Enhancing Popular Problem-Solving Projects: Chair Design Activity

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Abstract
Problem-solving activities are popular and potentially high value learning exercises when well designed and executed. Many of these types of activities are highly competitive and use open-ended goals that are difficult to determine the level of quality until well after the activity is completed and comparisons between student outcomes are made. These two factors combined can reduce the learning value for many students since the benchmark of quality is only determined after the activity is completed. By establishing measurable benchmarks that can be recognized as quality before the activity begins, many students will be more motivated to reach the desired or required objectives. This work explores ideas for reducing the negative impacts of open-ended goals that can only be accurately evaluated after an activity ends, by making it possible for students to recognize the quality of their results prior to submitting final projects for review. The ideas shared in this example can be transferred to a wide range of problem-solving activities that could benefit from the recommended improvements to objectives used for these types of educational activities.

Introduction
Learning through problem-solving is a popular educational strategy. This method is common in science, technology, career and technical programs, and others. Cotton and Calkins (2011) reported, “Problem-solving activities let students use knowledge gained in various areas of their academic education. They help bring together skills and knowledge from such areas as science, math, art, and English by simulating activities and projects students will encounter later in career and life experiences” (p.24). Problem-solving activities provide students with realistic experiences. This approach helps students recognize how a variety of skills and knowledge acquired in different subjects are applied in their lives. There are many popular and commonly used design projects today which teachers have modified for a variety of objectives and audiences. It is important to ensure that the expected outcome stated is clear, concise, measurable, and objective (Cotton, S., & Calkins, C, 2011).

The purpose of this work is to help instructors make problem-solving activities more effective. One weakness in many popular problem-solving projects is objectives that can only be evaluated by comparison with other student outcomes. In a common project type, students design products to carry loads, like a bridge or chair. A common required goal is to make the strongest product. Because strongest can't be determined until all projects are completed there is little evidence that these designs were adequate until it is too late to revise. When a student knows an objective precisely, the objective can be measured for success prior to completion, increasing motivation because success can be recognized prior to comparison to other products. This is also realistic to real world designs. An engineer does not design a bridge to be as strong as possible because overdesign is costly and often prohibitive. Normally the load that a structure must support is determined prior to starting the design phase. Only then is the structure designed to support that design load. A product can be tested for design load but a "strongest" goal becomes a competition which impedes some students from engaging because of a feeling of inequality compared to abilities of other students. Also, competition generally requires comparisons to recognize quality or success. Some students are difficult to motivate when they do not clearly understand the goal and how to recognize their work is high quality prior to comparisons with others.

In an educational environment, students participating in a competitive design that does not provide a specific outcome may actually experience reduced motivation. Since "successful design" under these conditions cannot be recognized until after it is too late to make revisions, students often submit first designs as final products hoping they will be adequate. Providing outcomes that can be recognized as successful prior to testing will encourage students to experiment. For example, a design outcome that requires a product to support between 150 and 250 pounds is testable during the development process. A required outcome of making a product as strong as possible allows little control over what adequate is and is not realistic to real structural design objectives.

This work proposes a structural design activity that is similar to projects that many instructors have used in the classroom. It will then explore ideas for improving the learning outcomes by making them less open-ended so that students can recognize the quality of their results prior to submitting their product for evaluation. The discussion will also explore strategies for executing and assessing the activity.

Simulating Reality

This project is designed to be very similar to the process that a designer in the corrugated paper industry would experience. Projects like this chair design activity can be beneficial for students who are looking to become Industrial Designers, or are interested in occupations within a production and manufacturing environment. Industrial Designers and manufacturers incorporate all aspects of art, business, and engineering to construct products that people use every day (Bureau of Labor Statistics, 2014-15). For students wanting to continue in this direction, successful completion of the chair design activity will better prepare them for industrial design positions, and improve manufacturing skills.

