# The Design of Projects and Contests - the Rules of the Game

**Rolf Faste and Bernard Roth**

Dept. of Mechanical Engineering, Stanford University
Stanford. CA 94305-4021, USA
E-mail: ?????

[Received October 27. 1998; accepted November 25, 1998]

**This paper describes some of the ideas and guidelines the authors have developed for designing student projects in engineering design courses. In our teaching we use projects extensively, and have taught project-based courses at all levels. We find that in most courses we face the same basic issues on how to design and use projects to achieve our educational goals. This paper briefly outlines our philosophy and touches on the following basic topics: what is a project and why do we use them, how does one design a design project, what is the philosophy behind a project, issues in the use of design teams and deciding on project rules. In addition we briefly critique the concept of head-to-head contests.**

**Keywords:** Design projects, Design contents, Student teams, Creativity

## 1. Introduction

The authors teach in the Design Division of the Mechanical Engineering Department at Stanford University. We, along with all our colleagues in the Design Division, believe very strongly in project based learning. This paper describes some of the ideas and guidelines we have developed for designing projects for our students. Since we use projects extensively, we have experience with project-based courses at all levels from introductory undergraduate level courses to highly technical graduate programs. Although the goals of each course and the technical skills required may differ. there are basic issues which are common concerns in almost all cases. This paper outlines how we view and deal with these basic issues.

## 2. What is a Project and Why Use One?

A good project challenges students with a desired goal that may be satisfied in a variety of ways. We don't consider activities with one right answer to be projects. This also applies to projects having many possible approaches or answers, only one of which is acceptable to the instructor. A project should be open ended with exciting and unexpected possibilities, not a guessing game that converges on

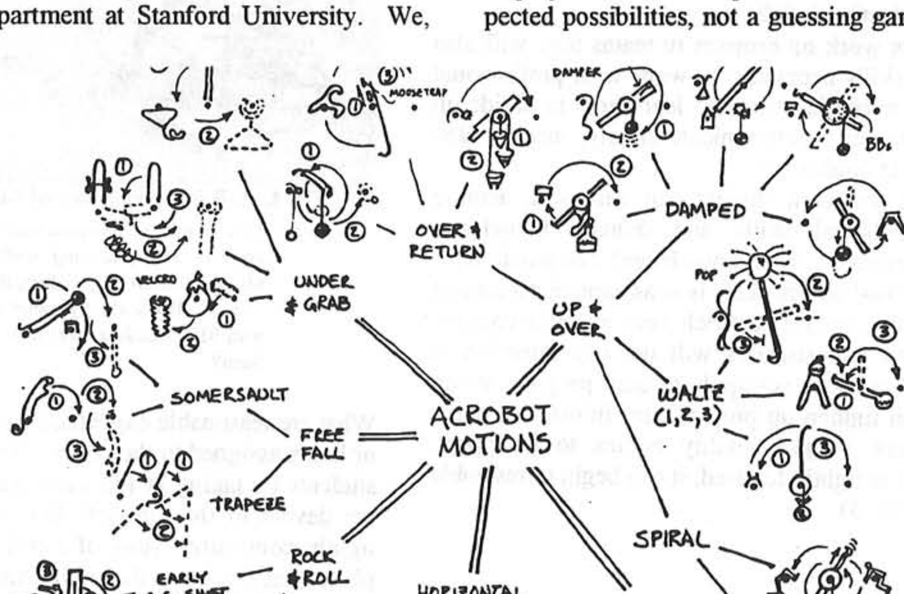


Fig. 1. ME 313 Ambidextrous Thinking (Prof. Paste).

**This idea nap shows the large number of solution approaches found by two-student teams on an open-ended problem. The assignments involved three parallel bars and a pair of "Acrobats." The task was to have the acrobats begin on bars one and two and, with each other's help, wind up on bar three. The large number of different yet successful solutions indicates a well designed assignment.**

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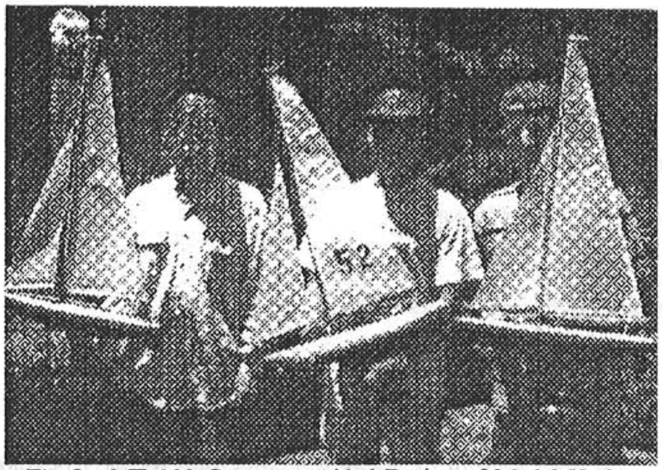

