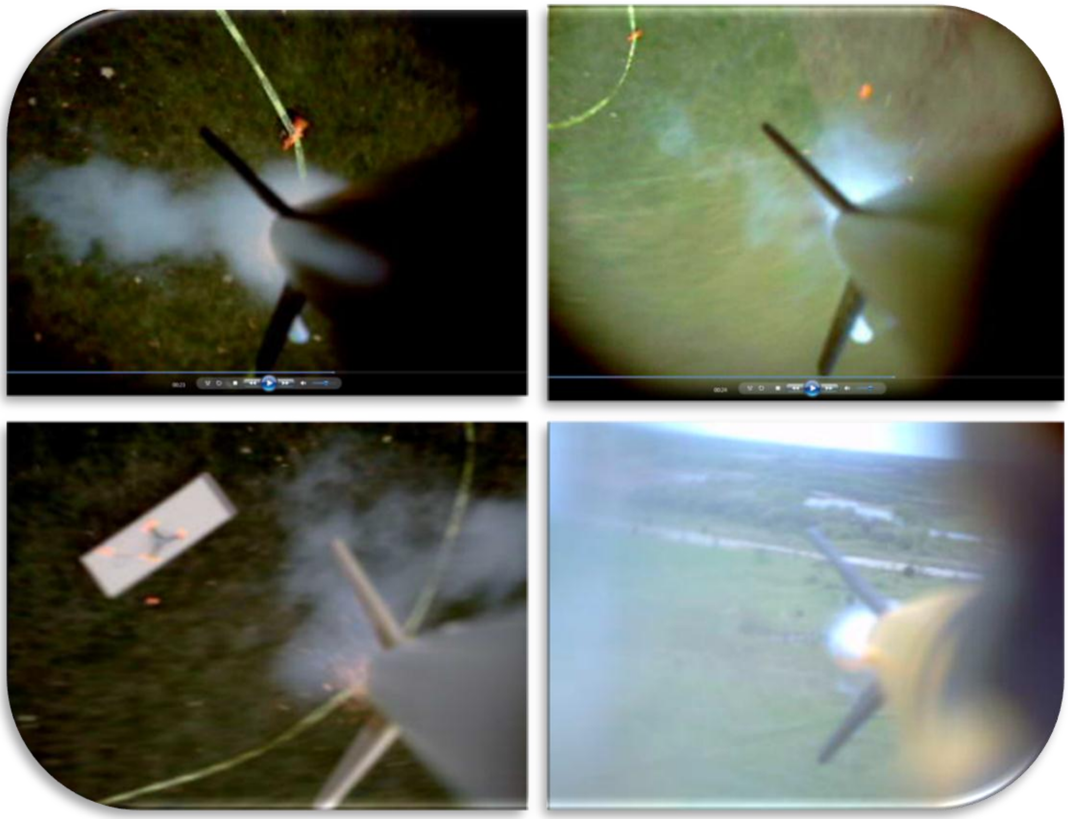

Figure 5 Samples from Successful "Cam-A-Rok" Videos

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Biography

WILLIAM C. FARROW has been teaching at the Milwaukee School of Engineering full time for 10 years in the Mechanical Engineering department. Besides teaching courses related to engineering design and engineering mechanics he works with students pursuing aerospace career goals. Dr. Farrow has worked for McDonnell Aircraft Comp., Eaton Corporation's Corporate Research Division, and at NASA's Jet Propulsion Lab as a Faculty Research Fellow.