Since many corrugated products, such as store displays, are structural in nature and often do not use adhesives for assembly; this product will use this same design parameter. Many corrugated products, other than sealed packaging used for shipping, require user assembly, so this is also a design parameter suggested for this project. One universal principle in producing products for the general public is the lack of control over the characteristics of the purchaser/user. This is simulated in this project by the lack of control over the size and skill of the person who will be assembling the product.

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The time period indicated in the design brief is very general so the instructor can adjust this to meet the needs of each class/instructor. Three weeks is suggested as an appropriate time requirement, but more or less may be used depending on how much time per day and how many days per week are allowed. Another time factor to consider is whether the students will be expected to work on this project outside of class time.

An interesting and realistic approach to some problem-solving activities is to restrict the materials used and/or time available (Cotton, S.E., 2002). A good example of replicating real situations is the Apollo 13 experience of experiencing a problem, which had to be resolved only with materials on board the capsule and within the time remaining for oxygen supply after an onboard explosion. It is recommended that materials for this project be very restrictive, and consist of only single strength corrugated paper. As with any assembly, clear instructions are needed to guide the person assembling the product. This is a valuable opportunity for students to experience the impact of poor written language skills, by seeing how poor grammar, spelling, word choice, and punctuation can confuse readers who require the written word to accomplish a complex task. Since there is limited control over the purchaser's ability to read, it is critical that instructions are not restricted to text only, since quality graphics is another important communication tool.

Since the primary objective of the project is to develop a portable and easily assembled chair of corrugated paper, there is a size limit. The product simulates a marketable product, not a prototype, so the product must be clean and appealing. One cannot control the size of the customer, but it would be reasonable to identify a maximum design weight which would be indicated on the product and in the instructions.

Selecting test "customers" and load testing

There are several methods that may be used to select sample customers, but it is suggested that some type of random selection be used to prevent the preparation of the person assembling the product and to add equity to the selection from a varied population. This may be as simple as inviting another class to be the testers without advance notification of the participation.

The product can be load tested by either the person doing the assembling or another selected individual. It is advisable to have the tester, for a short period, lift their feet to eliminate the chance of not fully loading the product. An alternative would be to have a randomly selected dead weight load placed on the product to decrease the safety concern regarding a product that fails the load test. This could be accomplished with blocks, bricks, or other weights. When using dead weight, it is suggested to vary the load used by random drawing to simulate the varied weights of users.

Evaluation

In this example there are ten different product measures used for evaluation, each of which accounts for 10 percent of the total score (see "Assessment Worksheet"). Knowing how the project will be scored, students will be able to determine the potential impact of concentrating on any particular facet of the design. This helps overcome the negative affects of a student perceived weakness on any single design goal, whether it be artistic, quality control, structural soundness, etc. It is important to note that students also learn from mistakes, so a failed effort in any single measure factor, does not result in a perception of being significantly disadvantaged, which will help encourage students to concentrate on strengths instead of giving up because of perceived weaknesses in one of the skills required.

Note that 60% of the evaluation results from objective observations are from an independent observer and not the instructor. By using an independent observer for the objective observations made during the testing, it becomes possible to assemble several products at one time and allows the instructor to monitor the process. The observers record the findings/observations using the checklist provided. Only the final 40% of the evaluation process involves subjective measures normally determined by the instructor after testing. It is recommended that the instructor devise a rubric or other informative document that will explain to the student how the subjective portion will be evaluated. This should contain enough detail that the student will be able to accurately anticipate the outcome of this part of the evaluation. This subjective measure is not included in this example because a subjective measure is largely determined by the personality, teaching style, and priorities of each individual instructor.

Draft Example

Below is a general guide for what types of items can be included in the student instructions handout. This has been presented in brief, so that the teacher can add and customize information to the activity in order to fit his/her particular purposes. Teachers can incorporate different safety practices to the instructions like making sure students do not cut corrugated paper directly on work surfaces. Teachers can also take necessary precautions and use scrap material to protect working surfaces. Other basic instructions include a detailed timeline for the project goals and due dates, as well as information detailing how the product will be constructed.