**Fig. 2.** ME 109 Computer Aided Design of Model Yachts (Prof. Faste).

**This challenging elective class requires the learning a huge knowledge and skill set: The technology of sailing: nomenclature, aerodynamics, hydrodynamics, vector math; Computers: MeSurf (a naval architecture program, Vellum (a drafting program), Lasercamm (for cutting plywood with a laser), Manufacturing skills: laying out, setting up, planking and fairing a hull, woodworking for the spars and details, fiber glassing, moldmaking and casting ballast, finishing with paint and varnish, sewing and making and braising brass fittings.**

one right answer (**Fig. 1**).

When a project (or design contest) is well designed, students learn the process of problem solving in the real-world and how to get a job done in a self-directed manner. Moreover they learn how to learn on their own, enhancing self-confidence and self-esteem. Students learn how to deal with failure and also how to overcome obstacles. They learn how to become unstuck. Much of this is what we call being creative and productive in life.

When students work on projects in teams they will also learn the social skills necessary to work with professional colleagues. For example, they will learn how to divide up work, set expectations, communicate clearly, mediate disputes and arrive at consensus.

In doing any project a student can, and will, acquire specific new technical skills and domain knowledge (**Fig. 2**). The question is, what knowledge? The single most common mistake instructors make is to assume that a project will be an effective means to teach very specific content. Experience shows that students will not pay attention to subject material that does not apply to their project. When steps are taken to tighten up project rules in order to teach a specific content, project vitality begins to disappear. When the project is tightly focused, it can begin to resemble a problem set (**Fig. 3**).

## 3. How to Design a Project

Before generating project and contest ideas it is necessary to have a clear idea of what we wish to accomplish. We ask ourselves: What are our primary educational goals? What are our secondary goals? Are the projects to be done by individuals or teams? If with teams, do we have some restrictions in mind with regard to team size and formation?

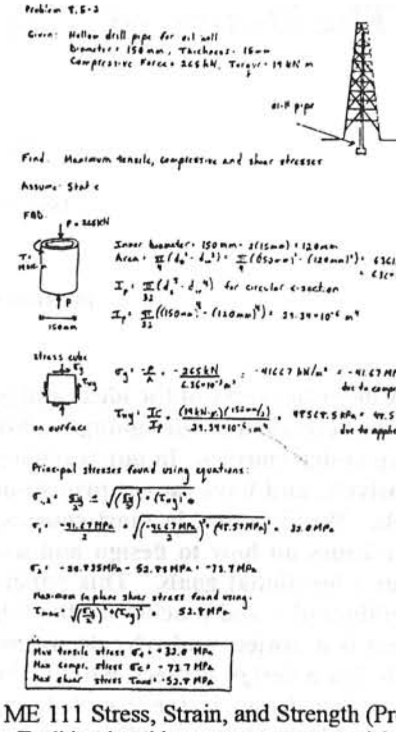

**Fig. 3.** ME 111 Stress, Strain, and Strength (Prof. Sheppard).

**Traditional problem sets generate one right answer.**

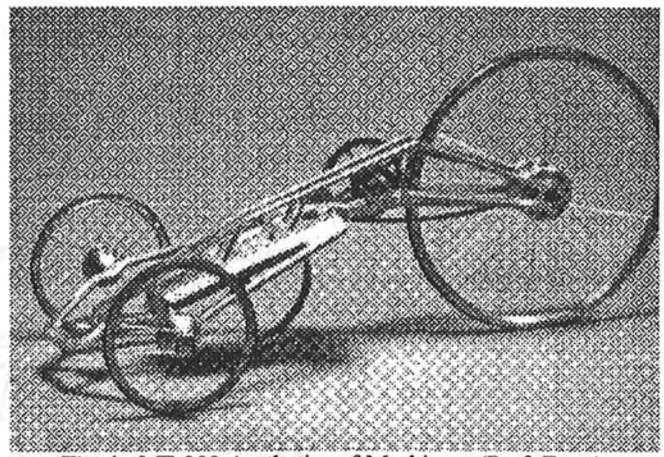

**Fig. 4.** ME 209 Aesthetics of Machinery (Prof. Faste).

**This mousetrap powered vehicle demonstrates a strong synthesis of engineering, aesthetics and craftsmanship. Machined from magnesium, this vehicle weighs 6 ounces. The perfectly round wire wheels are strung with 010" stainless steel wire. How did he manufacture them?**

