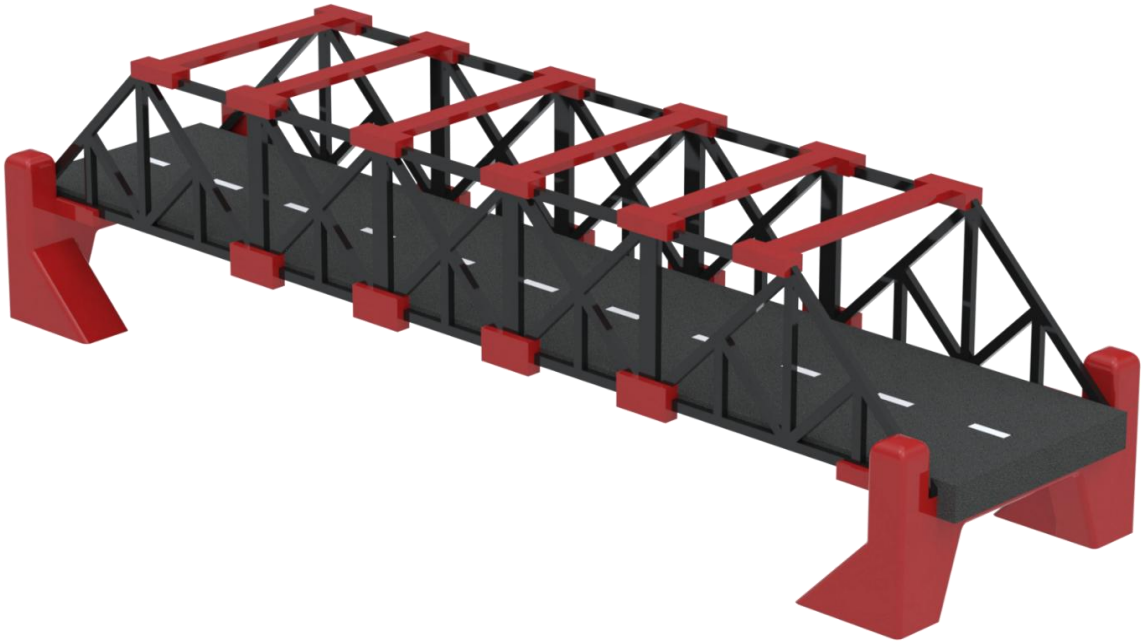
SOLIDWORKS

# DESIGN PROJECTS

## TEACHER GUIDE

3DEXPERIENCE



# BRIDGES

DASSAULT SYSTEMES

# INTRODUCTION/GENERAL GUIDELINES

Welcome to the Design Projects Teacher Guide for Bridges. This activity presents a wide range of possibilities for the instructor. The individual components are simple enough for beginners to learn the basics of designing with CAD and the result is a model that can be used to explore the aspects of bridge design. This project is suitable for individuals and teams to eventually design and build their own bridge.

It is recommended that you have a completed model to pass around the class during the Presentation. As an instructor, you have several resources at your disposal:

1. **Overview PDF**
    - The initial document that introduces the project providing a brief overview.
2. **Teacher Guide**
    - This document contains information that corresponds to the sections of the Presentation PowerPoint (see below). Each section discussed in this guide provides further details on how you can use the PowerPoint.
    - Also included are additional ideas you may want to use to enhance the activity in the classroom or adjust it for different skill levels.
3. **Student Guide**
    - This document is intended for students and provides basic guidelines for the activity such as deliverables, tips for creating the individual components and 3D printing guidelines.
4. **Presentation PowerPoint**
    - The PowerPoint is used to introduce the project to the class.
    - Feel free to customize any part of the presentation such as history, design concepts or any STEM related materials.
5. **Video**
    - The video is located on YouTube, and is intended to provide an overall approach to how the model could be created in CAD.
    - You may want to watch it together with the students in class.
    - LINK TO YOUTUBE VIDEO
6. **Step-by-Step Course**
    - This is where every step of the design process is demonstrated with short easy to follow procedures and video clips as well as overall videos showing the entire process.
    - LINK TO STEP-BY-STEP

# BACKGROUND

This section is intended to provide students with an introduction to bridges. Provided is a list of famous bridges from around the world and their uses. You may want to look these up online and have further discussions regarding them.

Since this project is specifically focused on truss bridges, a slide with several types of truss designs and the history behind them is included. This can be used as a starting point for discussing how truss designs differ from each other and what the advantages and disadvantages between them might be.

It is important to understand the different parts of a bridge. Basic bridge construction terminology is highlighted using the project itself to make the connection to the design project.

Also included in this section is a slide for the discussion of key design terms.

- **Flat-Pack Design** – Materials are expensive. Encourage students to create designs that minimize waste *and* meet design requirements.

- **Design Intent** – It is always best to have a clear definition of how a product should look, function and feel to the user. This is referred to as form, fit and function. Spend some time discussing this vital step in the process of designing a solution to a problem.

- **DFM/DFAM (Design for Manufacturing, Design for Additive Manufacturing**) - In addition to Design Intent, the concepts of DFM/DFAM are equally important. When designing anything, the question, "How will this be made?", should be considered. This particular project is designed to be 3D printed. As such, it is important that students understand the capabilities of the machine you have available.