Let's Take it Easy!
Chair Design – Usability Study
Camping/Fishing Chair Product Study

This project is intended to give the student exposure to studying the usability of a simple product design and the assembly instructions for that product. The product will target the general population with the concept that it would be marketed through department stores with little control over the end purchaser. It may be desirable to identify a maximum weight the product will support, as is the case in most load bearing products in real product design. It is suggested to use 300 plus or minus 50 pounds. The student will create a product according to guidelines provided in this document and then will use a random sample experimental study to test the usability of the product and supporting documentation.

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Materials and other information
Teachers should be sure to detail what kinds of materials will be used. This example guide assumes that students will be using only single strength corrugated paper. Each student will prepare the product components, a company name and logo, and a set of instructions for assembly. See figures 1 and 2 for an example chair with no fasteners or other enhancements. Note the securing strap used in place of glue or tape in figure 2.

Instructions should be on plain, letter-size paper. No parts of the product should be preassembled; only precut, pre-marked, or pre-scored parts of single strength corrugated paper may be provided. Note this is also an opportunity to help student recognize the difference between corrugated paper and cardboard, with cardboard actually being a solid stock with no corrugation. The students must create instructions that contain both written and graphic information. The instructor should determine whether graphics are limited to photos, drawings, or a combination of the two based on the skills set to be experiences in the specific program involved. The person testing the product should not have any prior knowledge of the product or the instructions. The finished product will be evaluated on ability to carry design load, logo design, assembly success and appearance, quality of instructions, and product appearance.


Figure 1 - assembled example


Figure 2 - Interior Structure

Parameters of Product
1) The product is a camping/fishing type chair, which can be transported and disassembled.
2) The assembled chair must be no larger than an 18” cube, with a seating surface no lower than 16”.
3) The chair must include a minimum of 6 separate components/parts requiring assembly.
4) Each part may be pre-cut to shape and include appropriate markings or scoring.
5) At least one page of assembly, step-by-step instructions must be provided.
6) A company name must be provided along with a logo.
7) The assembled product must be capable of supporting the maximum weight.
8) The student should not be permitted to assist the person assembling the product.
9) The product will be tested for strength after assembly is completed.

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Testing Suggestions
The product should be tested by a third party who is not familiar with the designer or the product. Evaluators will observe the testing procedure and complete an objective list of observations to serve as input for the final evaluation (by the instructor). The “customer” will be provided with a packaged product and allowed to review the parts list to confirm that all parts are included and to sort the parts for quick access. The person assembling the product will then be allowed to open the instructions and attempt assembly of the product. The assembly will be timed and this will be factored into the assessment of the activity. Ease of assembly and clarity of instructions are important factors in the design of this product.

After successfully (or unsuccessfully) assembling the product, the product will then be load tested for reliability of performance. The test will require a person to sit on the product for a minimum of 20 seconds without product failure, followed by an additional 10 seconds with feet raised off the ground to insure full loading occurs. An alternate testing procedure will require the product to support a randomly selected dead weight for 30 seconds. If dead weight is used, care should be taken to load evenly with no pressure well off center to avoid torque failure. See figure 3 for example of dead weight used to test product strength.

Reminder: The designer cannot directly or indirectly assist in assembly in any way.

Figure 3 - Example loading

Assessment
Factors included in the final assessment of this activity will include the following: (see figure 4 - example evaluation form)

- All required materials submitted properly and on time.
- Appearance and completeness of instructions and parts list.
- Appearance, placement, and proper development of the company name and logo.
- Time required for constructing the product (when the “customer” feels it is completed). [This factor will be based on the final range of times required]

- Whether the product meets all design parameters (size limits, required documentation, material limitations, etc.).
- Whether the product was successfully (or sufficiently) completed without interference of the student designer or from any other outside source (other visitors).
- Appearance and desirability of the final product.
- Performance on the load test. [Any failures will be in part evaluated based on the final time to failure]
- Apparent reusability (durability) of the product. (Was the product destroyed or damaged beyond reuse during the load testing)
- Originality of the project. (If a product is very similar to another in class, then it will not be deemed "original" so protect your designs from the other class members. Commercial espionage can be damaging to any manufacturer.