What are reasonable expectations given the number of units or hours assigned to the course. What other classes will our students be taking at the same time? How much time can we devote to this project? Do we want a project that is tightly constrained (lots of rules) or unrestricted (few explicit rules)? What is the appropriate level of finish or craftsmanship? What concerns, like esthetics or manufacturing are included in the project, and what are exclude? (**Figure 4**) Are we planning to provide materials or will the students provide them?

When actually designing projects we use the same creative methods which we expect the students to use in solving them. We call this design process E.T.C., for Express, Test, Cycle. This basic design methodology is:

1) Generate of lots of ideas. (Express)

We use brainstorming and other idea generating techniques, such as idea-mapping, to generate concepts for projects. (see Figure 1) The quality of these ideas is enhanced by having everyone involved in teaching the course (instructors, teaching assistants, project coaches, etc.) help brainstorm these ideas.

2) Test solution candidates to see if they will work. (Test)

After brainstorming possible projects, we ask ourselves: what kind of solutions are the students likely to come up with? Is what the students would do during this project what we want them to learn? To answer these questions, we often generate our own preliminary solutions and rough mock ups.

3) Use test results to iterate design solutions. (Cycle)

We often find that our first ''great'' project ideas require extensive modification based on the unexpected results we get from the preliminary solutions we generate in Step 2. We continue to modify the project until we are satisfied that it meets our goals, and that it ''feels good.'' As instructors we never assign anything to our students that we would not be excited to work on ourselves.

## 4. Project Philosophy

We base many of our teaching practices on McLuhan's expression ''the medium is the message.'' All projects (and all teaching) have two aspects: content and form. Students learn as much from the form -}which is usually implicit -}as they do from the content which is explicit. When we assign projects, students learn to do what they are made to do. When we tell them what to do next, they learn how to follow instructions, not how to decide what needs to be done next. If we stage projects as contests where they compete against each other, students learn to be secretive, to spy and not to cooperate. Thus the way a project (or contest) is set up can encourage or discourage competition or cooperation; greed or generosity; hate or love; envy or admiration. Students are very impression-able and will learn the behavior required to survive in the situation we put them in. Given the same project (or contest), the structure and rules of the game can lead to many different educational outcomes. It is even possible to teach opposite lessons with the same project concept.

## 5. Teams

Placing students in teams is often the most economical way for teachers to deal with large class sizes and still offer project based experiences. Aside from such practical considerations for the institution, there are direct benefits to the individual student. They can learn to respect and value other peoples' styles and viewpoints. They can realize that learning does not require professors or other authority figures - they can indeed learn from their peers, and they too can teach others. These experiences are empowering and very useful in their later professional life as engineers.

There are two basic issues when creating teams. One is the size of the team and the other is how it is formed.

Teams may have 2, 3, 4, 5 or more members. Each size has resulting positive and negative attributes and tradeoffs. Two person teams cut the grading burden for the instructor in half (versus individual projects), and allow the students to have the experience of working with differing viewpoints. This is the easiest arrangement for students since every time the two people meet they can have a team meeting.

For three people, team meetings take more time to organize. Three person teams can split with two against one, or more often, one against two. Meetings are still harder to arrange with four person teams. On such teams it is possible for one member to do almost no work and be carried by the team. Teams of four also can split into two groups of two and fail to agree. There is no tie breaking vote.

Groups of five must arrange formal meeting times. It is mandatory for the instructor to provide in-class time to accomplish this scheduling. Providing actual working time in class is also a good idea. Some say that five should be the minimum team size if the instructor desires a diverse number of skills or personality types on each team. The chances are that differences between personality types will become bigger issues in five person groups than in smaller groups.

For teams with six or more, the students usually divide up the work and form sub-groups in order to avoid both.scheduling problems and time consuming meetings.

Finally, it is possible to group half a class or a whole class as single team, in which case sub-groups of various sizes will form in an organic way.

