

AC 2010-1144: INTRODUCING ENGINEERING DESIGN USING IMPROMPTU DESIGN PROJECTS

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Introducing Engineering Design Using Impromptu Design Projects

Abstract

In this paper, the use of impromptu design as a tool for introducing the engineering design process is discussed. In a typical impromptu design exercise, a simple design problem, capable of being completed in a short amount of time, is solved by teams of engineering students. In solving the design task, the students organically progress through the engineering design process. This provides a unique opportunity to introduce beginning engineering students to the design process and to reinforce engineering design concepts for more senior students. This paper focuses on the development of impromptu design projects, the use of this activity to introduce the engineering design process, and thoughts and observations gained over three years of using this exercise in freshman and sophomore engineering design classes.

1 Introduction

Impromptu design exercises (often presented as contests) are commonly used as ice-breakers at engineering student gatherings. If properly utilized, these exercises can also be used to introduce the engineering design process. Specifically, in the course of completing the exercise, student teams organically progress through the design process (even without prior knowledge of the design process). This gives them the opportunity to gain critical insights into different design process steps. This paper focuses on impromptu design project development, the use of this activity to introduce the engineering design process and to enrich more advanced design education, and author thoughts and observations.

In a typical impromptu design exercise, students are given a simple design task capable of being completed in a short amount of time, for example one class period. The student team approaches the problem as they best see fit – this may include trial and error, design-build-test-redesign, and any number of different approaches. When complete, the designs are tested to determine a “winner” based on some predetermined metric. To use these exercises as a design education tool, guided discussions are used to construct a model of the engineering design process based on the student impromptu design experience. This model can then be compared to and reinforced by standard models of the engineering design process^{1,2}.

In a university course setting, impromptu design activities are often used as ice-breakers³⁻⁵. In addition, there has been some research on these design exercises with a focus on their ability to foster creative thinking and team building³. The novelty of the present paper is its focus on harnessing the impromptu design competition as an explicit design education tool.

For the past three years the author has used impromptu design exercises to introduce the engineering design process to freshman and sophomore level mechanical engineering students. This experience has yielded a number of insights, including: 1) that this exercise is fun and engaging, making the introduction to design enjoyable for the students – provided the problem is set up correctly and 2) the exercise facilitates detailed discussion of the engineering design process because the students are able to build on their hands-on impromptu design experience.

2 Impromptu Design Exercises

At the beginning of the impromptu design exercise, participants are asked to form small groups. Each group is given a bag of construction materials. Then, the design problem is posed and the students approach the problem as they see fit. In the following, an example impromptu design problem is presented and elements of a good problem are discussed.

2.1 Example Impromptu Design Problem

The following impromptu design problem has been used with over 100 freshman and sophomore level design students at both Seattle University and Villanova University. It should be noted that this project was originally adapted from an American Society of Mechanical Engineers (ASME) website which is no longer available and is thus, not provided as a reference.

Problem Statement: The general premise of the following impromptu design project is to design and build a truss structure using marshmallows and straws. For example, at Seattle University, the students were given the following problem statement:

Need Statement: Street Performers in rain-prone areas (e.g. Pike Place Market in Seattle, WA) need a way to keep their tip cups off the ground.

Problem: Design a tip cup holding device from straws and marshmallows.

Scoring Metric: Distance from the bottom of the cup to the bottom of the truss structure in inches (h) multiplied by the number of pennies the cup can hold (N), i.e.

$$\text{Score} = h * N.$$

Materials: The supplies given to the students were a plastic Ziploc bag containing 20 straws, 10 marshmallows, a roll of pennies and a Styrofoam cup. In addition to these supplies, scissors and additional pennies were available at the front of the room.

Project Time: The amount of time the students have available to them is flexible and depends on the setting – for example in-class projects must be completed with time left for reflection.

Instructor's Role: In general, the instructor's role in impromptu design contests is to give the problem statement, hand out the materials, and then step back and let the students design and build. The only other instructor responsibilities are to clarify rules (for example, in the design contest described above, students tend to ask if they can incorporate the Ziploc bag into their design) and to make sure the students are aware of time constraints.

Project Variations: The author has used many different variations of the presented projects. For example at Villanova University, the students designed marshmallow and straw bridges to help Charlie the Unicorn escape Candy Mountain (this references a YouTube viral video). There are

also a number of impromptu design ideas on the internet (Note that this information is not consolidated, so a bit of searching is required). Also, there is another example in Reference 3.

