## LESSON 10: Design a Bridge Project

### Introduction

In recent years, economists have recognized three key things bridges do that help boost economic activity: (1) Bridges are a critical component of a nation's infrastructure, making it possible to ship raw materials and finished goods to factories, warehouses, suppliers, distributors, stores, and end-consumers. Bridges also facilitate travel so consumers can purchase goods and services in their own communities and beyond. When a bridge closes, economic activity slows down or grinds to a complete halt. (2) Wages earned by bridge construction and maintenance workers have a positive economic impact when used to buy things at local businesses. An investment in wages, and the related consumer spending that results from it, is proven to pay off many times over. (3) Bridges increase cash flow when they join two places that complement each other economically. It can have a powerful impact when an area that has a large money supply is connected to one that has goods or services to sell or people who need work. The same is true when a community that has raw materials gains easy access to another that has factories able to convert them into salable goods. Since bridges are a critical component of national and local economies, local, state, and federal government agencies have made it a priority to keep bridges in decent repair because they play a necessary role in moving goods from one place to another and providing customers with access to businesses. They are aware that a structurally deficient bridge or one nearing the end of its design life could be closed to traffic at any time without notice, stalling business activity.

**Learning Goals:**

- learn about the cycle of product design through an activity that follows the steps of a simplified engineering design process. The activity topics are: 1) identify the need and define the problem; 2) conduct background research, such as an idea web, internet patent search, standards and codes search, reverse engineering, and user interviews; 3) specify requirements and constraints; 4) brainstorm, develop ideas and possible solutions; 5) evaluate alternatives, perform design analysis and choose the best solution; 6) develop and construct prototype; 7) test prototypes; 8) perform evaluation, refine design and prototype; and 9) communicate results.

**Your Challenge:**

Houston is the 4$^{th}$ largest city in the United States and its economy is booming but some of its bridges are old, outdated, and/or in a state of disrepair. There are also some locations where bridges are badly needed to help move people, materials, goods, and services across the city and beyond. Your team has been invited to submit a project proposal for the construction, repair or replacement of a bridge in Houston. You may choose from among several locations.

The bridge has to be environmentally-friendly, technology-driven, space-saving, cost-effective with a capacity for maximum payload. You will present your project proposal, design and prototype to a panel of engineers, professionals and community stakeholders.

**PART 1. Define the problem.**

**Identify the need. Imagine an "ideal" solution.**

Guide Questions:

Are you building, replacing or repairing a bridge? Where is this bridge located? What do you know about this bridge? What problem needs to be addressed? What do you think is the "perfect" solution to the problem?

*Tell us about the problem. Sketch your idea here (How does it look like?)*

TIPS:

In this section, you will practice the initial steps involved in an engineering design challenge. You will begin by reviewing the steps of the engineering design process and discuss the need for the project. You will make assertions about the problem/s that have created the need for the design or project that you are proposing. You will identify a relevant context, define the problem within your design team and examine your project's requirements and constraints.

What problem are you attempting to solve? State the problem clearly.
What kinds of expectations do you have for your solution?
What kinds of limitations exist?

(See Activity: Engineering Design – Defining A Problem)

**PART 2. Do background research.**

**Dig into the problem.**

Guide Questions:

Where are these old, dilapidated, outdated bridges in Houston found? Which two areas in Houston can be connected by a bridge to help boost the economy?
(Once you have located them, pick one bridge that you would want to work on. Find out everything that you need to know about your bridge and the area where it is located and how it will help boost the economy if it is built, repaired, replaced? Go online. Do your research on bridges and bridge constructions. Go to City Hall. Interview people.)

*Write what you learn here.*

TIPS:

In this section, you typically do not discuss the design solutions that you propose. Rather, you tell your audience everything that they need to know about the problem and your proposed solution. Present evidence from respected sources. The source of these evidence (journal articles, books, or other sources) should be included in your reference listings.

Identify the conditions that must be met to solve the problem. Identify anything that might limit a solution, such as cost, availability of materials, time, etc. Be specific.

