Promoting Active Learning and Creativity in the Strength of Materials Course

Abstract

"Active learning" has proven to be a better way of engaging students in the learning process. Traditionally, creativity has not been one of the requirements in instructional engineering problems. A progressive open-ended problem has been incorporated into the strength of materials course. The idea is to allow students to advance from the basic straightforward experiences to more open-ended ones. A beam has been chosen as the open-ended problem. Given specific restrictions on size, shape and materials, students are able to go through a cycle of design, construction, testing and redesign. In addition to meeting the mechanical requirements, it is stipulated that the design must be creative. Performance of the beam is weighted at a 40%, and creativity is weighted at a 20%. Critique sessions, oral presentations and formal reports are required as part of the process, and constitute the other 40%. This paper provides a description of the open-ended problem, the requirements and the results obtained during its implementation. These results are compared to previous groups where creativity was not considered. The paper discusses how this project promotes active learning, fosters teamwork, increases communications skills and prepares students for further experimental activities. Students' perceptions of the importance of creativity are presented and discussed. It has been found that by providing open-ended experiences, students become actively engaged, exhibit a high level of satisfaction with the course, and become aware how important it is to enhance their practical skills and capabilities.

Introduction

The Engineer 2020 Report from the National Academy of Engineering outlines the key attributes that engineers must have in order to succeed in the future[1]. The report states that engineers in 2020 must have strong analytical skills, must exhibit practical ingenuity, must be creative, etc., amongst other attributes. Creativity is stated, will grow in importance due to the new challenges and new technologies in the 21st century. Creativity can be defined as being usefully innovative in diverse situations. Typical words associated with creativity are invention, innovation, thinking outside the box, art[1]. Creative work typically involves a trade-off or an amount of risk. Engineers and engineering students must decide where the balance between creativity and other requirements is. Measuring creativity has become the topic of research in many fields including engineering[2,3]. The development of a creative model or the validations of a model is not the scope of this article.

Creativity has been linked to projects and problem-based learning since several engineering professors argue that creativity can be enhanced through the project method[2]. On the other hand, literature shows that individuals who are faced with complex problems typically resource to familiar, bounded and narrow subset of potential solutions[4]. In this article, the introduction of creativity as a requirement in a project is described, discussed and the results are presented. More importantly, the results give insight to the students' perspective of creativity.

The word "active learning" is used to describe the involvement of students in their own learning process. The active learning model can be divided into activities involving some type of observing/doing experience and activities involving some type of dialogue. A balanced percentage of these types of learning activities can have an additive or cumulative impact. This project provides for all aspects of the active learning model.

Open Ended Problem Description

A beam has been chosen as the group problem in the Strength of Materials Course[5] because it has an open-ended solution space such that there is no single solution that will fulfill all the requirements; therefore, it can be considered an ill structured problem. Two objectives are defined for this project:

1. To design and construct a maximum strength beam out of wood board to span ~30 inches and carry a concentrated load at mid-span. The beam must not exceed 8 inches in height.
2. To test the constructed beam, record its response and prepare a report describing the structural response and failure characteristics of the beam.

The class was divided into groups with a maximum of three members. Students were given specific restrictions on size, shape and materials. Figure 1 presents the initial guidelines given to students. The beam was tested in a three point bending setup[6]. The project was evaluated from several aspects. Table 1 presents the evaluation criteria employed in Fall 2007.

DESIGN AND BUILD A BEAM

1 Introduction

In this exercise you will design a beam which will be subjected to three-point bending. The objective of the beam design is to achieve the maximum load possible before collapse. The material for the beam will be wood. Each group will receive one 3' x 3' piece of wood. The thickness of the board is 3/8 in. The entire beam is to be constructed exclusively with the materials provided: wood and 12 ounces of glue. A maximum stress of 4500 psi is typical for this material. (You cannot bring in steel reinforcements, or any other reinforcements for that matter.) The beam must span 30 in. so, in reality, it will have to be a bit longer to have a bearing surface at each end. Figure 1.1 shows a schematic of the loading set up.

