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## **AC 2012-4692: FRESHMAN CAD MODELING COMPETITION TO INCREASE STUDENT INTEREST AND RETENTION**

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# Freshman CAD Modeling Competition to Increase Student Interest and Retention

## Introduction

One of the first courses that all Engineering Technology students must take is Engineering Graphics I. In this course, students are exposed to SolidWorks (Dassault Systèmes SolidWorks Corp., Vélizy, France), an industry-standard CAD software package. For most of the students, this course is taken during their first semester in college, so they are overwhelmed by the new experience of college and the rigors of college coursework. As such, when asked to choose a project to demonstrate their accumulated skills during the CAD course, the decision is typically put off until the last minute and rushed to get some small trinket submitted by the deadline.

This most recent semester, however, the authors, each of whom was teaching a section of Graphics, agreed to add a competitive element to the course. Rather than allowing students to choose their own project, the students were broken into teams randomly within their section to work on a Competition-Based Learning (CnBL) assignment. This approach has been used previously in other disciplines and has met with some success.<sup>1</sup>

Each team was required to design a racecar in the style of the Pinewood Derby, a competition sponsored by the Boy Scouts of America (scouting.org), which would then be rapid prototyped using a commercially available 3D printer. At the end of the semester, the teams within a class competed in head-to-head, best-of-three races until the fastest car in the class was determined; the winner of each class competed against the winners from the other two sections in a similar fashion. The overall winner received a small number of bonus points for the semester and a “medal” and the winning car was displayed like a trophy in a departmental display case. It was hoped that this would motivate students, not only as bragging rights for current students, but also a point of pride for the winners and designers of well-made cars and to help motivate future students to take the class even though it might not be a requirement for their specific major.

In addition to being a commonly-used software package in industry, SolidWorks can help students get their first taste of the design process, in that it forces them to plan their design with “downstream” features in mind, it helps them learn to think in three dimensions, and allows for tie-ins with many analysis and prototyping packages. To illustrate the last of these points, the students were allowed to create rapid prototypes of their models to race the cars. The rapid prototype machine used was a STRATASYS Dimension sst768 (Stratasys, Inc. Eden Prairie, MN), which printed three-dimensional models out of ABS plastic based on the solid part files produced in SolidWorks (Figure 1). This, too, is becoming more and more prevalent in industry because of the speed and low cost of the models which allow designs to be tested before full-scale production. The project was called the “SLA Derby,” after a rapid prototyping method.



Figure 1. Student project car being built in Stratasys 3D printer.

The hope was that this would be a project that inspired teamwork (each student was required to design one component of the car), require designing a product within constraints (the maximum weight, width, length, wheel base, etc. were all specified so that the cars roll down the track), increase familiarity with the CAD software and give students a way to creatively explore their chosen profession. Learning objectives (LOs) for the project were: dimensioning and constraining sketches, creating assemblies within software, and identifying mass/center of mass/critical dimensions of a SolidWorks® part. Though they were graded by individual instructors, each instructor had a rubric that included LOs from the project.

The remainder of this paper is organized as follows: the Methods section will outline the structure of the project as well as the assessment tools used, the Results & Discussion section will cover the student submissions, as well as the results of the grading and surveying outlined in Methods. Next, the results will be summarized and some conclusions drawn and finally some plans for future research will be laid out.

## Methods

Each class of 20-25 students was divided into groups of 3-6 students, depending on class size. Each team was allowed to choose its own name and meet on their own to discuss their strategy toward meeting the goal, which was to win the race at the end of the semester. The reward for winning the race was a small number of bonus points, a “medallion” (see Figure 2) and bragging rights (the winning cars would be put on display in the trophy case in the department hallway). Winning the race was *not* required to receive a good grade on the project or in the class, which matches with the strategy put forth in Burguillo.<sup>1</sup>



Figure 2. Rapid prototype medallion for winners of the inter-class race.

Each student team was given the task of building a race car based on the Pinewood Derby cars made famous by the Boy Scouts of America. Using both in-class and personal time, each team member was required to design and model an individual piece of the car and the cars were required to be made of entirely SLA material (no lead weights could be added) but decals, paint and other “flash” were allowed. Due to the granularity of the produced ABS parts, the students were provided with 3/16” diameter steel drill rod axles. Design criteria for the cars were:

1. When assembled, the car must weigh no more than 5 ounces.
2. When assembled, the car must be no wider than  $2 \frac{3}{4}$ ”, the width between wheels shall not be less than  $1 \frac{3}{4}$ ”.
3. The minimum clearance between the bottom of the car and the track surface shall be  $\frac{3}{8}$ ”.
4. When assembled, the car must be no longer than 7”.
5. The wheel base between the front and back wheels shall be  $4 \frac{1}{4}$ ”.
6. Each component must be smaller than 8”x 8” x 8”; the resolution of the machine is 0.10”, so make sure you have enough material around holes to provide appropriate strength.
7. With the exception of the axles (which will be provided), every component of the car must be rapid prototyped; modifications (sanding, painting, machining) are allowed and encouraged.
8. Only graphite or powdered Teflon “white lube” will be allowed for lubricating the wheels.

