The use of Design Contests to increase the student's Motivation

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Abstract

The use of Design Contests has becoming more and more frequent in Engineering Courses and even in High School level students, as one of the most effective tools in Design disciplines. Most of the Engineering Education researchers agree that the use of this kind of "hands-on" contest can improve many important skills, for a future engineer, like creativity, reality modeling, team work, leadership and communication, while student course motivation raise to non negligible levels. Negative side effects of this kind of Contest can be observed too, like the lost of motivation of the "losing teams" and the change of team focus from "winning the contest" by an well designed and built "machine" to an "winning by the contest rules", where the engineering aspects are in a second plane so, be the "winning team" is everything that really matters.

In its first part this paper describes some of the most important aspects of the Design Contest, related with most common undergraduate student Contests. The second part shows the results of a 3 years study, using a 350 student total sample, made with a 10 questions poll and the analysis of student academic performance after Design Contest participation. The data analysis shows clearly that the benefits of the use of Design Contest over take the eventual negative side effects and points into the direction of increasing this kind of educational resource, even in high school and graduate level students.

1. The Basic Structure of a Design and Prototype Contest

The intent of this paper is not to fully cover such a vast subject, nor is it to formulate concepts that apply to such a wide variety of engineering courses, but to relate the author's experience during the last 20 years and to contribute to the improvement of Mechanical design teaching.

A common saying in engineering schools is: "you learn how to design by...designing". In its simplicity, this saying summarizes the idea that, in order to develop and increase a student's capacity in designing he must faces a typical design task. This task, also referred to as a "hands-on" activity, is a possibility for the student to be involved in some of the main stages [4] [6] [12] of a project, like for example:

- The establishment of the need - that is mostly explained in the definition of the project, but which must be detailed and analyzed deeply so that the design team may clearly establish the line of thought to be adopted.
- Identification of parameters /Technical Specifications - in this stage the fundamental parameters, that each proposed solution must accomplish, are established and and according to them the proposed solutions will be evaluated in the choosing step.
- Creating solutions for the propotype and Contest strategies.
- Choosing the best solution.
- Modeling and simulating.
- Sensibility analysis - which allows greater understanding of the system's responses, identifying the critical parameters of the design, verifying and indicating the limitations/restrictions and quantitatively estimating the performance of the design.
- Formal Optimization
- Development of the Executive Project and Manufacturing Processes
- Prototype Building
- Prototype Testing

- Analyzing the results/Redesign

If on the one hand the concept of “learning how to design by designing” [10] seems rather simple, putting it in practice is not. How can we reproduce the complexity of a real life project in an academic environment, while respecting the curriculum of the school and consequent material and human resource limitation, inherent to any educational institution, without harming the essence of the idea?
In addition, after having answered the previous question, another one immediately appears: “How can the design and project activity be evaluated? Traditional methods of evaluation, in its limitations, are almost totally focused on and specialized in the evaluation of the analytical capabilities [1] [2] of the students, where in most cases: “there is just one correct answer for each problem” and therefore, the concept of “right x wrong” prevails. Would this maniqueist concept be applicable to a project? Let’s imagine a typical engineering project: “Develop a compact urban vehicle, with space for up to 4 passengers and luggage”. The answer to this is in our streets in showing innumerous car models manufactured by several different companies. Who, in the academic environment or not, could define which of these projects/cars is right and which is wrong?
Evidently, although the concept of right or wrong does not apply to projects, the concept of better and worse does. It is necessary to establish the criteria for evaluation methods that reproduce, in a way, the evaluation that society applies to real projects, taking into consideration some examples of successful projects and others of failure, with all other possible situations in-between.