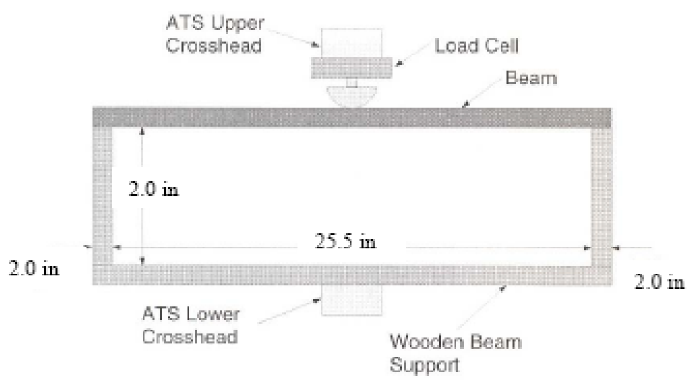

Fig. 1.1: Support for three-point bending test of your beam design.

Three other restrictions must be considered:

(a) the maximum height of the beam is 8 inches
(b) the maximum width of the beam is 12 inches
(c) no **I-Beam shape** is allowed

The Baldwin machine will be used to load the beam. The computer will be used to record the load applied to the beam and the displacement of the lower cross-head of the testing machine. Because of its nature, you are not provided with much background information for this exercise. The purpose is to provide an "open-ended" problem that does not have a single solution and that is not easily solved from similar examples provided.

Figure 1: Guidelines and Requirements for Team Project

Table 1. Project evaluation criteria

Criteria	Percentage	Explanation
Creativity	20%	Your design will be evaluate for creativity with a rubric by your classmates and professor
Performance of the Beam	40%	Did you beam achieved the highest load? Comparison to the highest load achieved overall. (competitive), 20%
		How close is your predicted load to the actual load? , 20 %
Report	20%	
Presentation	20%	Classmates will evaluate your presentation

In addition to being an open-ended problem, this project gives the instructor the opportunity to introduce and/or remove restrictions allowing the instructor to modify the project requirements easily. In the Fall 2005, the project was initially introduced. The 2005 guidelines had no restrictions in terms of the shape that could be selected (i.e. the 2006 and 2007 guidelines called for no I-beams) and the wood measured 4’ x 4’, instead of 3’x 3’. The reasoning behind the change in the amount of material was to force students to be more creative. It was observed that students had extra material and were not optimizing its use. The 2006 results are the control group for the results presented here. This project was also employed during the 2006 Engineering Summer Camp in order to have a different type of control group. High Schools students, with no formal course in Strength of Materials, were given basic information in terms of moment of inertia, bending and mechanical properties. They had no restriction in terms of the shape and were given a 3’ x 3’. They had not been exposed to common type of beams and structural practices as the college students. The results will be presented and discussed later in the paper.

Deadlines were introduced through out the semester in order to allow a constant feedback and communication between the groups and the instructor. In two occasions, student built prototypes of their beams. According to the groups, the prototypes allowed for a scaled down testing. Prototypes were not required, but their construction demonstrates the students’ interest and involvement in active learning. Participants were able to go through a cycle of design, construction, testing and redesign. In terms of the mechanical testing, the students were introduced to the operations of the Baldwin and SATEC (i.e. mechanical testing machines) through out the course and laboratory. Before the test could be performed, students had to state the predicted maximum load the beam could hold. These values were later employed when evaluating the effectiveness of the beams.

Results

Before 2007, from the students’ perspective, the main objective of the project was to design a beam that would be able to achieve a maximum load before it reached failure when subjected to a three-point bending[6]. There were no restrictions in terms of the shape. These students were enrolled in the Strength of Materials course; therefore, the project had a direct connection with the topics discussed in class. Table 2 and Figure 2 present the pictures and the results of the three-point bending test of the beams constructed in Fall 2006. In 2007, creativity was a required component of the project, as stated earlier. Figure 3 presents the beams constructed in 2007 while Table 3 shows the predictions and the results of the three-point bending. As stated earlier, the project was introduced during the engineering summer camp. The results are presented in Table 4 and Figure 4.

