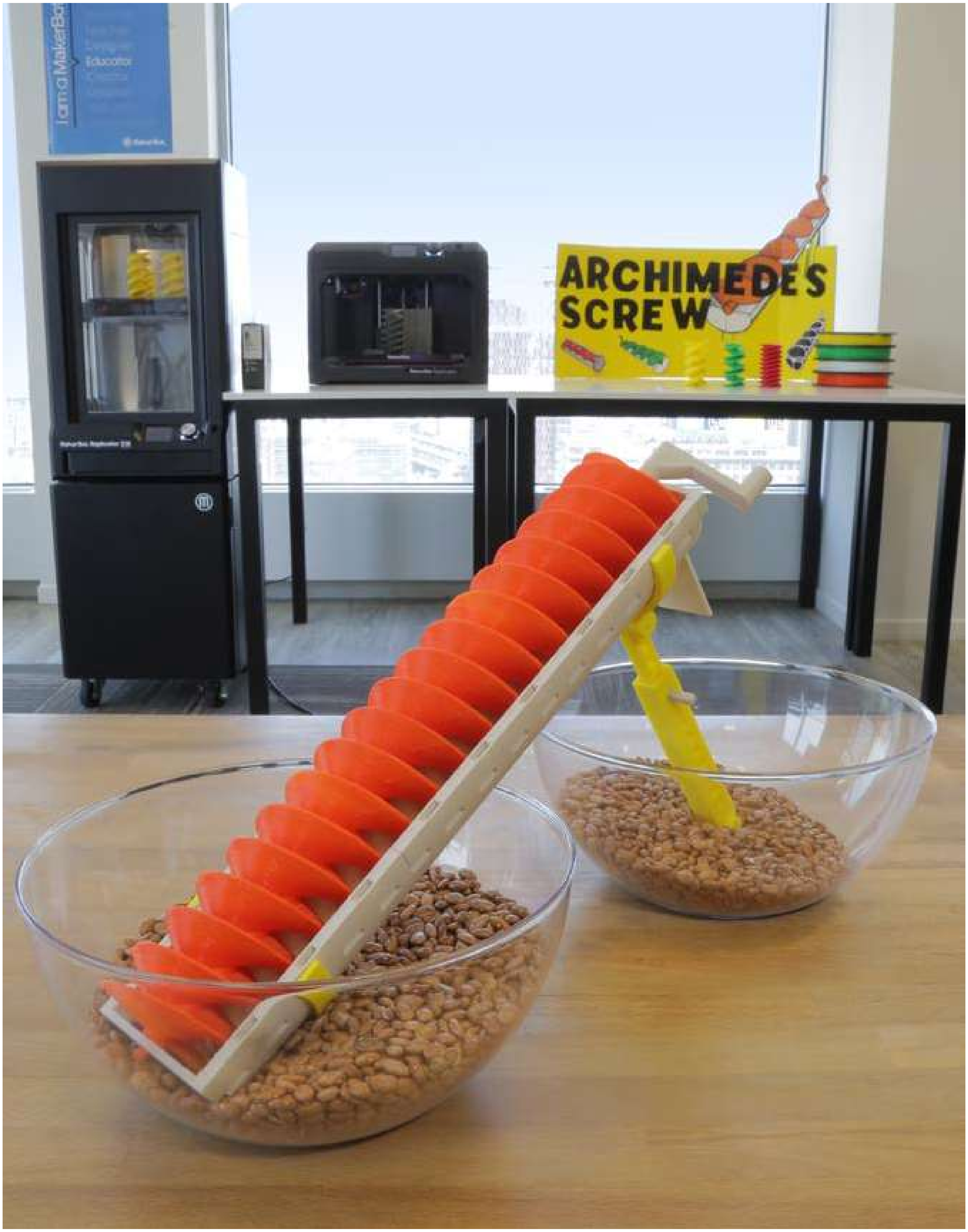
PROJECT NINE

ARCHIMEDES SCREW BONANZA



LINK: *thingiverse.com/thing:1769714* for access to handouts, videos and other materials associated with this project.