1.1. Contest Parameters

Working for over 16 years in this specific area has shown that some parameters are of great importance for the establishment, in academic terms, of a project procedure that reproduces the conditions of real professional life with reasonable similarity. These are some of them:

1.1.1. Suggesting broad project themes with a certain degree of innovation

Suggesting broad themes assures the increase of possible solutions and stimulates the creation capacity and creativity of the students. Instead of proposing a theme like: “design and build a conveyor belt that takes objects from point A to point B in 5 seconds” it would be wiser to use a theme like: “design and build a device capable of transporting objects from point A to point B in the least possible amount of time”. It is important to notice that in the second example, there is a much wider variety of possible solution and consequently, of possible projects.
Innovation is important in order to avoid that the students simply try to adapt an existing project to the theme. Although detailed analysis of similar projects must be stimulated, the students must have the chance to create something new, using their technical, theoretical and practical knowledge.

1.1.2. Breaking paradigms

One of the main tools for stimulating creative thinking is presuming that everything that exists or that was designed can be made better. This also decreases the tendency of the designer to assume fictitious restrictions to the project. These restrictions are parameters that the designer assumes, many times without noticing, that limit the potential for innovation and creativity. For example, in the theme mentioned earlier - “Designing a compact urban vehicle, with space for up to 4 passengers and luggage”- many designers could assume that the project would involve an internal combustion, Otto cycle, or Diesel engine. In the end, these might be the best options; however, they should only be adopted after evaluation of other possible options and not as initial assumptions just because they are the most used nowadays.

1.1.3. Establishing restrictions

While in a real project the restrictions are a natural result of technical, economic and social conditions, in the academic environment they should be planned carefully, in a way to simulate in the best possible manner the professional environment. At the same time, these restrictions are a way to ensure the viability of the project, be it in terms of deadlines or in terms of necessary resources, besides that, fulfilling these restrictions also demands greater creative and innovative effort by the designing team.
There usually is a natural resistance to accept restrictions, which are often seen as something negative, and students

normally react in the same manner. If, for example, the kind of energy to be used in a project is specified beforehand, students will often question why other kinds of energy cannot be used.

Contrary to what many beginning designers think, the existence of restrictions is far from simply being an obstacle to be overcome, it is also an important guide and driver for the project. Without restrictions, the number of possible solutions would be so great that the definition of a final solution would be practically impossible. Just imagine the amount of time spent by a student design team just to analyze all possible "energetic solutions" before deciding which one to use in the project.

The most important restrictions [4] [5] to be established are:

- Time – Includes the deadlines for the completion and evaluation of each stage of the Project.
- Energy – This restriction defines the type of energy/power that may be used, its form and eventually quantity. It is also interesting to define if the type of energy/power specified may be transformed to another one.
- Dimensions – Maximum and minimum mass, dimensions and tolerances that the prototypes may have in the environment that they will be put to use.
- Material – Quantity and types of material that may be used in building the prototype must be defined. Besides ensuring a reasonable amount of resource needed, the standardization of material resource requires greater creative use of resources, even in finding new ways to use them.
- Actuators/Motors – The two most used options are: Total standardization of the actuators/motors, with the same types and quantity for every team, or the specifying only the type and quantity of energy (power) supplied to each prototype. The second choice allows the team to decide the type and quantity.

1.1.4. Teamwork

Teamwork is imposed for several reasons. The first reason is the possibility of substantially increasing the potential for innovative ideas and opportunity of more critical analysis of each of these ideas. Secondly, the development of communication, interpersonal and understanding skills of a future engineer are imperative and can be achieved by the interaction of the students with their peers. Another very positive side effect of this interaction is a mutual learning process. A third reason, among many other reasons, is that teamwork requires the ability to coordinate work, distribute tasks and other fundamental responsibilities of the professional workplace. These concepts have, in fact, been the basis for one of the most traditional Design and Prototype contests of engineering students, the International Design Contest- IDC – ROBOCON, where the author as been a member of the academic committee since 1993. In IDC teams are formed with students from each of the participating universities, all from different countries

1.1.5. Analysis of the results and redesign

Although the ideal situation involves a continuous process where projects can be improved after each test or contest, the academic schedule restrictions result in the fact that this type of activity could happen in only one or two classes. In such cases, it is recommended that, as soon as the evaluation stage/contest is finished, a deep analysis of the results be conducted where the causes for success and failure can be identified and understood, in an activity known as "learning by failure" . It is also important to stimulate the discussion of possible changes to each project among the participants. Audio-visual material from the contest is an important support tool for attaining good results.