Figure 2: Fall 2006 beams, creativity was not a requirement

Table 2. Beam testing results, Fall 2006: no I-beams, 3’ x 3’ wood piece

	Group 1	Group 2	Group 3	Group 4	Group 5
Predicted Maximum Load (lbs)	9,616	13,230	12,000	6,500	8,370
Actual Maximum Load (lbs)	9,050	13,400	9,500	8,500	8,000
Percentage Error (%)	6.25	1.19	26.31	23.53	4.62

Table 3. Beam testing results, Fall 2007: no I-beams, 3’ x 3’ wood piece, creativity was a requirement

	Group 1	Group 2	Group 3	Group 4	Group 5
Predicted Maximum Load (lbs)	7,917	6,148	7,172.5	2,197.6	9,500
Actual Maximum Load (lbs)	9,600	6,020	8,520	1,900	5,000s
Percentage Error (%)	17.53	2.12	15.81	15.66	90.00

Table 4. Beam testing results, 2006 Engineering Summer Camp: no shape restrictions, 3’ x 3’ wood piece

	Group 1	Group 2	Group 3	Group 4	Group 5
Predicted Maximum Load (lbs)	8,354	12,523	2,880	10,030	11,540
Actual Maximum Load (lbs)	9,175	2,300	3,275	225	5,225
Percentage error (%)	8.94	444.48	12.06	4358.78	120.86

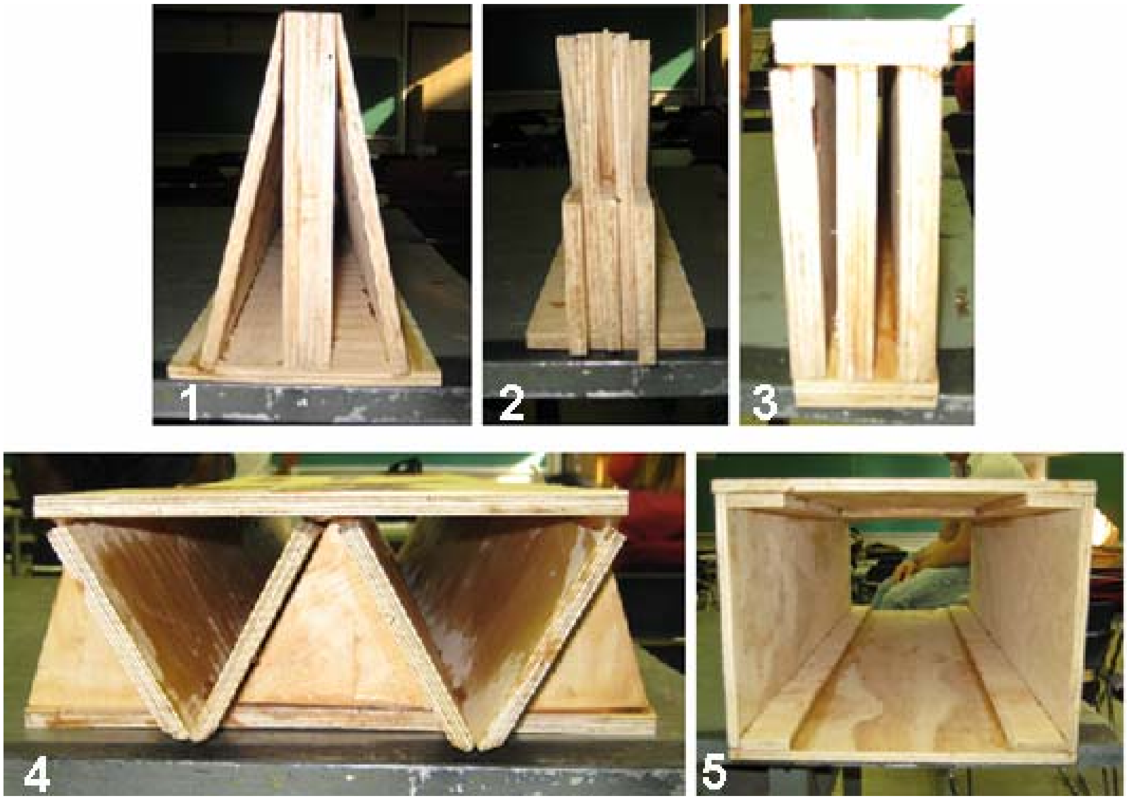

Figure 3: Fall 2007 beams, creativity was a requirement

Figure 4: 2006 Engineering Summer Camp Beams, no shape restrictions, no creativity requirement

Assessing Creativity

Literature presents several models to measure creativity[2-4,7]. The assessment of these models is not the scope of this work. In order to have students evaluate creativity, a simple five-point rubric for creativity/originality was provided to students in Fall 2007. Table 5 shows the rubric employed while Table 6 presents the students' assessment of creativity based on a five point scale.

