Wind Power for Developing Nations; Sustainability Meets Junkyard Wars

J. Ledlie Klosky and Gunnar Tamm, West Point, The United States Military Academy

Inspiring students to truly take charge and execute ill-defined, real-world capstone projects is a significant challenge. To meet this challenge, it is imperative that the project topic be carefully chosen, as the topic is the genesis of the student's efforts. This paper asserts that successful project topics should contain three key components: the project must be rigorous but within the student team's capabilities, the students must feel that the project matters, and the topic must engage the interest of the project mentors, be they professionals or professors. Both authors have experience with a variety of successful and less-successful capstone projects and the broad aspects of successful project topics are discussed. Specific attention is given to a new project topic, Wind Power for Developing Nations, which requires the construction of wind generators from scrap parts using only tools and methods available in developing nations. The authors have sponsored this project at West Point in 2008-2009 and again in 2009-2010. The project aims to engage students in designing and constructing an electrical generation project suitable for construction in the developing world. For 2009-2010, two teams will compete against each other in this project and it is hoped that in future years the challenge can be extended to additional engineering programs outside of West Point.

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Introduction

At West Point, as elsewhere, the nature of engineering education has been in significant transition since the turn of the century. That transition has definitely included two key growth areas; globalization and project-based learning (PBL). This change has been driven by an increasing desire on the part of both students and faculty to participate in significant projects with real-world implications. However, inspiring students (especially undergraduates) to truly take charge and execute ill-defined, real-world capstone projects is a significant challenge. The authors have supervised a wide variety of undergraduate student capstone projects, and this paper first details some basic observations about what makes an effective project and then describes the Wind Power for Developing Nations project, which is now in its second year at West Point in the Department of Civil and Mechanical Engineering.

Elements of a Workable Project: The Three Principles

Many professors, the authors included, have encountered significant success and failures in the execution of undergraduate student projects. This variety in performance is probably unavoidable, since truly open-ended problems do not have a fixed solution that is known at the outset, and thus success or failure is difficult to predict; indeed, responsibility for that success must rest on the shoulders of the student if the project is to claim to be real. Thus, this discussion will begin by assuming that what is desired is an actual design project versus a project with a known trajectory and careful fences to keep the students on-track. The question then becomes not how to avoid any chance of student failure, but how best to choose a topic which gives the students a real shot at success.

Over the years, the authors have engaged in a wide variety of projects, from water turbines to simulated Roman siege equipment to precision chambers for calibration of high-pressure explosive force gages. From this experience, one might expect that the principle challenge for undergraduates would be technical in nature, like computing stresses for an unusual loading or solving a complex dynamics problem. However, we have noticed that the main difficulty is not student ability or training; the central feature of unsuccessful teams is a lack of motivation. "Regardless of the student's learning style and basic intelligence, he or she will not learn if not motivated" [1]. Teams that possess the drive to finish rarely trip over technical or resource issues but instead adapt and overcome, achieving far more than seemed possible at the outset. But how do we put that motivation in place?

Figure 1 Students display their tower and blades, executed using only discarded materials (junk) and simple manufacturing methods such as might be possible in the developing world

To inspire a team to excellence, it is imperative that the project topic be carefully chosen, as the topic is the genesis of the student's efforts. Broadly, teachers should turn to well-researched basic principle, such as the 15 principles listed by Wankat and Oreovicz "What Works: A Compendium of Learning Principles" [2]. The authors believe that the creation of successful project topics should follow three key principles:

1. The project must be rigorous but within the student team's capabilities,
2. The students must feel that the project matters, and
3. The topic must engage the interest of the project mentors, be they professionals or professors.

This rather closely parallels Lowman's contention that

> *"The two major issues concerning assignments deal, respectively, with the (1) ticklish relationships between the difficulty, the enjoyment and the educational value of the work… and (2) the methods used to motivate the students to complete it."* [3]

Projects that lack rigor almost always fail to excite the student. Legitimate questions for a too-easy project might be: Where is the meat of the thing? How do I use my training to solve this problem? A student on such a project is also often tempted to put off the doing of the thing nearly indefinitely, figuring there is always time to pull off the project at the last minute. This is not a recipe for motivation. Conversely, if the project is principally concerned with topics with which the students are not familiar or if there are insufficient resources (space, materials, equipment, training, etc) in place, the team will quickly figure this out and attempt to deliver the minimum necessary to simply pass the course without really committing to the project.

