Solar Boat/ Solar Car -- Challenging projects for first-year students

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1. Introduction

In the Spring semesters of 2003 and 2004, first year engineering students at Elizabethtown College were assigned time-consuming, challenging projects in the "Introduction to Engineering" course as part of their required curriculum. In the Spring of 2003, the assigned project was the design and construction of a solar-powered boat capable of carrying one person around the College lake in minimal time; the Spring 2004 project was similar – the design and construction of a solar-powered endurance vehicle (i.e., solar go-kart). I believe that these future engineers benefit from experiencing all facets of a project at an early stage – design, 3-D modeling, competitive presentation, project management, ordering, construction, testing, completion, and final write-up. These projects were both very successful with the teams coming together to complete the projects, as well as frustrating to some peer professors relating to perceived declining performance of students in other courses. In this paper, I will relate my experiences in assigning challenging, time-consuming projects to first year students.

In both projects, students were given two items: a 120 Watt solar panel and $400, with the further stipulation that no pre-fabricated items (boat, scooter, electric trolling motor, etc.) could be used without instructor permission. The students truly started from scratch –developing 3-D models, proposing and purchasing items, and finally assembling and testing their vehicles. These projects are effectively a hands-on application of the main topics in our Introduction to Engineering cycle: problem-solving, design, 3-D modeling, teamwork, project management, and communication skills.

"Introduction to Engineering" is a year-long course for first year engineering students. This survey- type course is "half" credit (two academic credits compared with the typical four credit course at the College) and meets four hours each week for the Fall and Spring fourteen week semesters. The Fall semester course covers the topics of history of engineering, engineering majors and career paths, problem solving, design, project management, teamwork, oral presentation skills, technical writing, and some basic computing skills using a spreadsheet (statistics, solution of equations, and optimization). A community-based project is assigned in the Fall semester to connect and apply these subjects.[1] In the Spring semester, the course covers four topics, as well as the major project – sketching and graphics, Solid Edge 3-D modeling software, Matlab software (including 3-D plotting, solution of simultaneous equations and optimization), and engineering ethics.

We strive to find projects for first-year engineering students that are both challenging enough to require real teamwork and project management, while not requiring skill-sets developed in upper-level science and engineering courses. Further, our Introduction to Engineering course is for all engineering majors and thus ideally should address both mechanical and electrical systems. Finally, members of our department feel that creativity and open ended design is beneficial to the students and projects such as the solar car / solar boat are very open-ended and can be solved in many ways.

A major concern of these projects is that they can be time-consuming. Students with poor time management have worked 24 hours straight to attempt to complete the project on the last day. These cram sessions can be detrimental to coursework in other classes. Overall, however, students have responded extremely well to the challenges of these projects and appreciate the opportunity to showcase their talents. Several students have stated with pride that they are able to undertake projects generally reserved for junior and senior students. In both years, we have had juniors and senior students become interested in the projects and challenge the first-year student teams. This added incentive to beat the upper-class students has added a positive element to the course. The upper-class students have been willing to voluntarily undertake the project for zero credit and risk "losing" to the first-year students just to experience the challenges of a complicated / open-ended design project.

The projects have been successful and even been covered by local newspaper and television crews both of the past two years. I contend that these projects provide an excellent foundation for the students and a once-in-a-lifetime opportunity for students to take a full-scale product with almost zero constraints and requirements from initial design, through material specifications, construction and final testing. The students truly start from ground-zero and finish with a complete product. Nevertheless, some professors could argue that this time might be better spent concentrating of basic mathematical and physical principles that are the core of our current engineering education paradigm. Especially in a half-credit introductory course, I must take these arguments seriously and have not fully developed a proper response. In this paper, I survey the projects and format of the class. After summarizing the projects and highlighting some of the positive and negative aspects of assigning such challenging projects, I end with some open-ended remarks about the experience that attempt to address my current dilemma concerning the assignment of such challenging first-year engineering projects.

2. Course Flow

The Introduction to Engineering Spring semester course covers several topics starting with students first studying sketching and graphics concurrently with computer-based solid modeling (Solid Edge by EDS). Within the second week of classes, the major project is introduced and design teams of three to four students are formed. Teams are formed by the professor based on students self ranking of their abilities in the areas of: 1) Design / Sketching, 2) Creativity / Ideas, 3) Organization / Planning Skills, and 4) Oral and Written Communication Skills. Further, the professor uses information on their intended majors and performance in previous coursework. Additionally, students are afforded a line on the questionnaire to anonymously request to exclude or include one person. These design teams then generate a detailed design on the computer with supporting material specifications and costs.