Table 5. Rubric for Creativity/Originality employed by students[8]

5 Points: Excellent	3 Points: Great start but needs work	1 Point: Not "shaped" yet, still rough
1. Project is unique, does not look like the others. 2. Shows creativity that works, it is not just weird but exciting and fresh.	1. Project is nice and works, but is not unique. 2. It has similar components as other presentations or known structures.	1. Project appears forced, hard to follow. 2. Has too many parts that are strange and do not serve any purpose. 3. Tried to be creative but does not work.

Table 6. Results of student's assessment of creativity, Fall 2007. The group number corresponds to the numbers in Figure 3 the results in Table 3.

	Group 1	Group 2	Group 3	Group 4	Group 5
Creativity (5 points scale)	4.33	4.33	3.67	5.00	3.09

Discussion

As the results of the implementation of the beam design project in the Strength of Materials Course, the following observations can be made:

- <u>Students learn more in a hands-on / creative environment.</u> Building was an important part of this project. In 2007, some groups were extremely thoughtful in terms of assembly: grooves were made to improve the integrity and reduce the dependence on the glue. One group ran a FEA on the beam (this is typically an elective course during senior year). Prototypes were made by two groups, as mentioned earlier.

- <u>Foundations are always necessary.</u> As the percentages of difference between the predicted and actual values of maximum force are observed (refer to Tables 2-4), it is clear that the summer camp students with no previous knowledge lack the necessary basic background to design acceptable performing beams.

- <u>Although lectures are important to establish fundamental knowledge, they can deaden the imagination.</u> When this project was introduced into the summer camp, the creativity level was much higher than when a control group was used with the undergraduate students (refer to Figures 2 and 4). The undergraduate control group (i.e. creativity was not required) had very simple and similar designs as can be observed in Figure 2. This control group (Fall 2006) did not look for potential solutions; they simple selected shapes from a narrow solution space.

- <u>When including creativity, a trade off must be made.</u> When comparing Figures 2-4, it is clear that a high level of creativity was achieved when students did not have extensive prior knowledge of the subject (i.e. Summer Camp beams). Students taking the Strength of Materials Laboratory were more concerned with reinforcements at the points of load application than with a creative design. Two out of the five groups in 2007 stated that they felt that structural integrity was more important than creativity; even though they were evaluated on that aspect. They said that they were willing to sacrifice creativity because "in the real world, no one will be impressed with an exotic design if it fails."

- Measuring Creativity can be easy. A simple rubric proved to be effective and gave a good indication of the students' perception of creativity (refer to Table 6). There are many sophisticated models to measure this attribute which are outside from the scope of this article.

Students' perceptions

At the end of every semester, a university course evaluation and a Mechanical Engineering web-based course exit survey is administered for each course. Under the general questions, students were asked "What did you liked best about the course?" Out of 15 students, nine responded; out of the nine responses, four made reference to the beam project:

- *"The Build a Beam project was enjoyable as it added a hands-on experience to the Stress section of the course…"*
- *"the beam project"*
- *"group project"*

Another question asked the students to suggest comments for future improvements. There were five answers and one stated: *"More group hands on project, I learned a great amount building the beam."* It is clear that the project has increased the course satisfaction; the survey responses proved that when compared to previous years. On the other hand, trying to change students' perceptions has proven not to be an easy task. Creativity vs. performance was a constant argument during this project.

Conclusions and Future Plans

A simple, hands-on, open ended problem was introduced to the Strength of Materials Course. This open-ended exercise facilitated communication between the instructor and the students, encouraged team work amongst the students, and provided an opportunity for active learning and for emphasizing creative problem solving. Future plans call for the development of additional projects that can be incorporated into the Strength of Materials Course. Project-based courses have proven to achieve the course objectives in higher levels and improve the learning experience.

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