Your notes here will help you come up with a design brief which is a short write-up that would include the goal/objectives of your project and its specifications. It will also help you define which of the solutions that you come up with are best, given your specification. You might also want to conduct additional research about the problem so you can see what solutions have already been designed or attempted. The specifications of your project will set the stage for the types of solutions you will be coming up with. For example, you could ask yourself questions about: - Cost - Safety - Effectiveness - Efficiency - Legality. You may come up with even more categories that are important based on your specific problem.

**PART 3. Specify requirements. Identify criteria and constraints.**

**Meeting your "users'" need.**

Guide Questions:

> Will your design be environmentally-friendly, technology-driven, space saving, cost-effective and able to carry maximum payload? What features of your "ideal solution" do you think will work and which one will not? Why? How much will the project cost?)

*Write what you think here.*

TIPS:

Here you will formally state your proposed design or solution to the problem. Often, the design has two to four specific objectives. State your objectives in order. You will also have to discuss more fully what you mean by your design objectives. The explanation will include a discussion of not only what you intend to do, but also a justification of what you will not do (in other words, what your audience might assume that you will do). Identify the conditions that must be met to solve the problem. Identify anything that might limit a solution, such as cost, availability of materials, time, etc. Be specific

Note: that if you have done a good job in stating/defining the problem, then all your design objectives should make sense to your audience.

**PART 4. Brainstorm, develop ideas and possible solutions.**

**Create alternative solutions to test.**

Talk to your team. Imagine at least 3 different ways to meet or solve your “users’ needs. Make sure that each is as different as possible from the next.

*Sketch your 3 or more ideas here.*

TIPS:

Note: Talk to your team. Discuss solutions. Consider what others have done to solve the problem and include prior research. Generate new ideas for solutions. Brainstorming is a group creativity technique used to generate a large number of ideas for the solution to a problem. The process itself can boost morale, enhance work enjoyment, and improve team dynamics. Suggested brainstorming guidelines include:

1. Focus on quantity: You want to capture as many ideas as you can — even if they seem silly.
2. Withhold criticism: Not only should you refrain from criticizing the ideas of others, you should make sure not to criticize your own ideas as they emerge during the brainstorming process.
3. Encourage wild ideas: We know from experience that (with a bit of reworking and refinement) wild ideas usually lead to the most innovative designs.
4. Record all ideas: During a brainstorming session it is helpful to designate a person on your team to write down each idea as it is thrown out. Sentence structure, spelling and grammar do not matter for this list, so wait until later to review or edit anything you write down. Just make sure to capture all the ideas.
5. Combine and improve ideas: In the midst of brainstorming, try to build upon the ideas of others. Think of your brainstorming session as a snowball rolling down a "mountain of ideas." Initially, the snowball is small, but it quickly grows and gains momentum as it travels down the hill. The best ideas in engineering are generally a team effort.
6. Stay focused on the topic: Although brainstorming is meant to be creative and free flowing, make sure you focus your ideas on the topic at hand. This helps you later when you are organizing all the ideas generated in the brainstorming session.

**PART 5. Evaluate alternatives, perform design analysis and choose the best solution.**

Ask your "users" or other teams in your classroom what they think about your ideas. Choose the best solution. Do not forget to consider all design criteria in choosing. Use a rubric. Based on all the insights you have gained, what do you think is the best design for your bridge?

*Explain and sketch your idea here.*

TIPS:

Once you have created a number of possible solutions to your design problem, you need to choose which one is best. First, look at whether each possible solution met your design requirements. Consider solutions that did a much better job than others, and reject those that did not meet the requirements. Make a detailed sketch of each design. Label each sketch with dimensions (measurements and units) and include the materials needed to build a model or prototype. Select one design to construct. Justify your choice by listing the reasons why you selected this design.