PROJECT INFO

AUTHOR
MakerBot Learning
@makerbotlearning

SUBJECT
Engineering

AUDIENCE
Grade Levels 9–12

DIFFICULTY
Advanced

SKILLS NEEDED
Some Onshape®
software experience

DURATION
10—12 Class Periods

GROUPS
3–4 Groups
6–7 Students / Group

MATERIALS
2 Large Bowls
Superglue
Bag of Dried Beans
Dual Lock Tape
Ruler or Calipers

SOFTWARE
Onshape (**web app**)

APPLICABLE PRINTERS
Works with all
MakerBot® Replicator®
3D printers

PRINT TIME
Prep: 65 hrs
Lesson: 25—30 hrs / Group

FILAMENT USED
3–4 Large Spools

"This projects brings an ancient invention to life using modern technology. While the project is definitely an investment in printing time and filament, the students' final products make this lesson well worth the effort!"

– **MakerBot Learning**

LESSON SUMMARY

The Archimedes Screw is a device believed to be invented by Archimedes, one of the world's greatest scientists, in the 3rd century B.C. It was most often used to transport water from lower ground to higher ground for irrigation, flood prevention, and more. Interestingly, it is still used today in many different applications.

Well before power tools were created, people had to cleverly use common materials to make their work more efficient. The Archimedes screw is one example of this type of simple machine. A basic design consists of a screw (helical spiral part), a tube (full or partial), and a crank. By rotating the crank, you can move large quantities of material up an incline much more efficiently than by simply carrying it. All Archimedes screw designs have the same basic components, but can take many shapes and sizes depending on the application. Check out some videos in the Thingiverse Education ™ post (thingiverse.com/thing:1769714).

In this project, students will create or modify an Archimedes screw to transport material from lower ground to higher ground. The sample file included was designed in Onshape. The students' task is to observe the sample printed screw design, and create a more efficient screw design that fits into the supplied case.

LEARNING OBJECTIVES

After completing this project, students will be able to:

› **Discuss** the history of the Archimedes screw

› **Apply** engineering principles to design a simple machine

› **Comprehend** and apply the fundamentals of parametric 3D design

› **Understand** the impact of changing design parameters

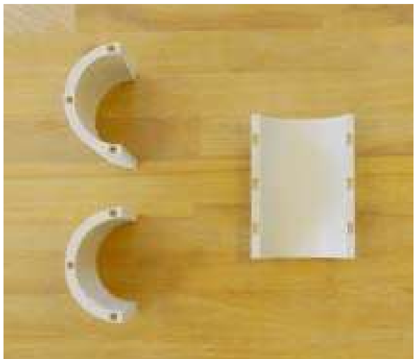
NGSS STANDARDS

HS-PS3-3: Energy Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-ETS1-2: Engineering Design Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

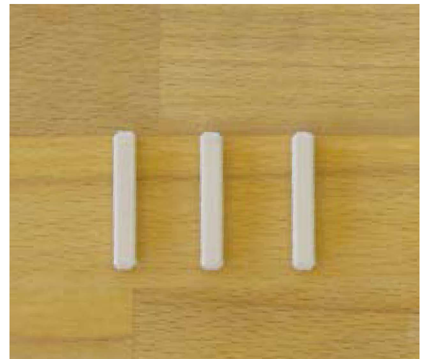
HS-ETS1-4: Engineering Design Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

