Educational Objectives
At the conclusion of this lesson, students should be able to:

- Assemble and analyze a design that presents a missing component
- Access the Rokenbok digital parts library to start a design
- Navigate, manipulate, and create a component using Tinkercad 3D
- Understand the process of designing and engineering new components using 3D modeling and printing
- Produce a high quality, 3D printed component
- Effectively communicate the details of designing and engineering a new component to complete a design

Education Standards

**NGSS**
- 3-5-ETS1-4 Engineering Design
- MS-ETS1-4 Engineering Design
- HS-ETS1-4 Engineering Design

**ITEEA**
- STL8- Attributes of Design
- STL9- Engineering Design
- STL10- Invention and Innovation
Introduction
This project is designed as an introduction to 3D modeling and printing. Students will use the components in a Rokenbok SnapStack Module or Advanced Projects Lab to build a design that is missing a component. The missing component will be researched, designed, and printed using 3D modeling software and a 3D printer. Through this experience, students will gain confidence in their ability to design and engineer their own components to solve problems.

Classroom Management
Students in groups of four can work together to build the structure of the airplane in this project. As students begin the process of designing and engineering a 3D component, it is recommended they work individually or in pairs. All four students can use the same airplane structure as they work on their design.

Resources Needed
Rokenbok Mobile STEM Lab: SnapStack, Advanced Projects, or Programmable Robotics
3D Printer/Manual
Computer with Internet
Measuring Device (Metric)

Activity Time
120-180 Minutes
Building Basics with Rokenbok
The following tips will be helpful when using the Rokenbok Student Design and Engineering System.

**Connecting/Separating ROK Blocks:**
ROK Blocks use a friction-fit, pyramid and opening system to connect. Simply press pyramids into openings to connect.
To separate blocks, pull apart.

**Connecting/Separating Rokenbok Components**
Smaller Rokenbok components use a tab and opening system to connect. Angle one tab into the opening, and then snap into place.
To separate, insert key into the engineered slot and twist.

**Snapping Across Openings**
The tabs on Rokenbok components can also be snapped across openings to provide structural support to a design.
This will also allow certain designs to function correctly.

**Attaching String:**
In some instances, string may be needed in a design.
Lay string across opening. Snap any Rokenbok component with tabs or pyramids into opening. Make sure tabs run perpendicular to string for a tight hold.

**Measuring:**
The outside dimensions of each Rokenbok connector block is 2cm³. This means the length, depth, and height are all the same.
To determine the size of a Rokenbok build in cm, simply count the number of openings and multiply by two. Repeat this process for length, depth and height.
Airplane Assembly Instructions
Follow the step-by-step instructions to assemble a Rokenbok Airplane.

Bill of Materials: The following parts will assemble one Rokenbok Airplane.

1. Building Elevator Assembly

2. Building and Attaching Wing Assembly
3 Attaching Rudder

4 Attaching Fuselage
5 Attaching Rear Landing Gear

6 Attaching Front Landing Gear
Defining the Problem
After the Rokenbok airplane has been assembled, you will notice that a key component is missing: the propeller. The propeller is used to provide thrust to the airplane, which is what moves the airplane forward.

This lesson will provide step-by-step guidance on how to design and engineer a propeller using 3D modeling and printing. The propeller will snap onto the front of the rokenbok airplane to complete the design.

Video Tutorial
Visit www.rokenbokeducation.org/takingflight to access the propeller design tutorial for this lesson. Use the project checklist on the following pages to help guide you as you progress through the design.
Project Checklist

Instructions
Check off each step in the project checklist as it is completed.

☐ Rokenbok Build Plan
Every Rokenbok 3D design activity/challenge will include a build plan. Each build plan will include step-by-step graphic instructions to assemble a design. In this example, step-by-step instructions were given to assemble a Rokenbok airplane that is missing the propeller. Check off the box when the build plan is complete.

☐ Base 3D Building Component
Every Rokenbok 3D design activity/challenge will include a base 3D building component. The base component will provide a starting point to begin the 3D design. This will also insure that the design will correctly integrate with the build plan after it has been printed. For this activity, the Rokenbok red block will be used as the base 3D building component.
Create Tinkercad Account
For learning the basics of 3D Modeling, Rokenbok recommends using Tinkercad. Visit www.tinkercad.com and create a new account.

Once an account has been created, click the Create New Design button to get started.

Understanding Tinkercad Workspace
Before any designs can be created, it is important to get familiar with the workplane and tools that will be used to create the design.
**Project Checklist**

- **Exploring Rokenbok 3D Parts Library**
  All of the Rokenbok components are also available as downloadable digital files. Visit [https://rokenbokeducation.org/education/3d-parts-library](https://rokenbokeducation.org/education/3d-parts-library) to locate the downloadable files.

- **Downloading Base 3D Building Component**
  To start designing the airplane propeller, a Rokenbok red block in .STL format will be used. Find the red block in the digital parts library and click on the .STL link to download the file.

- **Importing a Digital File into Tinkercad**
  To import a Rokenbok 3D digital file into Tinkercad, click the Choose File button that is located under the Import Tab in Tinkercad. After a file has been chosen, click the Import button to upload the file to the workplane.

*Video tutorial displays slightly older version of Rokenbok 3D Virtual Parts Library*
**Project Checklist**

**Manipulating Objects in Tinkercad**
Get familiar with the ability to move, rotate and understand the dimensions of objects in the workspace.

**Avoid Adjusting Dimensions of Base 3D Building Component**
To insure that the base 3D building component will correctly integrate with the Rokenbok design, avoid adjusting the dimensions of the base component. In this example, the Rokenbok red block has been adjusted and is no longer 20mm cubed.