- **Nesting -** In manufacturing, nesting refers to laying out cutting patterns on raw material to minimizing waste during manufacturing processes, such as laser cutting. In 3D printing, it is the process of laying out parts to fit on the bed of the 3D printer to print several components at one time. It is important to discuss how parts should be prepared for manufacture, specifically 3D printing.

## COMPONENT DESIGN

This section contains slides for each of the components. The purpose of this section is to discuss how Design Intent and DFAM is to be applied to each part.

For detailed dimensions and step by step instructions for the parts, refer to LINK TO STEP-BY-STEP, in the **ADDITIONAL RESOURCES** section below.

## 3D PRINTING

This section provides an opportunity to discuss the specific ways the individual components will be oriented and prepared for 3D printing on whatever machines are available to the students in the classroom.

It is recommended that you develop classroom procedures for using machines and a method for keeping account of materials used. One thing you may want to do is have the students calculate the cost of each project. The way the components are designed and oriented on the 3D printer will have an impact on this. This can also be an opportunity to discuss sustainability, being mindful of the environmental impact we have when designing and making things.

## CLASS DISCUSSION

Included in this section are a couple questions to get the conversation started. The intent here is for you to tailor the discussion to suit your specific course goals and students needs. Some ideas may include:

- How does adding the decking improve the strength of the bridge?
- Why should the bottom angles of the abutments face inward?
- How long of a span can be achieved in order to support a 10lb weight? (add center sections, with decking or without).
- How does the Baltimore Truss design compare to other bridge designs?

## PROJECT TASKS (ASSESSMENT CRITERIA)

Depending on the goals of the class, at a minimum students should be able to accomplish the following tasks.

- Create the following bridge components in CAD:
    - Center Section
    - "A" Section
    - Lateral Brace with Snaps (Bottom)
    - Lateral Brace (Top)
    - Abutment
    - Deck
    - Deck Connector
- Create an assembly of the bridge in CAD.
- Print the physical components on a 3D printer.
- Assemble the bridge.

Some other possibilities for assessment may be in the following categories:

- **SUSTAINABILITY** – How much waste is generated in the manufacturing process?
- **ASSEMBLY** – With no adhesives or fasteners, does the model hold together on its own?
- **MANUFACTURABILITY** – Do the components fit within the parameters of the 3D printer? Laser cutter?
- **PERFORMANCE** – How long of a span with the bridge?

## ADDITIONAL RESOURCES

LINK TO DOCUMENTS

LINK TO YOUTUBE VIDEO

LINK TO STEP-BY-STEP

**The following sections do not correspond to the PowerPoint, and are included here for added benefit.**

## ADVANCED OPTIONS

For more experienced students, you can challenge them with more advanced concepts and tasks that encourage creativity, engineering principles, and real-world application. Below are some ideas that could be suitable for this level:

### Advanced Bridge Types

- **Arch Bridge**: Have students design an arch bridge that can bear high loads through compression forces. They can experiment with different arch shapes.
- **Truss Bridge with Advanced Geometry**: Implement complex trusses with intricate geometric patterns, including diagonal and vertical members that optimize weight distribution.

### Material Efficiency and Load Analysis

- **Finite Element Analysis (FEA):** Students can use CAD software to conduct Finite Element Analysis to simulate how their bridge design will perform under various loads and stresses.
- **Stress Testing, Failure Analysis and Redesign:** Students could study historical bridge failures and use their knowledge to redesign bridges that minimize the likelihood of collapse under specific circumstances.

### Collaboration

- **Team-based Design:** Have students work in teams to design different parts of a complex bridge structure, with each team member responsible for different tasks, such as load-bearing analysis, aesthetics, materials, or safety.
- **Cross-disciplinary Design:** Combine bridge design with electrical or mechanical engineering to add functional elements to the bridge, such as solar-powered lights, a draw bridge or sensors to monitor stress and strain.

By including these advanced design elements, students will be pushed to develop critical thinking skills and a deeper understanding of engineering concepts.

## EDUCATIONAL CONCEPTS

A bridge design and construction project is an excellent way to integrate multiple STEM concepts. Here are some potential teaching approaches:

### SCIENCE

- Discuss properties of materials like tensile strength, compression, elasticity, and their suitability for bridges.
- Test the strength of different 3D printing materials, such as PLA vs. ABS.
- Explain forces acting on a bridge (e.g., tension, compression, shear, and torsion).

### TECHNOLOGY

- Teach students to use 3D modeling for creating their bridge designs.
- Demonstrate how 3D printers work, from slicing software to the actual printing process.
- Discuss additive manufacturing principles and how they differ from traditional methods.
- Emphasize the importance of DFAM, Designing for Additive Manufacturing, by minimizing waste through smart design.

### ENGINEERING

- Compare designs like suspension, arch, truss, and cable-stayed bridges.
- Challenge students to select a design type based on specific constraints (e.g., span length, weight capacity).
- Introduce failure analysis to identify and fix weak points in the design.
- Focus on problem-solving and overcoming design failures.

### MATHEMATICS

- Discuss geometric principles used in bridge design, such as triangles in trusses for stability.
- Calculate angles, lengths, and dimensions for accurate CAD modeling.
- Measure and analyze load capacities of printed models, comparing results to predictions.
- Have students estimate material costs, factoring in 3D printer filament usage.
- Compare budget-friendly designs to more elaborate ones.