In addition to the race, each team project was going to be judged on style (groups were encouraged to make their designs unique and take pride in the appearance of their cars) and

group participation (team members were asked to score themselves and their team members based on how much/little they participated in the project).

A survey was developed to gauge the student response to the design project from this introductory graphics class. The survey was approved by the Institution's Committee for the Protection of Human Research Subjects (CPHRS) and was posted on SurveyMonkey ([www.surveymonkey.com](http://www.surveymonkey.com)). A link to the survey was mailed to every student in the department – both currently enrolled in Engineering Graphics and students who had taken the course in previous semesters. A copy of the survey is attached as Appendix A.

Student teams were also required to give an 8-10 minute presentation toward the end of the semester to discuss their project; this presentation was then part of their final project grade. They were encouraged to take photos of the car during construction and to “spice up” the presentation and verify that they had met all design criteria using graphics from SolidWorks.

At the conclusion of the semester, student grades were anonymously compiled and compared to grades from previous semester's projects. Since only two of the instructors had taught the course previously, theirs were the only grades used in the study - the thought was that their grading would be consistent between semesters and would give adequate comparison between project types. It was expected that the grades from the current semester would be higher than previous.

## Results & Discussion



Figure 3. Student submissions to the SLA Derby Competition.

Virtually every team seemed to take great pride in its car and its team. Teams had names like *Fuzzy Chickens*, *Team Wombat*, *Derby Daddies* and *Rocket Turtles*. Most students could be seen spending every extra minute of in-class work time meeting or designing their cars; which showed in the quality of the final products (see Figure 3). There were scale reproductions of a number of different classic cars, as well as one or two real innovations; one such innovation was when a

freshman Mechanical Engineering Technology student designed and fabricated a set of rapid prototype wheels with functional ball bearings.

There were a handful of submissions that were disqualified from racing by the fact that they did not meet the design requirements, but the students on those teams reported later that they learned a lesson regarding teamwork and checking their data before production (see below).

Between the three classes, a winner was crowned and the top three finishers were given places of honor in the display case outside the Engineering Technology faculty offices as shown in Figure 4.



Figure 4. Third, first and second place finishers in the SLA Derby Race.

Even among students not in the class, the project seemed to be a success. TAs in the various sections of this semester's Graphics class and students of previous semesters were heard to say things like: "That's so much cooler than when I was taking the class." or "Why couldn't we have done a project like that?"

Based on their comments in- and out of class, as well as the care and detail most took with their cars, it is apparent that the project was well-liked. But since the purpose was to teach something, it is also important that the students learned something. From comments given during their final presentations and their team evaluations, it appears that they did. Below are some actual comments from final presentations and evaluations submitted by students:

- Throughout this design process we have realized that we did not make the perfect car, but we have learned from our mistakes and we compiled a list of what we would change in the future
  - Design the front wheels to be larger than minimum requirement
  - Reposition axle mounts to better fit the track
  - Design up with a better method to attach the wheels to the axles
  - Use better time management and more preparation
- What Was Learned
  - Group projects require ample communication. If one thing is not thought about it can sabotage your project. 3D printer is not extremely precise at small scale.

- Just because you meet requirements doesn't mean your 'Good' [sic].
- Field of design is very complex. There are lots of variables/factors to take into consideration.
- Never know if your design will work until tested.
- Lessons Learned
  - Make sure there is enough clearance between the track and the car.
  - Make the hole for the axles bigger so the wheels will roll more smoothly.
  - Should have used lubricant to help axles rotate better.
  - Can't always be a winner.
- Lessons Learned
  - ABS plastic is brittle, thus making modifications harder.
  - Check, check, and recheck your dimensions.
  - Leave room for error in prototyping.

In addition to their comments, the grades showed that they learned something, as well. The two instructors who had taught the course previously used the same grading criteria as for previous projects to facilitate comparison of the scores. The results of the different instructors' project grades are shown in Table 1. Since extra credit was given as reward for winning the competition, the Fall 2011 scores were normalized to a max score of 100%. Instructor A's class average for the non-competition project was significantly lower than when using a competition-based project ( $p$ -value = 0.001). Also of interest, the range and standard deviation were smaller for the Derby year, indicating that a higher number of students did better, not just that a few high scores biased the results. Instructor B's class average for the two different groups (competition vs. non-competition) were not statistically different ( $p$ -value = 0.07); however, the range was much smaller for the year in which the competition project was used, indicating that the students' learning experiences were similar for that year.