At the end of four weeks of design and research, the teams present their final design to the public including students and faculty. The audience votes (faculty votes count three times, but students can weight the ballot box by inviting friends from other departments) on the best designs and the top 50% of the designs are then constructed. Teams are combined such that most teams have seven or eight members. These new teams then construct the final product. In most cases, this competition has been good-natured and newly formed teams are able to take ideas from both camps in building their final design. Additionally, both years, a team of junior and senior students completed the project for no academic credit. Their design was not judged competitively, but they were asked to meet most all requirements, such as presenting their design at the public design presentations. These upper-class students did not tend to have any advantage in terms of structural design, but did have a superior electronics understanding than the first year students. In the spirit of collaboration, this advantage was graciously used in the early design and construction stages to help educate the first year students. In other instances, however, the upper-class students were occasionally surprised to be educated on products and ideas that they themselves did not know about by the first year students.

Gantt charts and progress reports were required throughout the project. In the second year, weekly deadlines were added to discourage procrastination. For example, after the construction teams were specified, they had one week to order something, two weeks to assemble something, three weeks to have a vehicle that could be pushed around on wheels and steered, four weeks to have a vehicle that could be driven off a battery, and five weeks to have a solar-powered vehicle. This idea is essential, however, in the Spring of 2004 course insufficient incentive was provided for all teams to meet deadlines. Thus two teams still hit the last day 24 hour crunch. Not surprisingly, the team that avoided this crunch won the competition handily.

The students specify all parts and order all parts. In most cases, the students were asked to show proper design considerations prior to ordering essential/more expensive components. Most students are very reluctant to spend money early in the construction phase of the project, despite carefully researching materials and their design. Thus instructor encouragement is essential to speeding the process and avoiding weeks of indecision.

Three weeks before school ends, the final product and a practice presentation is due. A technical paper with design and construction information, materials, and detailed budget as well as updated timeline is also required. A competition is scheduled for the following week with brief presentations to follow. The project assignment and schedule for the Spring 2004 final day event is listed in Appendix 1. The first year, we needed one rain day, while the 2nd year the event took place as scheduled from the beginning of the semester.

3. Results and Highlights

Two projects were undertaken in the course. The original intent of these projects was to create a four-year cycle of projects such that no group of students would see a repeat project. Thus, each set of students truly starts with a clean-slate and must build their design ideas from scratch. Very little guidance is provided for the projects. Students have a short list of rules and objectives. The original Solar Boat project statement is listed in Figure 1. Only minor changes were made to this project assignment for the Solar Car project (see Appendix 1).

Introduction to Engineering II Spring Project

Solar Powered Boat.

Rules:

1) Boat must carry one person.
2) Boat must be able to complete one lap around Lake Placida.
3) Power for boat propulsion must come from Solar Panel.
4) No supplemental propulsion (paddles, combustion engine, ropes, etc.)
5) All components must be pre-approved by the instructor. You may not use a pre-fabricated boat or outboard motor.
6) Solar panel must be attached to boat with an easy attach and detach mechanism.
7) Additional rules may be added if loopholes are identified!

Objective:

Design and construct a boat powered solely by solar energy, capable of transporting one person, that can complete one circuit around Lake Placida in minimal time.

Materials:

1. Solar Panel, 120 Watt, 12 volt nominal (Size : approximately 59 by 26 inches) (see back page)
2. The rest is up to you. Shoot for a budget of around $300 with a hard limit of $400.

Timing:

01/31 - Initial Schedule / Plan / Gantt Chart
02/07 – Initial design concepts and sketches
02/14 - Initial proposal due including budget and sketches
02/21 - Final budget and CAD drawings due. Consider scale model and testing.
02/28 – Final plan due. Presentation to class.

After spring break, we will break into two groups and enter the second phase of the project. The second phase will include final design modifications, purchase, construction and testing.

Figure 1: Initial handout/ project assignment for the Spring 2003 solar boat project for first year engineering students. Note that the schedule does not include the construction phase of the project.