There are many ways to choose team members. Students left to their own tend to do it by friendships. This can work well on short projects, but often leads to serious problems on longer ones. Just because someone is a friend doesn't necessarily mean he or .she will be easy to work with. When problems do occur, they are often more difficult to solve. We have some colleagues who believe strongly in creating teams in very intentional ways. They use such factors as personality and thinking styles, geography, nationality, sex, age, experience and field of study to create diversity. Other colleagues use either random selection methods or methods based on shared interest in a particular project, or shared levels of commitment.

We find that a lot is gained by explicitly dealing with group formation and individual style issues in the context of a student' s actual group experience. When faculty members avoid dealing with the realities of interpersonal issues they lose much of the educational value of the experience. Worse, student groups that experience problems may think there is something wrong with themselves or their team members. They do not realize that interpersonal problems are natural by-products of people working together.

## 6. The Design of Rules

Every project needs good unambiguous rules, unless, of course, it is the instructor' s intention to have the students learn how to deal with ambiguous rules.

Rules need to be worded in such a way as to insure that, during the process of obtaining solutions, the students achieve the desired academic goals. In addition, the rules need to be designed so that there are a wide range of good

**Fig. 5.** ME 101 Visual Thinking (Prof. Faste).
We use current events as inspiration for projects, and also to ensure that projects are fresh and new. When a Japanese firm purchased the Pebble Beach golf course we created a project called 'Potential Putt Putt Possibilities' to design a new golfing spectator sport for Japan. Here a golfer is facing the Godzilla obstacle.

solutions.

The basic thing students are concerned with is how they will be graded. The rules should spell out a clear set of evaluation criteria. We find that simple rules are the best. It also helps if the rules are self checking, meaning that success or failure is visually obvious. Rules requiring elaborate measurements and testing to determine success are less satisfying, especially if the final event is public with cheering fans and spectators.

There are two types of rules we usually deal with: hard rules and spirit rules. An example of a hard rule is "The only energy source that can be used is one A size battery which will be installed into your project by the instructor at the time of presentation." An example of a soft rule is: "Please be aware of the safety of the team and the audience, avoid ballistic objects." Instructors should be careful to avoid creating rules they have no intention of enforcing. If, as in this example, no ballistic objects are allowed, there should be consequences for students who choose to violate this spirit rule.

Also in the spirit vein, there is the issue of creativity, or perhaps we should say,too much creativity, that takes the form of what we call a "lawyer' s solution." A lawyer's solution is one in which the creativity is verbal - something a lawyer might come up with by exploiting loop-holes in the rules, rather than true engineering creativity. Thus one of our rules is the "meta-rule": no lawyers' solutions. What we mean by this is that the students are expected to know what types of activities we expect them to engage in during the given course. Solutions need to satisfy both the letter and the spirit of the rules. At the same time we may accept an ingeniously creative solution which bends the rules provided it satisfies the spirit of the project.

Another reality of rules is that they must occasionally change as the project moves forward. We forewarn the students that this may happen, as it does in real life. We also make a point of sharing all rule clarifications with the

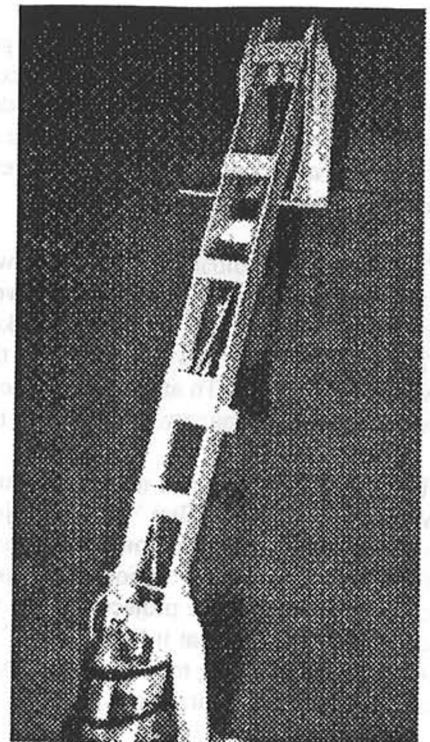

**Fig. 6.** ME 101 Visual Thinking (Prof. Faste).
This water powered device was created to transport itself between two table tops for a project called Lever's Leap, a play on the expression Lover's Leap. Projects that have snappy titles, perhaps with alliteration (as in Fig.5) or incorporating puns (as here), can capture the imagination and help create a playful exploratory mood. Another example was a project called "Der Derby Derby." This project required the construction of specialized racing hats that could pass balls great distances using only one's head.