TEACHER PREPARATION

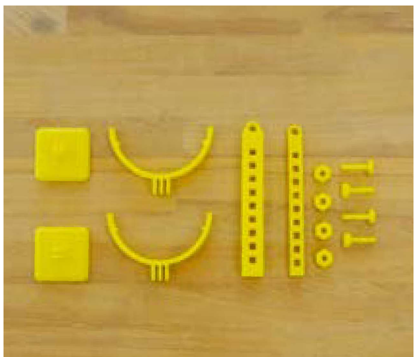


CASE BOTTOM

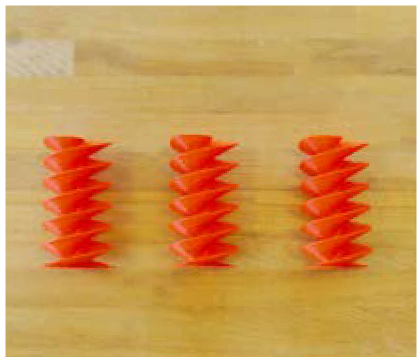
CRANK



BLADE CONNECTORS



SUPPORT PIECES

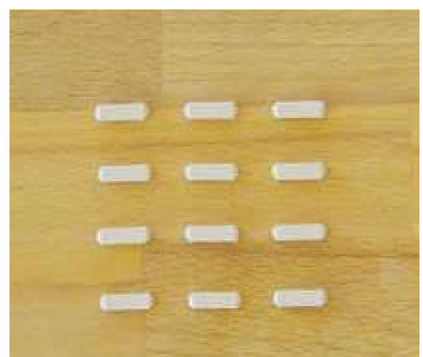


BLADE

SPILL PLATE

BOTTOM ADAPTER

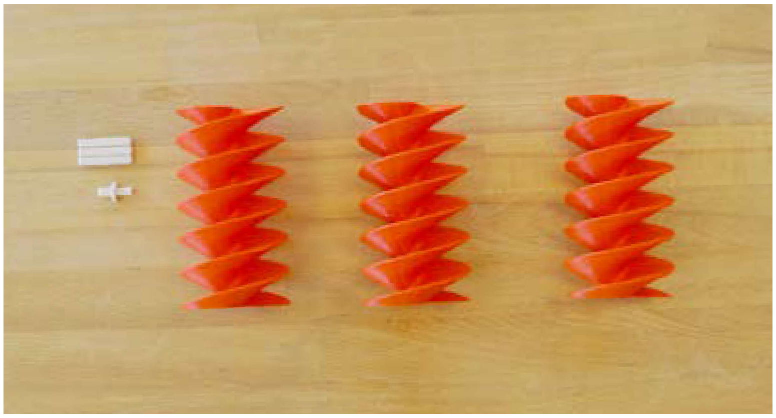
CASE BRACKET

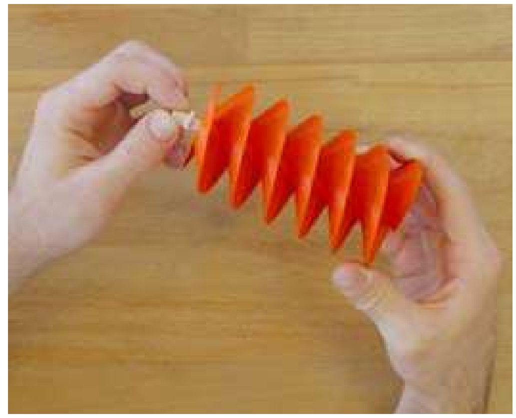


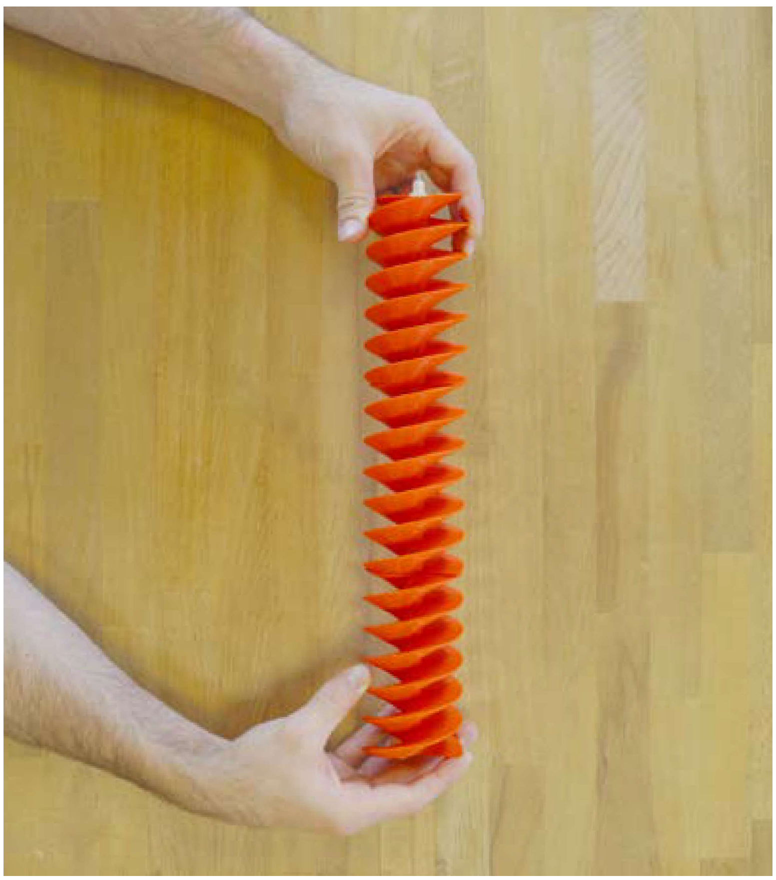
CASE CONNECTORS

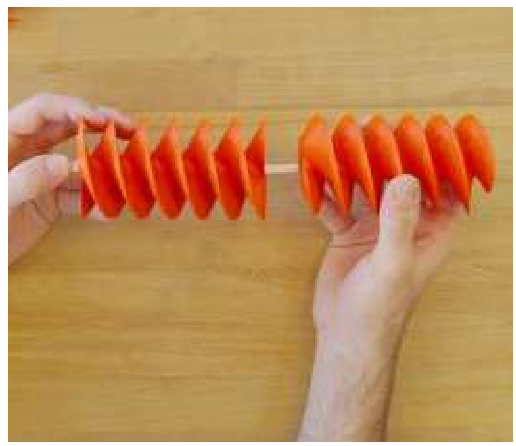
A. 3D print the sample files from Thingiverse®: Leave yourself at least a week for printing and assembly. Print the following quantities of parts:

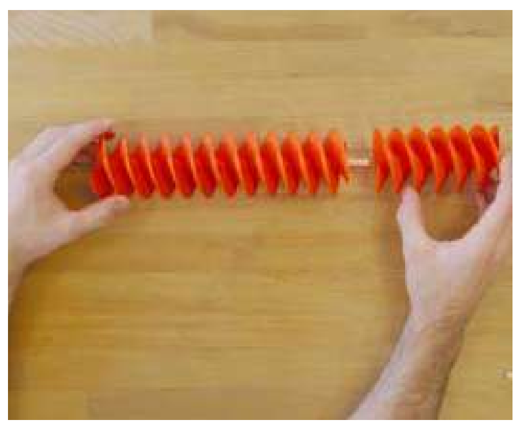
- 3x Case Bottom
- 3x Blade
- 1x Bottom Adaptor
- 2x Case Bracket
- 1x Crank
- 2x Support Clamp