2.2 Elements of a Good Design Problem

The author has had a great deal of experience with impromptu design contests, both as an instructor and a participant. The following key ideas tend to lead to successful contests:

- 1) Keep the problem simple.
- 2) Carefully choose supplied materials.
- 3) Make the needs statement interesting.
- 4) Don't give too much information in the problem statement.

Keep the problem simple: The goal of impromptu design exercises is not to test the students, but rather to give the students a hands-on experience with the design process. Thus, a simple problem is of great importance, as it increases student understanding of the problem, limits student frustration, and increases the variation in student solutions. It should be noted that simple problems may lead to complicated solutions. For example, in the marshmallow and straw truss problem, students have delivered a number of interesting solution variations such as using the marshmallows as glue (the marshmallows are kneaded until they form a sticky paste).

In contrast, the author personally participated in a contest that was too complicated. The problem was to design a tele-operation device for a nuclear power plant – the end device was supposed to manipulate tennis balls on a table while the operator was seated in a chair 10 feet away. This project proved to be far too complicated and not one team succeeded – another key issue that made this project difficult is also discussed below in the section on choosing supplied materials.

Carefully choose supplied materials: Intimately related to keeping the problem simple, is to choose the supplied materials with care. Marshmallows and straws are easy to manipulate, allowing the student design ideas to come through. In contrast, with the poorly designed tele-operation exercise (from above), the supplied materials were not well thought through. The organizers supplied a random assortment of office supplies that were incapable of yielding a solution to the problem – this compounded project difficulty and student frustration. It should also be noted that simple problems can have poorly chosen supplies. For example, if instead of marshmallows and straws, paperclips and tape were supplied, the problem could be frustrating.

Make the needs statement interesting: The needs statement should engage the students. The above needs statement, given in the example marshmallow and straw truss problem, was given to freshmen students at Seattle University. Freshmen students have inevitably visited Pike Place Market and seen the street performers, as it is one of the major tourist attractions in Seattle. This gives them some context in which to design their tip-cup holder. This problem statement can be modified to include a reference from a popular television show, YouTube video, or a current event.

Don't give too much information: Although this may seem obvious, do not give the students too much information regarding the task – just the basics. Too much information will stifle their

creativity. Also, if there is missing information, the students will be more than happy to point this out. In addition to not giving too much information in the problem statement, it is advisable to not guide the students while they are designing and building their designs.

3 Using Impromptu Design to Introduce the Engineering Design Process

The use of impromptu design exercises to introduce the engineering design process has been used over the past three years by the author in classes at both Seattle University (MEGR181 – Innovative Design) and Villanova University (ME2505 – Mechanical Engineering Analysis and Design). The details of this design introduction, followed by some thoughts about further leveraging impromptu design contests are discussed below.

3.1 Impromptu Design as a Design Education Tool

Impromptu design contests, as described in section 2, provide a fun exercise that facilitates team building and creative thinking. With some guided discussions, these contests can be extended to provide an excellent introduction to the engineering design process. The content of this guided discussing is presented below.

Following the impromptu design contest, students are asked,

“What steps did you follow as you built your ... (truss structure for example)?”

Students are given time to reflect on this question both individually and in groups. Each group is then asked to make a list of steps it followed when solving the design problem. In doing this, they are developing a model of the engineering design process they followed. Finally, the student teams are asked to share their individual design models with the class.

Some example design models that may result from this exercise are shown below.

<u>Example 1</u>	<u>Example 2</u>	<u>Example 3</u>
Draw out a design	Build	Look at materials
Build design	Test	Brainstorm
Test design		Choose an idea
Modify the design		Build

The given examples all contain steps of the engineering design process. For example, one model for the engineering design process uses the steps¹:

- Recognize the Need
- Define the Problem
- Plan
- Gather Information
- Conceptualize Different Ideas

- Evaluate the Alternatives
- Select the Preferred Alternative
- Implement the Selected Design.

As can be seen, the student design models appear in the textbook engineering design process model shown above. It is noted that information regarding the first two steps of the textbook model was provided in the problem statement and thus does not typically appear in the lists.