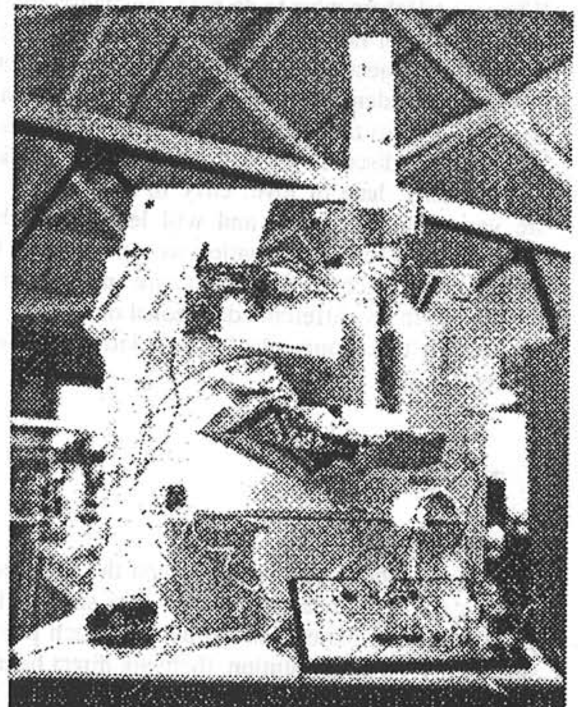

**Fig. 7.** ME 218 Smart Products (Prof. Carryer).
This crude mock up is a mid-project test for a device to sort coins. Because such prototypes are made exceedingly quickly out of foamcore and found materials, we often call then "crap ups."

**Fig. 8.** ME 210A Experiences in Team-Based Design (Prof. Leifer).

Bicycles made from paper and paper products are designed and raced every year in this course. Students have access to previous designs, and can decide to use non-paper components at the cost of incurring increased tine penalties.

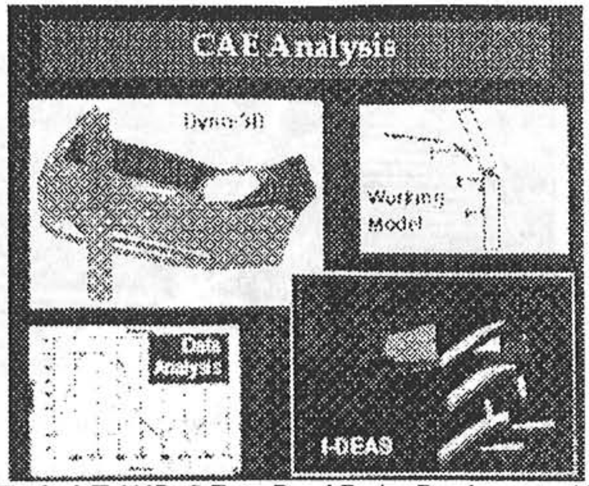


**Fig. 9.** ME 210B, C Team-Based Design Development with Corporate Partners (Prof. Leifer).

This project for Ford Motor Corporation is an example of a project assigned from industry.

entire class. All rules should ensure fairness, so that no one has an unfair advantage.

## 7. Project Attributes and Considerations

We find that student enthusiasm and acceptance is enhanced when we use a project theme and title that the students think is "cool." We often make up a story for the context of the project. Again, "cool" goes a long way. Current events in sports, politics or science make rich sources of inspiration for these ideas (**Figs. 5** and **6**).

Students will always let things go for the last minute, and will yield to where they are pressured most. A series of intermediate deadlines and checkpoints can help the students maintain effort. Mid-way presentations are good times for students to share ideas, give each other valuable and constructive critiques, and test ideas to see if they will really work (**Fig. 7**).

Testing models and prototypes is crucial in the learning and solution process. Intermediate deadlines ensure that ideas get tested with hardware. We find that iteration is a very valuable experience, and, where time permits, we build this into the project experience. Iteration is one of the least used tools in education, yet it is of prime importance as a learning vehicle.

To apply iteration in project learning one can insist that students redevelop their ideas several times before making their final presentation.Alternatively, we have at times made the problem statement and rules for a project identical to a previous project the same students have "completed." We have one colleague who repeats the same project each year. He makes all the previous solutions available to the new students and expects that they will improve and surpass the previous results (**Fig. 8**).