- 1x Support Bar Top
- 1x Support Bar Bottom
- 2x Support Base
- 4x Support Nut and Bolt (you can subsitute 1/4-20 Nut & Bolt)
- 12x Case Connector (24x if you print the Case Top parts)
- 4x Blade Connector
- 1x Spill Plate
- 3x Case Top (optional - only if you want to fully enclose the screw)











Print Settings:
Support Parts

Rafts	Yes
Supports	No
Resolution	0.2mm
Infill	25%

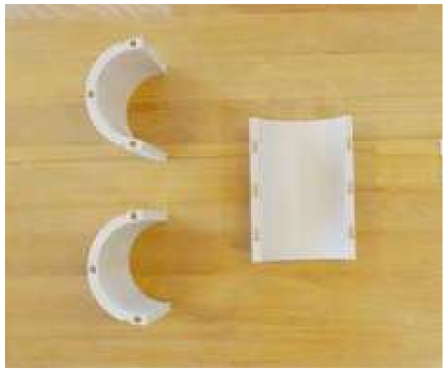
Print Settings:
All Other Parts

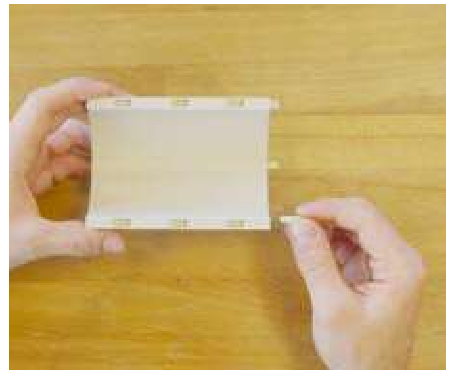
Rafts	Yes
Supports	No
Resolution	0.2mm
Infill	5%

B. Assemble the sample screw:
Glue a **blade connector** into the top hole of each **blade** part (3x). Once dry, connect the blade parts together and glue them into place.