Table 1. Grade results for class projects. Results are grouped by instructor and broken out into semesters in which there was a competition-based project and not.

	Instructor A		Instructor B	
	Non-Competition	Competition	Non-Competition	Competition
<i>n</i>	43	20	82	24
<i>mean</i>	83.0	91.0	92.4	89.2
<i>SD</i>	23.0	8.3	9.1	10.2
<i>min</i>	16.5	71.4	59	70
<i>median</i>	93.6	94.6	93	90
<i>max</i>	100	100	100	100

The results of the survey also seem to bear out the fact that the project helped increase student involvement and interest in Engineering Graphics. As of the time of this publication, 46 students from various majors had completed the survey. The population broke down as shown in Figure 5. The vast majority took the class as a requirement (97.8%) and had already chosen a major by the time they took the class (95.7%). Of the two students who had not chosen a major before entering the class, one student (a freshman plastics major who took the class this semester) said

that the project did not alter his decision of major, rated the final project as *Neutral* and said that the final project did not raise his interest in his current major because “[The final project] made it seem that it will be very difficult.”

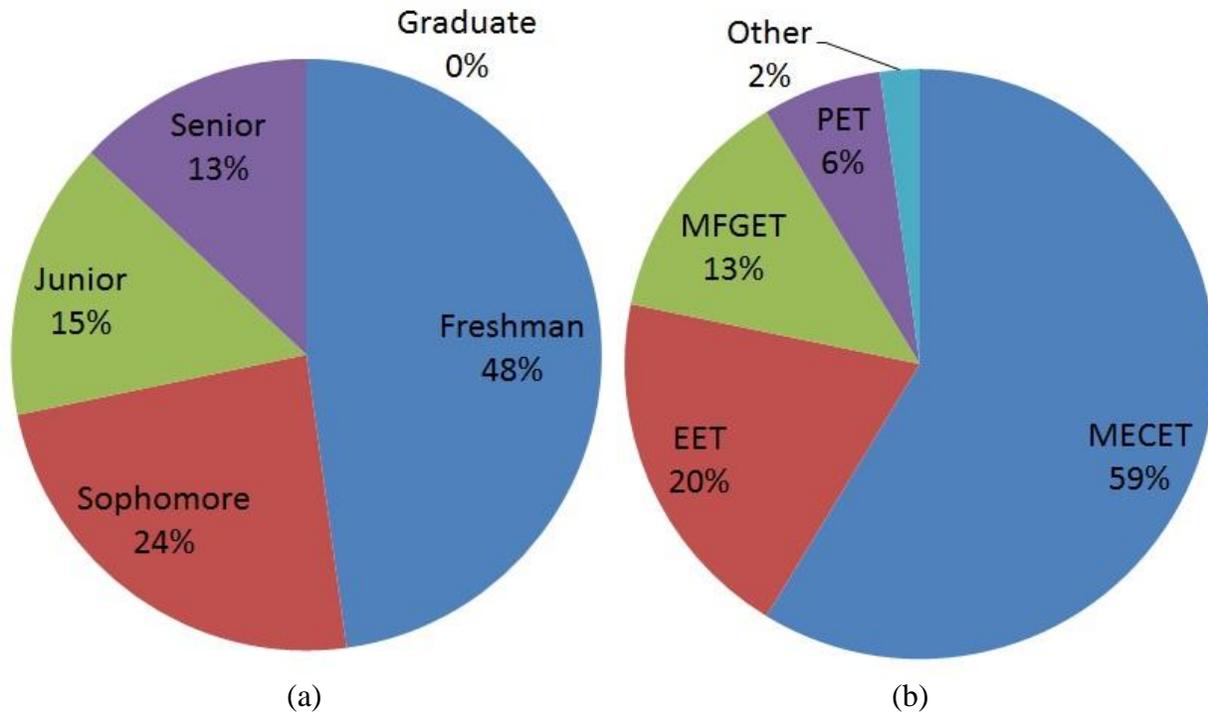


Figure 5. (a) Percentage of survey population by year in school. (b) Percentage of survey population by major: MECET – Mechanical Engineering Technology, EET – Electronics Engineering Technology, MFGET – Manufacturing Engineering Technology, PET – Plastics Engineering Technology.