**Preparing to Create Design**
Before a design is created, it is important to do research and consider the resources you are working with. Finding out the typical shape, size, and placement would be important information to consider when designing an airplane propeller. Also, make sure to check the manual of the 3D printer that will be used to make sure the size of the part being designed can be printed. Good preparation and research will produce much better results when designing new parts!

**Airplane Dimensions**
Measure and record the dimensions of the airplane below:

- Length: _______mm
- Width: _______mm
- Height: _______mm

**3D Platform Dimensions**
Measure and record the dimensions of the print platform below:

- Length: _______mm
- Width: _______mm
- Height: _______mm (Check 3D Manual)
**Start Creating Design**

Use the geometric objects in Tinkercad to start creating a propeller for the Rokenbok airplane. In this example, the box and paraboloid will be used to create the propeller. Click and drag both objects onto the workplane to begin creating the design.

Click and rotate the paraboloid 90 degrees forward as shown below.

Grab the front-midpoint of the paraboloid and stretch it out so that it measures 60mm long. Next, grab the side-midpoint of the paraboloid and reduce the size down to 4mm wide.

Rotate the paraboloid 45 degrees to the left as shown below.
Combining and Aligning Objects

Objects can be combined to make a single object. In this example, the paraboloid has been dragged to the surface of the box. Make sure the objects are touching.

Select both objects by holding down shift and clicking on both. Once both are selected, find and select the Align option located under the Adjust tab at the top of the screen. Align the paraboloid by clicking on the two middle points.

Click on the box and reduce the width to 1mm as shown below. Make sure not to adjust any other dimensions of the box.
**Project Checklist**

- **Grouping Objects**
  Once objects have been combined and aligned, it is important to group them together. Select both objects and click the Group button at the top of the screen.

- **Placing and Aligning Propeller**
  Click and drag the propeller to the surface of the red block as shown below. Next use the aligning feature to make sure the propeller is centered on the surface of the red block.

- **Creating Support Material**
  When printing sharp angles such as the 45 degree blade used in the airplane propeller, it is important to add support material to the build to insure a high quality print. Use the Wedge object to create a support for the propeller. The support should be 16mm(Length) x 17mm(Height) x 1mm(Wide).
Removing Unwanted Material

To remove unwanted material, select an object and select the “Hole” option. In this example a new wedge “Hole” will be created to remove material from the support piece. Bring a new wedge onto the workplane and rotate it 90 degrees so it is set up like the support piece. The dimensions of the new wedge should be 12mm(Width) x 13”(Height) x 5mm(Depth). After the wedge has been sized up correctly, select the Hole option. This will make the wedge look translucent.

Position the hole on the support piece. Position it so that it sits 1mm from the left edge. Raise the hole 1mm as shown.

Hold down the shift button and select both the hole and support piece. Click the Group option to execute the removal of material.
**Project Checklist**

- **Placing Support Pieces**
  In order to fully support the propeller, make two copies of the support piece by selecting it and then selecting Copy and then Paste under the Edit option. Place the three supports underneath the propeller as shown. Space them out as evenly as possible and make sure they are touching the propeller.

- **Duplicating Propeller Blade**
  Select the propeller and three support pieces and make them a group. Select the newly grouped part and then Copy and Paste.
  
  Rotate the new propeller 180 degrees and place it on the opposite surface of the red block. Use the Align option to make sure it is centered correctly on the block as shown.
### Adding Nose Cone to Propeller

Finish off the propeller by adding and aligning a nose cone on the top of the red block as shown below. Use the Paraboloid shape to create the nose cone.

![Propeller with Nose Cone](image)

### Finalizing Propeller Design

To finalize the design, select all of the objects on the workplane and group them together. The finalized propeller will change to one color. It is a good idea to check the final dimensions of the part at this point.

![Propeller Final Design](image)
**Project Checklist**

**Downloading Objects for 3D Printing**

Once an object has been designed, it can be downloaded for 3D printing. There are different formats that can be downloaded. Typically, an .STL file will be appropriate. However, checking the manual to the 3D printer being used will specify what file types will be accepted.

![Tinkercad software interface](image1.png)

**Loading Object on 3D Printing Platform**

Open up the software that came with the 3D printer. Import/open the airplane propeller design that was created in Tinkercad. Move the design to the printing platform as shown below.

Note: Each printer comes with software that may slightly vary from what is being shown below. Refer to the 3D printing manual that came with the 3D printer being used for information on how to place files on the print platform.

![3D Printing Platform](image2.png)
Project Checklist

Adjusting 3D Printer Settings
Once a file is loaded on the print platform, the next step is to adjust the printer settings to specify the quality of print desired. Usually a printer will have settings for a fine, normal, or fast prints. Slower prints usually produce higher quality parts, however, an extremely high quality print isn’t always necessary. Normal or fast prints may work better for the amount of time available.

Different printers will have more or less adjustments that can be made. Sometimes trial and error is the only way to become familiar with the optimal printing settings for the 3D printer being used. Refer to the printing manual that came with the 3D printer being used to maximize efficiency and quality of prints.

Printing Design
After the propeller has been loaded onto the print platform and the printer has been set up correctly, it is time to print the design.
**Project Checklist**

**Cleaning Printed Object**
After the propeller has printed, carefully remove it from the printing platform. Most 3D printers will automatically use support material where needed. Remove all support material including the supporting pieces added under the propeller. Tools such as a flat-head screwdriver and snips are quite helpful when removing support material.

**Attaching Propeller to Airplane**
Now that the propeller is all cleaned up, it is time to test it out on the airplane.

**Reflecting Back on Experience**
It is important to be able to explain the process of designing and engineering a new object. Reflect back on the steps that were taken to complete this design. Consider any changes that you would have liked to make to improve or enhance the design. Be prepared to share the experience of designing and fabricating the airplane propeller.