The basic concepts described above, so far for the use of design and prototype contests in teaching, were put to use by the author in classes of the first four semesters of Electrical, Mechanical, Mechatronic and Naval Engineering course.

2. Some Concerns related to Design Contests

The use of Design and Prototype Contests as a teaching resource in the first or second year of the Engineering course must be preceded by some careful considerations since, in most schools, the majority of classes for these students are those related to their basic development, such as Physics and Calculus. Therefore, special attention to some important parameters is recommended in order to successfully structure these competitions.

2.1. Little previous knowledge of the concepts of Mechanical Design required

Most first-year engineering students in Brazil have a strong background in basic sciences (Mathematics, Physics, Chemistry, Biology etc). On the other hand, these students usually have little practical experience with the application of these disciplines in technology, more specifically, in Mechanical Design. Another important aspect to be considered is the great cultural influence of the "digital world" on teenagers. In most cases, teenagers feel very comfortable in virtual environments and realities, but have a lot of difficulties in modeling their ideas and turning them into something material and real. The professor must resist the idea that, because of this scenario, the students' education in high school nowadays is worse than in years before or less adequate to future engineers. It is important to understand that new students have a new set of aptitudes and abilities and that these skills are in a state of constant change and evolution throughout the years.

The challenge that presents itself to the professor is to understand these changes and look for ways to take advantage of these aptitudes while stimulating the student to learn all other abilities that are fundamental to the development of a first class engineer. Hence, the challenge is to find ways of complementing and developing these design aptitudes and abilities.

2.2. Linking the theme to the students' reality

The definition of a competition theme and title plays an important role in the motivation [8] of the students to participate in and win such a contest. As shown further ahead, in the analysis of the results of the conducted research, although linking the competition to a specific class and attributing grades are important factors to the success of such educational activity, most of the effort put forth by the students to succeed is due to the fact that they are stimulated by the possibility that they will design and build a prototype that will be able to execute the proposed tasks and, secondly, to compete and show a better project than those of their peers.

In order to clarify the definition of this parameter, the following example can be given: Suppose the competition involves building a structure and evaluating the maximum load that can be carried to this structure. One could easily tell the students that they will have to design and build a structure, which will be subject to a load and that a dynamometer will be placed to measure the maximum load before the structure breaks.

Another way of suggesting this idea is telling the students that they must design and build a prototype, in reduced scale, of a bridge and that its load capacity will be measured by a passing vehicle with increasing loads that will test the bridge until its failure.

In the first case, the student will be faced with a task of building a structure that has little or no significance to him/her in terms of real use in a real project. In the second case, the connection to the real world is immediate and the student has certainly seen or used a bridge in his day-to-day life.

2.3. Establishing continuous success indicators

How to define the success of a design/prototype project is critical to avoid situations where a continuous performance grade from worst to best result cannot be attributed. To clarify this concept, the following example can be given, showing the opposite of the proposed grade attribution: Suppose the competition requires to build a prototype that has the task of, in one minute, carry the maximum possible load from one point to another while overcoming an obstacle in its course. The grade attribution would take into consideration the net weight the prototypes are able to carry to the end point.

In this scenario, many prototypes would definitely be able to carry reasonable amount of weight but would not be able to overcome the obstacle in its course and therefore would not complete the objective of the competition. In this case, there would be many prototypes that could carry more weight with the same grade attribution as others with less load capacity, simply because they all could not complete the objective of the competition, because of the obstacle. Such situation has serious consequences pertaining to the motivation of the students for future similar activities, since there was no continuous grade attribution that would allow the evaluation of the project from the winner to the ones with lower performance.