In the author’s experience, the correlation between the steps of the engineering design process and the student design models will inevitably manifest itself, even when the students have no background in engineering design. This stems from the fact that the theoretical engineering design process is simply a model of the way engineers approach a problem. This exercise gives students insight into the logical basis for models of the engineering design process and gives them hands-on experience with the design process that can be further leveraged in future discussions of the design process (see section 3.2 below). In addition, the emergence of different and successful design approaches mimics the flexibility of the design process, i.e. the steps don’t have to be completed in a specified order.

When the discussion about the different design approaches is complete, a short lecture about different models of the design process can be used to help solidify the impromptu design’s introduction to the design process. This lecture should make broad use of the given engineering design project. For example lecture content, please feel free to contact the author.

3.2 Further Leveraging the Impromptu Design Contest

The impromptu design experience can be further leveraged to help solidify other design concepts. For example, when discussing the design process step “Define the Problem,” the impromptu design problem can be revisited. From the example design problem in section 2.1, students can develop a problem definition, for example:

Goal: Build a device that keeps a tip-cup off the ground

Objectives: Design an inexpensive tip-cup holder capable of keeping the cup from being washed away by rain in a typical winter rain storm. The holder should elevate the cup as high as possible and be able to hold as many pennies as possible.

Constraints: The tip-cup holder must be made from less than 10 marshmallows and 20 straws. The tip cup should be a Styrofoam coffee cup.

Leveraging the impromptu design in this way has proven very effective because the students already have an intimate understanding of the design problem, making it easy to extend the problem beyond the relatively simple initial problem statement.

4 Observations and Evaluation

Evaluation of the use of impromptu design exercises as design education tools is in its preliminary stages. Below, some general instructor observations are presented followed by some preliminary student reaction to the exercises.

4.1 Instructor Observations

For the past three years the author has used impromptu design exercises to introduce the engineering design process to freshman and sophomore level mechanical engineering students. In this time, it has become clear that the students truly enjoy the activity. Out of more than 100 students who have taken part in this exercise, no more than 5% have seemed disinterested, supporting the thought that this exercise is very engaging. In addition, the use of the impromptu design exercise as a repeated example throughout the class has proven to facilitate great in-class discussions, supporting the thought that the exercise can be leveraged in the discussion of more advanced design topics.

4.2 Student Reaction

Student reaction to the use of impromptu design projects as engineering design tools was assessed using a short open answer questionnaire (see attached). This questionnaire was given to 45 students in the Fall of 2009 after the impromptu design project was completed – data is not available for the other courses in which this exercise has been used. It is important to note that this questionnaire was extremely preliminary and a more complete assessment is being planned for future classes.

The primary question this survey focused on was whether or not the students understood the point of the exercise – it should be noted that the impromptu design exercise was not explicitly introduced as an introduction to design, but just given to the students without any context.

This was addressed by asking the students to respond to the question:

“What was the point (educational objective) of the marshmallow bridge exercise?”

Note that the project presented in section 2.1 was modified to have students build a bridge.

71% of the class identified “introduction to design” in their responses – this is a bit low, which seems to support the author’s worry that the point of the exercise might be lost in the fun. In future iterations of this exercise a more specific introduction to the impromptu design exercise will be provided. It is also interesting to note that, although not mentioned by the instructor, students identified “ice-breaker” (33%) and “team-building” (42%) as purposes for the exercise, which supports previous work on impromptu design projects³.

The second question asked about the effectiveness of the project in achieving the perceived goal. Students were overwhelming positive – 100% felt the goal was achieved. It is important to note that not all students understood the goal of the experiment, so this number may be misleading.

Finally, students were asked “What did you learn from the exercise?” Some comments from students who identified introduction to design as a goal were:

“It served as a good introduction to the design process.”

“It was a great way to begin the class and helped show that people already follow a general design process...”

“Definitely something I never saw before...”

4.3 Test Results

It has been observed, from student performance on exams, that they do learn the design process from the activity. In Fall 2009 students scored very high on the exam regarding the design process (8.2/9 average). This seems to imply that the learning objective is being met.

5 Conclusions

In this paper, the use of impromptu design contests as a tool for teaching design is discussed. It is noted that impromptu design contests are commonly used as ice-breakers and team building exercises. In this paper, impromptu design exercises were extended, using guided discussions, to teach students the specific steps of the theoretical design process. Using instructor observations and a preliminary survey, it was determined that students have responded well to this exercise.

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