Some criteria apply to virtually every design. Good designers consider them in every solution that they choose to implement. **Elegance.** An elegant design solution is simple, clever, or ingenious. It might have fewer parts to wear out or fail. It might combine solutions from different areas in an inventive way not seen before. All good designers strive for elegance in their designs. **Robustness.** A robust design is unlikely to fail, even when used in conditions more severe than it was designed for. It is sturdy or resilient, perhaps bending, but not breaking in hard use. **Aesthetics.** If everything else is equal, people prefer a solution that is tasteful and pleasing to look at. **Cost.** What will it cost? Can the target user afford the solution? Do you have enough money to build your prototype? **Resources.** Do you have all the materials and equipment you need for your engineering project, or will you be able to obtain them quickly and at a very low cost? **Time.** Do you have enough time to complete your design and make it before the due date? Allow time for doing additional research and fixing problems. It is very rare for everything to work correctly the first time. **Skill Required.** Do you have the skills to build and implement your solution, or can you learn them in the time available? **Safety.** Is your solution safe to build, use, store, and dispose of?

**PART 6. Develop and construct prototype.**

**Build a model or prototype, re-imagine your "ideal' solution**

Using the resources available to you (i.e. materials that will be supplied by your teacher) you will create a prototype of your solution. It might not match your ideas completely but it should help bring your ideas to life for your "users" and allow you to start testing them.

*Describe how you will create your prototype here.*

TIPS:

Here you will learn the manufacturing phase of the engineering design process. You will start by building prototypes, which is a special type of model used to test new design ideas. You will use a variety of simple building materials (that your teacher will recommend), such as popsicle sticks, wooden tongue depressors, nylon cord, string and hot glue within your allowable budget. You will present your prototypes to the class for testing and create prototype iterations based on feedback.

Write a detailed procedure for building your model or prototype. Include design specifications (measurements with units). List the materials that you will actually use to construct the model or prototype. Follow the procedure and build your model or prototype..

**PART 7. Test prototype.**

**See if your solution works.**

Using the resources available to you, test your prototype. If possible, ask your "users" oa audience what they think.

*Describe how you will test your prototype here and capture what you learn here.*

TIPS:

**Test:** (Each team will test their bridge to see if it can withstand the required weight for at least one full minute. Be sure to watch the tests of the other teams and observe how their different designs worked.)

- Write a hypothesis about your design's performance during testing.
- Use an "If…then…" format.
- Decide on a test for the model and try it out.
- Record the results of your test.

**Evaluate:**

- List the strength of your design.
- List the weaknesses of your design.
- Select the most successful aspects of your design and incorporate these in manufacturing your final product.
- Discuss what changes or compromises in your design (if any) had to be made due to constraints.
- Decide if your design solved the problem in Part 1.
- Once you have identified the successful attributes of your prototype and thought through how you might incorporate these attributes into your final product, you will create an engineering drawing. An engineering drawing fully defines all geometric features of a design in enough detail and clarity that another person could build that component or product.
- All the characteristics of your final product should be reflected in your engineering drawings
- Although your final product may resemble your prototype, you want to focus more on craftsmanship and aesthetics—making your final product look good! When you created your prototype, you were more concerned with functionality and testing different design alternatives. Now that you have worked out the kinks in your design, you can devote your attention to manufacturing a functional and polished final product.

**Part 8. Perform evaluation, refine design or prototype.**

If you have the time and the resources, use what you have learned by testing your prototype and improving your solution. You can do this once, twice, or as many times as possible.

*Write what you learn here.*

TIPS:

- Evaluate results.
- Based on the results of your tests, make improvements on your design.
- Identify the changes that you will make.
- Create a product according to specifications while working with more advanced building tools and materials. And give reasons for the changes. (For example, maybe you could work with sturdier materials—say pieces of sheet metal and screws. Or maybe you had trouble joining two parts of your prototype using regular classroom glue. So for your final prototype you can use a more advanced adhesive, such as an epoxy.)

**Part 9. Communicate results.**

**Share your design/solution.**

Now it's time to tell your "users" and the community about your solution. Using the resources available to you, create a presentation (with pictures if possible) that describes your solution, how it works, and anything that you have learned about it. Do not be afraid to share your ideas or designs that did not work. These are important because they tell you what the tough challenges are and help you make better solutions for the future.

*Write what you learn here.*

TIPS:

- Organize your findings (e.g. poster, digital collage, power point presentation, short video documentary, etc.)
- Present your findings to your audience for feedback.
- Compare your design with the other teams.
- If you were to build this model again, what would you do differently and why?

https://www.sciencebuddies.org

https://www.nasa.gov

https://www.teachengineering.org

https://www.jason.org

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