For the solar boat project in the Spring of 2003, we had four design teams of first year students and one team of upperclass students. Sample designs are shown in Figure 2.[2] The two best designs chosen by the audience of students and faculty were constructed after the teams were combined. The constructed boats are shown in Figure 3.[3] Solar panels were generously provided through a $1500 grant from the Sustainable Energy Fund of Southeast Pennsylvania[4]. Material budgets were provided by Elizabethtown College out of the standard engineering department budget. The final competition included a team of upperclass students. All boats successfully completed the project and one lap around the Lake on their solar powered boats (Figure 4). A campus wide turnout of over 100 students, as well as a local elementary school class, cheered the students on. Positive results from this first-year student project encouraged upper-class students to form a solar boat team for the International Solar Splash competition in Buffalo, New York for 2005.[5,6]

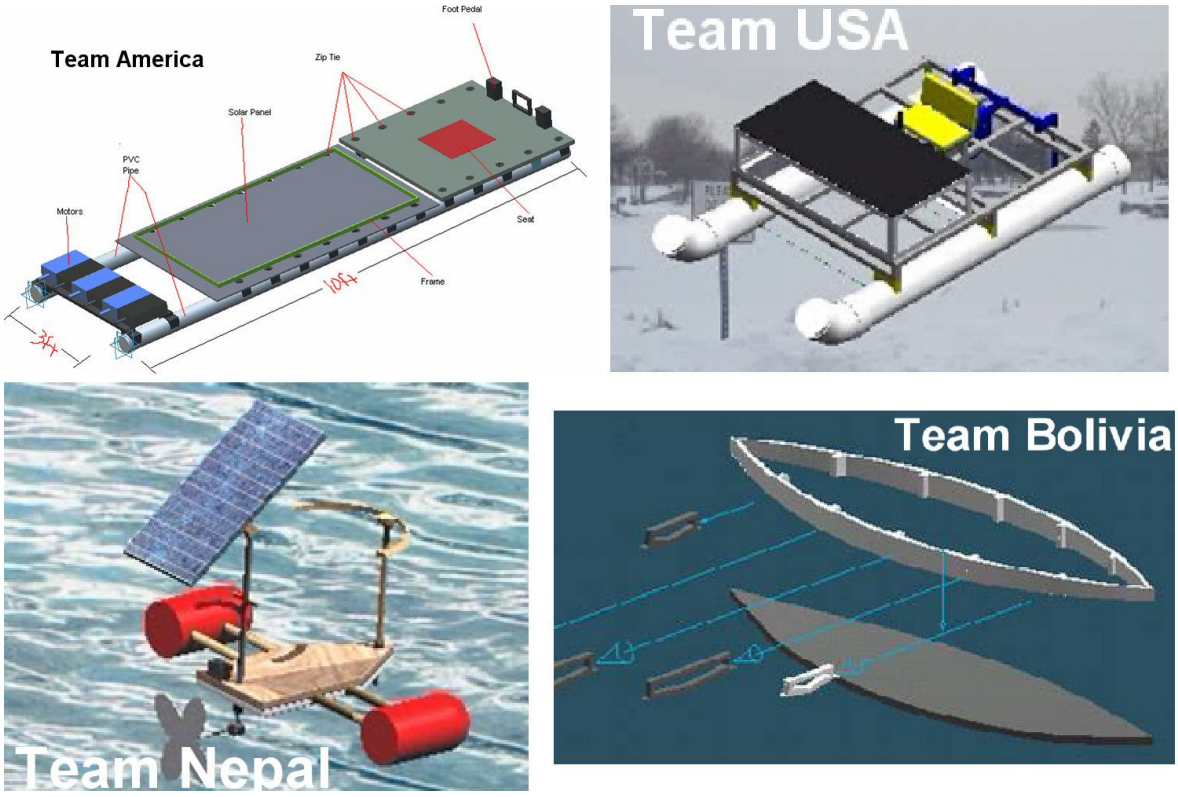


Figure 2: Solid edge designs of solar boats capable of carrying one person. Designs are by teams of 3 – 4 first-year engineering students. Each component is modeled separately and assembled in Solid Edge modeling software. The two designs on the right were chosen for construction by the audience.

Figure 3: Final construction of solar boats capable of carrying one person. Construction was by teams of 7 - 8 first-year engineering students. Prefabricated boats or trolling motors were not allowed for the project.