Although competitions involve one winner and n-1 "losers", it is necessary to minimize this effect through the establishment of evaluation aspects that are not binary but are continuous from best to worst.

2.4. Establishing evaluation criteria besides the Competition results

Although it is important to emphasize the concept that an engineering project shows its real performance in its field test, and even more so when compared to other similar projects, the results of a competition can many times be influenced by imponderable or even random factors. The future engineer must obviously be ready to handle such situation that will happen in real life in an even more dramatic manner.

The idea is not to create an ideal environment where such factors cannot interfere with the results, but to reduce the consequences related to the frustration, self-image and motivation of the students, taking into consideration that we are dealing with youth in technical, ethical and personal development [9] [11]. What is the best way to react to a situation where prototype A, which is much better designed and built, with brilliant performance in tests, is disqualified by prototype B, which is clearly inferior, for example, because of a simple electrical malfunction? Even if it were clear that if there were a rematch, A would be the winner, it would be unethical and not fair to cancel the results and establish a rematch. After all, the fact is that B proved to be more reliable than A and won.

One way to minimize this effect is to consider other aspects of evaluation for the projects besides the competition results, like for example, having the professors evaluating creativity, quality of the prototype, performance in tests etc. Adopting a conceptual evaluation of the project [3], in addition to the contest results, is important in order to avoid a situation where the result of the contest is the only evaluation parameter.

3. Academic Impacts of the Design Contest

In order to quantify the impacts resulting from the use of a Design Contest in the Engineering student's academic life, a 10 general question poll was applied, in a total period of three years, resulting in 350 student sample responses. Table 1 shows the questions directly involved with the design, prototype manufacturing and contest activities.

Table 1 – Poll Questions

Question	Content	Answer Options
1	Had you ever designed and built some mechanism, toy or mechanical device before joining the Engineering course?	YES NO
2	On receiving the Contest Rules, what was your expectation of achieving the proposed goal?	100% 75% 50% 25% 0%
3	How many weekly hours, on average, you do spent working on the project?	____ hours
4	In your opinion the final result of the competition was fair?	YES NO
5	In your opinion have you improved you design/manufacturing skills after the Contest?	YES, a lot YES, a little NO, they're still the same NO, they decreased
6	Suppose that you could participate again in the same Contest. Would you change your project?	YES, a lot YES, a little NO, it would be still the same
7	Would you like to have more contests, like this, during the course?	YES NO INDIFFERENT

Table 2 shows the percentage obtained in each of the Table 1 questions, considering only the valid the answers and Fig. 1, Fig. 2 and Fig. 3 show the same results in a chart representation.

Table 2 – Poll Answers Percentage Results – Integer values

Question	**Answers**	**Percentage**
1	YES NO	23% 71%
2	100% 75% 50% 25% 0%	7% 21% 43% 19% 10%
3	____ hours/week	8,7 (average)
4	YES NO	65% 35%
5	YES, a lot YES, a little NO, they're still the same NO, they decreased	71% 18% 8% 3%
6	YES, a lot YES, a little NO, it would be still the same	43% 30% 27%
7	YES NO INDIFFERENT	70% 16% 14%

Fig. 1. Expectation of achieving the Contest goal.