Special Notes

1) Any damage to laboratory work surfaces (example: cutting work surfaces with a matt knife) may result in serious deductions in scores.
2) Be sure to submit each item required by the dates noted in timeline, including the draft proposal. Waiting too long will almost certainly have negative impacts on the quality of the product and the instructions.
3) The student must provide the materials for the project, so it will be essential to get an early start on obtaining the materials. Many local merchants dispose of large quantities of corrugated boxes daily, this is a good starting point. Also, many merchants sell storage or moving boxes or stock corrugated paper sheets.
4) It would be advisable to experiment with designs and test a design prior to submitting, although this will not be a consideration in the assessment since there is no tool available to confirm this.
5) Design hint: In additions to your own testing of the product during design and development, have a friend try to construct and test the product using the current instructions prior to submitting the product for assessment. Note: This should not be the person brought to class to assist in testing since they should not be familiar with the product. The product should go through many revisions based on these tests.

(The timeline noted above must be established by the instructor based on time available for the activity and any modifications made to the basic model discussed and clearly documented for student reference.)

Draft Assessment Form

Let's Take it Easy! -- Assessment Worksheet

Student Name:____ Project #______________

Observer checklist:

1) All required materials submitted properly and on time (2 points each possible):
- ☐ Chair in disassembled condition
- ☐ Product in closed package
- ☐ Parts list included on separate page than instructions
- ☐ Instructions included
- ☐ Logo on project/documentation and name submitted materials

(Special notes for above: ____)

2)	Was the project successfully completed by "customer"?	☐ yes ☐ no
	Any interference or assistance by designer or others?	☐ yes ☐ no
	How many times? **(Circle)**	**1 2 3 4 5 +**
3)	Time required to complete assembly?	**Minutes**____ **Seconds**____
4)	Does the project meet design parameters?	☐ yes ☐ no
	Seating surface between 16" and 18"?	☐ yes ☐ no
	Tape, glue (adhesive), fasteners used?	☐ yes ☐ no
	Only single strength corrugated paper used?	☐ yes ☐ no
5)	Passed dead weight load test?	☐ yes ☐ no
	If not, how long did the product support the load?	**Seconds**______
	Successfully passed full load test. (if applicable)	☐ yes ☐ no
	If not, how long did the product support the load?	**Seconds**______
6)	Does product appear to be reusable?	☐ yes ☐ no
	Condition appears to be **(circle)**	**Poor Fair Good Excellent**

NOTE: The following to be completed by instructor only:

7)	Appearance and desirability of product.	______
8)	Originality of product and instructions.	______
9)	Appearance and apparent effectiveness of instructions.	______
10)	Appearance, placement, and development of logo.	______
Total Score		______

Figure 4 – Example evaluation form

Conclusion

There are many very good problem-solving projects in common use today with many new projects being continually introduced, but many use objectives that are too open-ended to encourage high student motivation to do quality work. This work attempted to offer strategies for creating more powerful and useful objectives for problem-solving instructional activities. Many problem-solving activities can be located through simple Internet searches. With minor adjustments to many of these already effective and proven projects, it is possible to refine them further and create even more valuable learning activities. By making end results observable, specific, and objectively measurable; student performance and motivation can be enhanced because when the objective is vague or not measurable students don't recognize success and may lower their own expectations. A clear target is important as a motivator for effort and direction in a design challenge. These minor changes make the objectives of problem-solving activities more overt and thereby help students better understand what is expected, helping them recognize when they have met or exceeded expectations without waiting until after the outcome or product is tested.

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