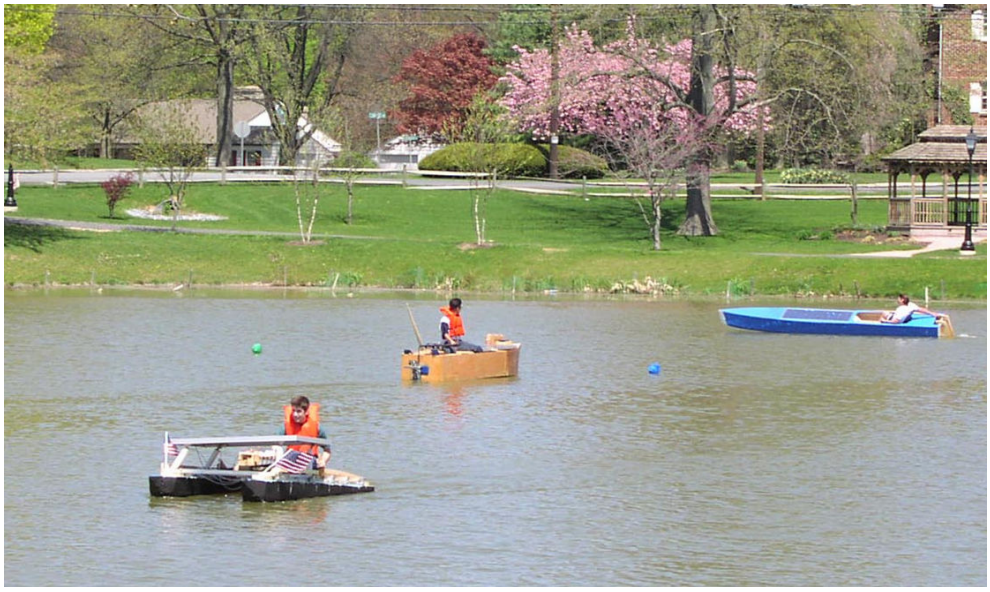


Figure 4: Race day photograph of the three solar boats on Lake Placida at Elizabethtown College

Similar design results and construction photographs can be seen on our website[7,8] for the Solar Powered Endurance Vehicle undertaken in Spring 2004. A sample design (Figure 5) is included to show the detail taken by the first-year students in their designs. This project involved a larger class of students and thus seven design teams and three construction teams (not including the fourth team of upperclass students) as shown in the final photograph in Figure 6. An additional $500 grant from the Sustainable Energy Fund provided an additional solar panel for this project, while material costs again came from the departmental budget. In this year, one team's vehicle failed to work on the day of the competition. Encouragingly, this team came back the next day and completed one very slow lap around the Lake to avoid failure.

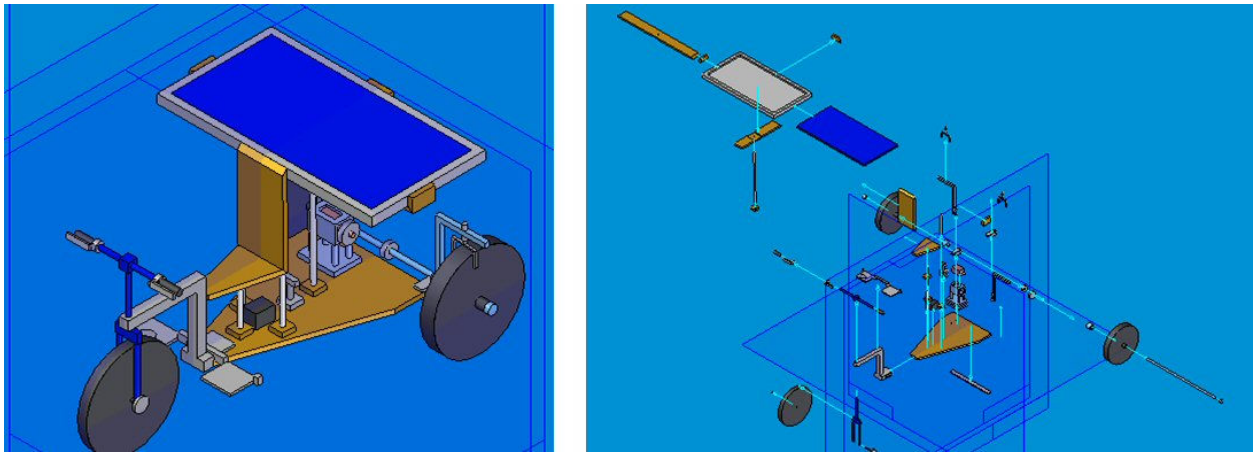


Figure 5: An example student design for a Solar Powered Endurance Vehicle capable of carrying one person continuously running off solar power. The left shows the assembled view and the right image shows the exploded view with all parts.

Figure 6: Photograph of first-year engineering students with their Solar Powered Endurance Vehicles in the Spring of 2004. The vehicles from left to right completed four, seven, three, and zero laps around the College Lake in a one hour period with a 120 Watt solar panel.

4. End Remarks

In this paper, the experience of first-year students working on challenging design projects is summarized. The projects have been highly visible at the college and well-received by the students. Upper-class students have voluntarily worked on these projects for the personal experience as well as to mentor the first-year students. The projects continue to be a heavy load on the first-year students at the end of their second semester, in some cases negatively affecting their grades and efforts in other courses. The instructor continues to see the strong merits of these projects, but hopes to implement better incentives for students to maintain excellent time management of the project. The author welcomes pedagogical comments related to the concepts of assigning challenging projects to first year students.