Projects that matter gets after the motivation piece of the problem detailed above. Of course, trying to nail down what matters to each generation of students, not to mention each specific student, is difficult. The instinct to follow what's hot, while perhaps condemned by many as simply faddish, is probably not a bad one. The "what's hot" paradigm likely follows current student interest; students are also typically pretty good at identifying the next big thing. Further, by following student interests one is far more likely to hit upon a project that excites student interest and stimulates activity on the project. However, following what's hot alone is not sufficient – it is also true that the project needs to *matter*. The project must have some relevance to the student in terms of the team's desire to make a difference in the world around them. Lately, as evidenced by the radical growth of organizations such as Engineers Without Borders, a strong desire to help in the developing world would be a good example of something that matters to students.

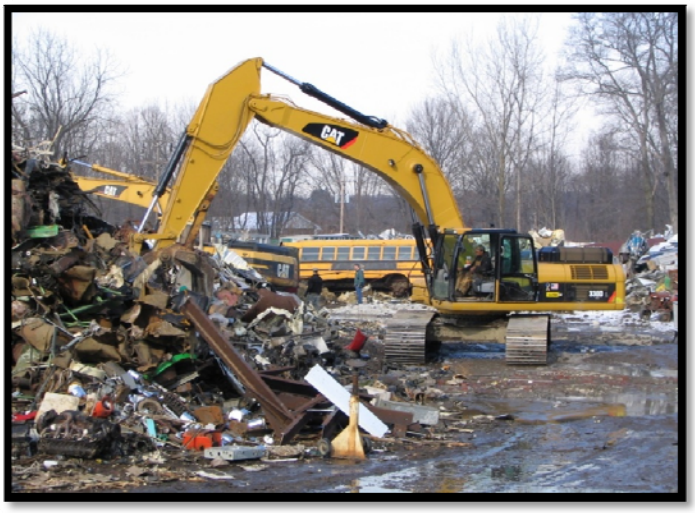

Figure 2 The Junkyard

Figure 3 Dr Tamm demonstrates Principle 3

Lastly, and perhaps less obviously, the project should be interesting to those guiding and mentoring the team. Students *know* when we are excited about a lecture or topic and really key in on that energy. The professor-as-leader aspect simply cannot be avoided or ignored. If an instructor or sponsor takes on the responsibility of guiding a student project team through the choppy waters of real-world design, there is a strong obligation placed on that mentor. Motivated leadership really does make a difference, and engagement with the students can get them over the rough spots and keep them focused when the inevitable February Lag comes into play.

An Example Project: Wind Power for Developing Nations

During the 2008-2009 academic year, the authors decided to attempt a new project entitled Wind Power for Developing Nations, subsequently retitled Junk to Juice; this project ran with one team during that year and is running again in the current year with nine students competing against each other in two teams. It is hoped that in future years the challenge can be extended to additional engineering programs outside of West Point. Stated briefly, the challenge requires the construction of wind-powered electrical generators from scrap parts using only tools and me-

thods available in developing nations. The project aims to engage students in designing and constructing an electrical generation project suitable for construction in the developing world.