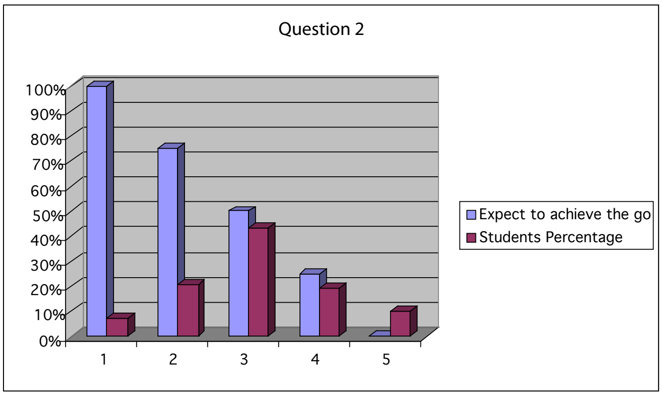


Fig. 2. Improved design/manufacturing skills after the Contest

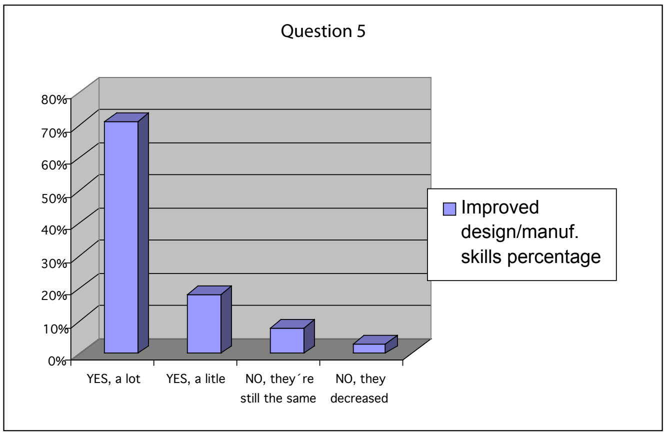
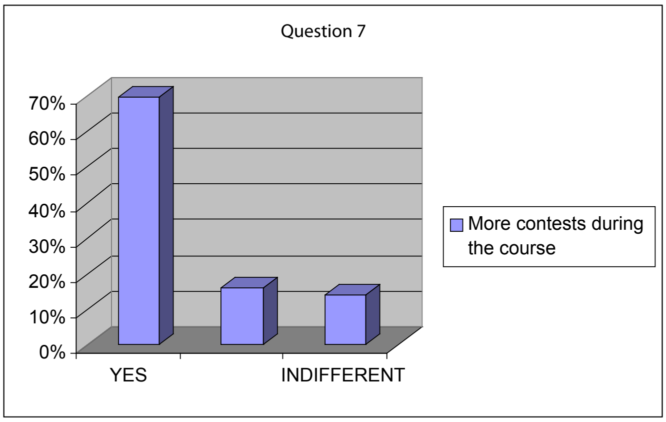


Fig. 3. Students that wish more Contest during the Engineering course.



3.1. Data Analysis

Of course the objective of this section in not to perform a deep statistics analyses of the poll results but try to understand what are the most representative and effective impacts of a Design Contest, on the academic student's life. These are some conclusion from the poll results:

- Just very few students have some "design and prototyping" previous experience.
- It seems to be clear that there is a non-neglecting gain in student self-confidence if we link the answers to questions 2 and 5.
- Considering that the average credits of the design discipline evaluated were 4 (classroom hours per week), student's efforts related with the Contest tasks was outstanding. Probably, this behavior is due the motivational potential of the Contest itself.
- Even dealing with the frustration problem of the "n-1 losers", the final balance of the Contest is very positive, considering the results of questions 4, 6 and 7.

4. Conclusion

Even though the use of Design Contests has becoming very frequent in Engineering Courses, special attention to some important parameters is recommended in order to successfully structure these competitions. Student previous skills, non-frustrating actions, self-confidence improvement and ethical behavior are some of the aspects that must be focused by the discipline professor.

The results of the poll questions and the results analysis shows clearly that the benefits of the use of Design Contest over take the eventual negative side effects, pointing into the direction of keeping and improving this educational activity as one of the most effective learning resources in Mechanical Design disciplines. On the other hand, considering the lack of previous design skills of the students that participate in this study, it seems to be correct extrapolate the results and recommend the use of this activity in any discipline related you a broad view of Design and Product development.

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