5. References

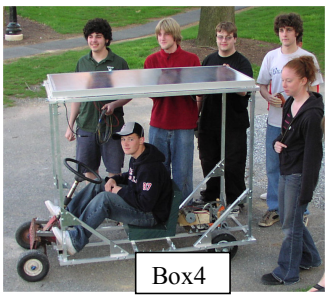
1. T. McBride, V. Bergel, and J. Fullerton, "Community-based projects by first-year engineering students", submitted to the 2005 ASEE proceedings of the Annual Meeting.
2. http://www2.etown.edu/physics&engineering/projects/firstyear/solarboat/designs
3. http://www2.etown.edu/physics&engineering/projects/firstyear/solarboat/receresults
4. http://www.sustainableenergyfund.org/
5. http://www.solarsplash.com
6. http://www2.etown.edu/physics&engineering/projects/SolarBlueJay3
7. http://www2.etown.edu/physics&engineering/projects/firstyear/egr101_spring_2004_projects/Designs
8. http://www2.etown.edu/physics&engineering/projects/firstyear/egr101_spring_2004_projects/Race

6.A. Appendix 1.a– Front side of pamphlet describing Solar Powered Endurance Vehicles project and competition.

Engineering 110 presents a

Solar-Powered Endurance Vehicles RACE

Thursday, April 29 at 2:15 pm (NEAR LAKE PLACIDA)



Solar-Powered Endurance Vehicle Design Project Objective:
The project objective was to design and construct a vehicle powered solely by solar energy, capable of transporting one person, that can complete the most laps around the outside of Lake Placida in the least time.

Team Box4	Team Hummer	Team Phoenix	Team UC2
George B.	Jake P.	Mee Mee H.	Jose C.
Chad W.	Mark L.	Tigist G.	Ruben T.
David S.	Wayne H.	Kaitlin H.	Chris H.
Mark D.	Amlan B.	Lauren S.	Matt S.
Curtis F.	Arindam K.	Jeremy D.	Adam B.
Ben C.	Doug F.	Taylor J.	Corey N.
Jason P.	Juan Pablo R.	Brent L.	Mitch D.
Gianfranco V.	Ermias M.		Ruth A.

DETAILS

Rules:
1) Vehicle must carry one person, such that the person does not touch the ground.
2) Vehicle must complete one lap around Lake Placida to pass.
3) Power for vehicle must come from Solar Panel
4) No supplemental propulsion (feet, combustion engine, etc.) except that you are provided a 12 Volt Battery (~14 Amp-hours).
5) All components must be pre-approved by the instructor. You may not use a pre-fabricated car, cart, tricycle, or drive system.
6) Solar panel must be attached to vehicle with an easy attach and detach mechanism.
7) Vehicle must fit on sidewalk and through the bridge on path around Lake Placida.
8) Additional rules may be added if loopholes are identified!

Materials:
1. Solar Panel, 120 Watt, 12 volt nominal (Size : 59 by 26 inches. Weight: 29 pounds)
2. The rest is up to the individual groups. The group budget is approximately ~ $400

6.B. Appendix 1.b– Back side of pamphlet describing Solar Powered Endurance Vehicles project and competition.

Phoenix

Race Timetable:

THURSDAY April 29 by LAKE PLACIDA

OPTIONAL CHARGING of BATTERIES

12:30 pm Teams may begin charging their batteries

HEAD-TO-HEAD RACES

2:15 pm Race BEGINS with "Down-and-back" HEAD-to-HEAD Race.

VEHICLE DESCRIPTIONS and Battery Charging

2:30 pm 3 minute vehicle descriptions (with open questions) by each Team, followed by the Endurance Contest.

ENDURANCE CONTEST

2:45 pm Race CONTINUES with Endurance contest

Teams complete as many laps as possible in 1 hour. Overall Winner must win by 1 point. Any ties will be decided by a final HEAD-to-HEAD race at 4:00 pm.

SPEV ENGINEERING PRESENTATIONS

4:15 pm *(or earlier)* 5 minute vehicle design presentations (with open questions) by each Team in Esbenshade 166. ***Refreshments Served.***

SCORING:

"Down-and-Back" Race:
First Place: 4 points
Second Place: 3 points
Third Place: 2 points
No completion: 0 points

Endurance:
Each Lap: 1 point

FUNDING:

Thank you to the sponsor of our solar panels -
Sustainable Energy Fund of Central Eastern Pennsylvania
(http://www.sustainableenergyfund.org/projects.htm)

Team Hummer