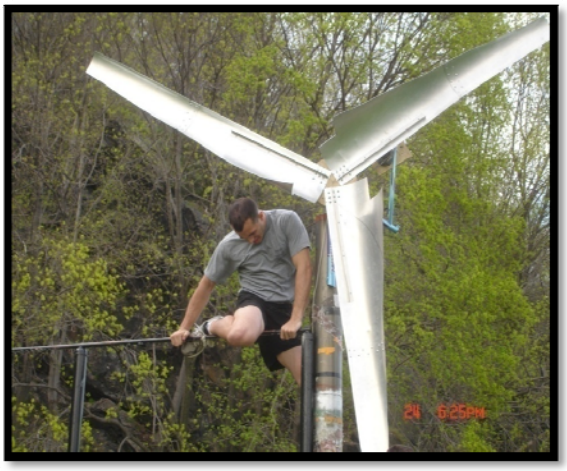

Figure 4 Expedient testing methods

This paper is not intended to describe the design process followed by the students in detail. Readers can get a fairly complete idea of the extent of the project from Figures 1 through 5. This project followed the three principles stated above in the choice of the topic and was perhaps only somewhat successful in terms of product produced; however, in terms of student *learning*, which is after all the point of the exercise, the project was a great success. There is little question that the students engaged in real engineering design, considering science for the solution of practical problems in elements like the blade design, considering individual and societal needs in their product manufacture, maintenance and operation as well as facing the very real challenges of connecting all the parts up and making them work in concert.

The project was definitely rigorous but achievable (Principle 1). The rigor required a high level of both technical and physical effort out of the students and the achievable clearly demonstrated by the final product. In terms of Principle 2, the students really believed that the project mattered. Clear evidence of this at the end of the project was the strong desire of the students to have "done more". The students absolutely bought in to the idea of the project and owned the process and product. Lastly, the nature of the project was appealing to the authors, who remained engaged throughout the design effort.

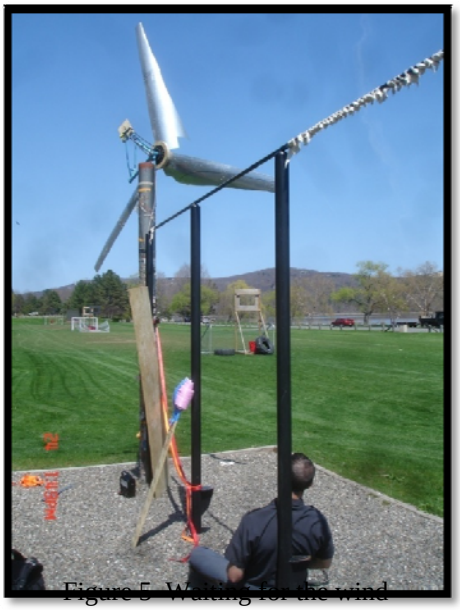

Figure 5 Waiting for the wind

As of this writing, the project is continuing into its second year of implementation and student enthusiasm is running high, with 9 students selecting the project from a wide field of available topics. In terms of details of design, during the 2008-2009 iteration, the students created an excellent blade system from 100% junk parts and had a working support tower but failed to address a number of key design challenges, including provision for a braking system, a coherent transmission-generator set and a swivel for the top of the mast. This year's teams have been divided into three groups for initial design; one is working on a vertical axis machine, another is working on a horizontal axis blade and tower system and the third is working to create a universal electronic test stand that can be connected to the machines for the purpose of generating power. The teams are highly motivated and have made a careful study of the previous year's trials

and tribulations. This year, the teams intend to prototype their devices using purchased parts prior to hitting the dumps for found parts – this should help to better focus their efforts during the junk search.

Conclusion

Through the careful selection of student project topics, it is possible to motivate students to complete complex work as part of their capstone design projects. Three principals were presented to guide topic selection and an example project was presented. In truth, these principles are an extension or refinement of more generalized teaching practice and it is worth comparing them with the assertions of Chickering and Gamson, who maintain that good practice in undergraduate education:

1. Encourages contact between students and faculty,
2. Develops reciprocity and cooperation among students,
3. Encourages active learning,
4. Gives prompt feedback,
5. Emphasizes time on task,
6. Communicates high expectations, and
7. Respects diverse talents and ways of learning. [4]

These seven practices weave in nicely with the 3 principles for project-based learning, and the authors strongly encourage those contemplating new projects to compare the topics to these practices and principles and using them to "tune up" the topic prior to release. Properly applied, great things can come out of undergraduate projects, particularly in terms of student learning.

Bibliography

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[3] Lowman, *Mastering the Techniques of Teaching, 2nd Edition*, Jossey-Bass, 1995.

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