Overall, the project was rated very highly by students, with an overall score for Question #7 of 4.43/5 (“Greatly” = 29 responses, “Somewhat” = 11 responses, “Neutral” = 3 responses and “Very Little” = 3 responses; see the survey in the Appendix for criteria rated by students). Considering the responses to question #6, most students (84.8%) said that the final project did not alter their choice of major. Not surprisingly, the seven students who reported that their choice in major was altered also rated the project very highly: the average project rating among these students was 4.86/5, which is statistically higher than for the group as a whole (one-tailed p-value = 0.02).

The final question on the survey was whether or not the students felt that the project raised their interest in their current major. The majority (80.4%) said that the project did raise their interest in their major and made comments like:

- It made me look at creating a single part in many different ways which interested me
- Because it gave us real life situations when creating something on solid works [sic]
- It helped to make me realize how it would be like to work in a group setting with other members not always participating
- It showed me how this could be implemented on a real world scale.

The students who did not feel that their interest was not increased through this project had a variety of responses (Note: of the nine students who replied negatively to Question #8, four took the class in previous semesters):

- It made it seem that it will be very difficult
- Most off [sic] the projects are mechanical in nature. Since I am an EET major I did not feel that it had any pertinence to my major
- Because I already knew I wanted to do my major SolidWorks is stupid I like Inventor way more
- I don't want to draw on the computer but I enjoyed using the system

If the data is filtered based on responses to Questions #7 & 8 and the year in which the student took the class, we get results that are at the crux of this study. For those nine students who took the class between 2008 and Spring of 2011, 44.4% said that the project did not raise their interest in their major. 84.4% of students taking the class with the competition-based project reported that it helped raise interest in their major. The average rating of the final project was 4.7 (5 = highest) for the competition-based project and 3.2 for previous semesters' projects (p-value = 0.004).

## Conclusions

Though there were a few overall negative reviews of the project, as a whole, it appears both from the improved survey results between previous semesters and the current semester, as well as the grades, that this was a well-received instructive project. Grades were either higher or at least not statistically lower for the current project than in previous semesters. Students appeared to benefit from the project as a whole and it seemed that it was well enjoyed by all, including the instructors. The instructors feel that the few negative reviews of the project were a case of “you can't please all of the people all of the time” or from students who were taking the class because they had to and weren't going to put in much effort, regardless.

The most important conclusion can be drawn from the last paragraph in the preceding section: almost twice as many students who participated in the SLA Derby reported that their interest in the project and the subject matter was increased through the competition-based project as in previous semesters.

Based on the results of this study, future classes will be implementing a similar competition-based project with the hopes that the competition can become a tradition around the department.

## Future Work

During the review process for this paper, it was suggested that the authors group data by gender, to see if the use of a “male-oriented” project like a car race would increase or decrease the interest and retention of female students in the class. Unfortunately, this suggestion came too late: by the time the reviewer submitted his comment, the survey had been approved by the CPHRS Committee and the addition of the gender study would have delayed the project. As

such, the authors will consider adding this question to future studies to investigate this phenomenon further.

Also, a follow-on interview was included as a part of the approved survey instrument. A number of the students have volunteered to be interviewed in more depth. Future research involves collecting data from these students to gain insight into their experiences with this class, both in the current semester and previous.

Finally, this paper uses grade results from 5 different semesters (one current and 4 previous) from two different instructors (one of the authors did not have previous grades with which to compare) as a basis for its conclusions. Future works will include grades from future classes in which this project set-up is re-used to determine whether the effectiveness of this project was a one-time event or an ongoing phenomenon.

#### Acknowledgements

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#### Bibliography

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Appendix A – Student Survey

**MECET 121**  
**Computer Graphics 1**

The following survey is being used to assess your perceptions about the class project for the introductory computer graphics course you took at Pittsburg State University. The data is **anonymous**, will not have any personally identifiable information and will be used to show general trends in interest in class projects.

- 1) What is your current year in school?      Fr   So   Jr   Sr   Gr
- 2) What is your major? \_\_\_\_\_
- 3) What semester (i.e. Fall 2011, Spring 2010) did you take MECET 121? \_\_\_\_\_
- 4) Did you take MECET 121 as a requirement or an elective? \_\_\_\_\_
- 5) Had you chosen a major by the time you took MECET 121?      Yes                  No
- 6) Did the class project alter your choice of major one way or another?      Yes      No
- 7) On a scale of 1-5, with 5 being the highest, how would you rate the final project in MECET 121 when you took it? (i.e. how well did it teach you SolidWorks? Did it make you like SolidWorks more? Did it make you like the class more?)      1      2      3      4      5
- 8) Do you feel that the project in MECET 121 helped raise your interest in your current major?      Yes      No

If *NO*, why?

If *YES*, how?

If you would be willing to answer a few follow-up questions via phone or in person, please provide contact information (phone # or email) so that the investigators may contact you.

Please answer the following questions based on **your experiences** in MECET 121 – Computer Graphics I.