However, in general, we do not repeat projects. Instructors are a role model for learning and professional behavior. If we wish students to be creative, the instructor must be creative in making the assignment. If we wish the students to take risks then the instructors must take risks. One fundamental way to do this is to never repeat project. In this way the instructors will not know all the answers and expected solutions, and will also be more open to the students' ideas and concerns.

## 8. Project Origination

Projects can come from three basic sources. First, projects may be provided by industrial sponsors. In this case, the main concerns are to obtain projects of appropriate size and the freedom for the students to redefine the project, so they can work toward solving the real problem. Industrial sponsors have a strong tendency to state problems in ways that define a favored solution. Agreeing to project definitions can be a challenge (**Fig. 9**).

The second source is the instructor him or herself. Most of what we have been discussing assumes the teacher is the source.

Third, the students may generate their own project statements. As may be imagined, self generated projects tend to create the most enthusiasm on the part of the student. Philosophically, self generated projects are attractive. Projects are assigned by leaders. If you want your students to become leaders, it follows that they will have to learn how to generate worthwhile assignments. The first author teaches a quarter long class, nicknamed "Need finding," that challenges the students to find projects which they will be willing to commit to the following term. Committing to a self-assigned project can be as difficult as thinking it up in the first place (**Fig. 10**).

## 9. Contests or Projects?

One common way to generate excitement for projects is to have them be contests. While this is often an easy way to generate student involvement, it can also be very destructive and teach what we feel are bad lessons. This is particularly true for the sports model which has a winner and a loser at each stage, resulting ultimately in a single champion. We feel that such zero sum games are not good educational tools and that design projects should avoid head-to-head

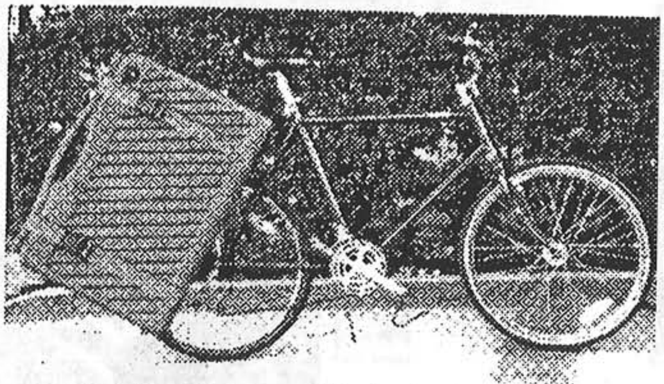

**Fig. 10.** ME 116C Advanced Product Design-Senior Project (Hoyle, Burnett).

This award winning portfolio case for bicycles is an example of a student initiated quarter long project. Stanford's product design program ends with a two course sequence. First cones a quarter long course in needfinding (Prof. Faste) during which students are expected to find a need for their final project. Many of these projects are patented and commercialized.

**Fig. 11.** ME 218 Smart Product Design (Prof. Carryer).

Stanford projects tend to end with final presentations that are best described as celebrations. Here the mechatronics class of Masters students is seen enjoying the launching of an autonomous vehicle which collects golf balls.

(perhaps in Japan we should say belly-to-belly) competitions. The motivation behind such contests is to beat someone else. Particularly offensive are "mechanical gladiator" projects aimed at literally destroying or disabling another' s work. Does this teach how to use engineering for the good of mankind? We think not. Engineering isn't athletic competition. Engineering is a social activity requiring friendship and teamwork.

When projects are set up so that students compete against themselves, in order to do their personal best and do not compete against their classmates, the results are far more healthy. There is a good chance students will share ideas, learn from each other and use each other as resources.

Projects can be exciting to watch and just as engaging as head-to-head contests. We prefer the concept of design festivals, rather than contests. In a festival there is the spirit of cooperation, entertainment and joy. Everyone has the chance to go away feeling good (**Fig. 11**). In a contest there are few winners and many losers.

## 10. No Right Answer

Projects resemble life. They are complicated and unpredictable. There is no one right way to organize them. There is no one best set of rules, and not everything works out even when all the proper things are taken into account. Projects can be magnificent or banal in their outcome. It is precisely this variability that make projects a great tool in preparing students for a productive and creative life in th face of uncertainty and change.

## 11. Conclusion

In this paper we have raised many issues we feel are important to consider when using projects as educational tools. If there is one message that we would stress, it is that in designing projects, instructors need to apply and model exactly the same techniques and frameworks that they expect their students to use. When instructors are creating and supervising projects, they themselves are actively engaged in the process of creative problem solving and design.