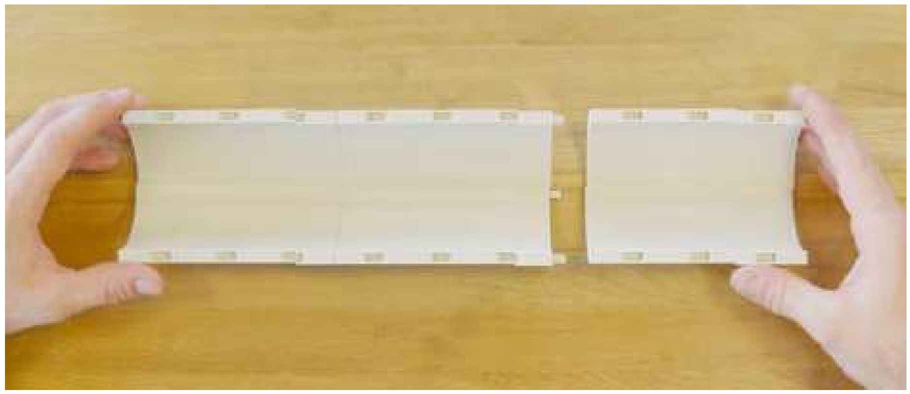
Insert the square end of the **bottom adaptor** into the bottom hole of the blade assembly and glue into place.

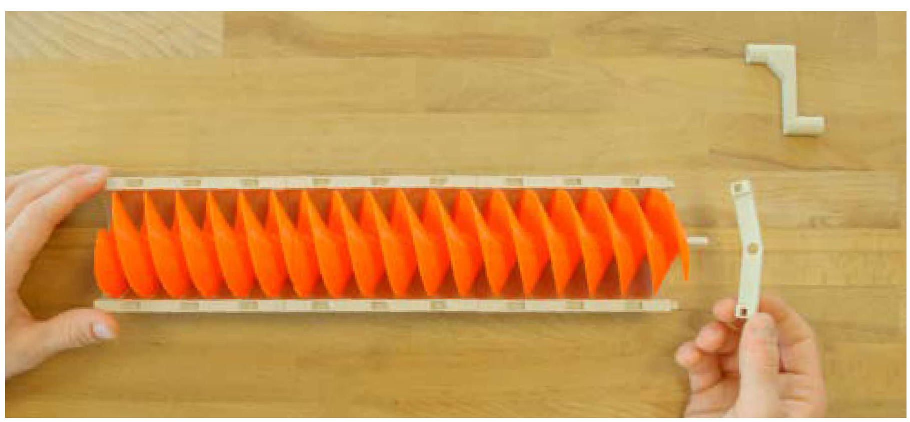
TEACHER PREPARATION





C. Assemble the case: Insert and glue **case connectors** into the 3 holes in the bottom of each **case bottom** part. Glue an additional 3 into the topmost **case bottom** part.





› Once dry, glue the 3 **case bottom** pieces together.

› Align a **case bracket** piece onto the **case connectors** at the bottom of the **case bottom** assembly. The pointed tip should be facing away from the **case bottom**. Glue the **case bracket** into place.

› Align the **spill plate** onto the center **case connector** at the top of the **case bottom** assembly. Glue into place.

› Insert the **case bracket** onto the **case connectors** at the top of the case, but **DO NOT** glue into place - this will allow you to remove the screw after demonstrating and replace it with student models.

Note: DO NOT glue the top bracket or crank - this will allow you to remove the screw after demonstrating and replace it with students' models later on. This way, you don't have to print a case for every group.

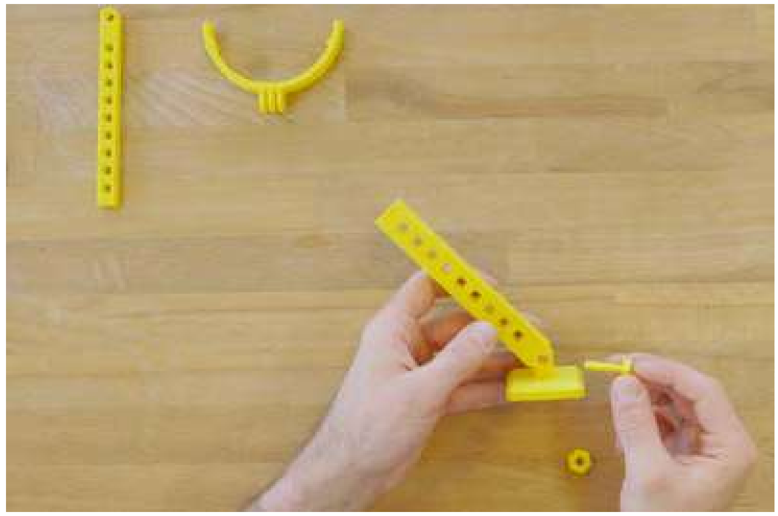
D. Assemble the supports:

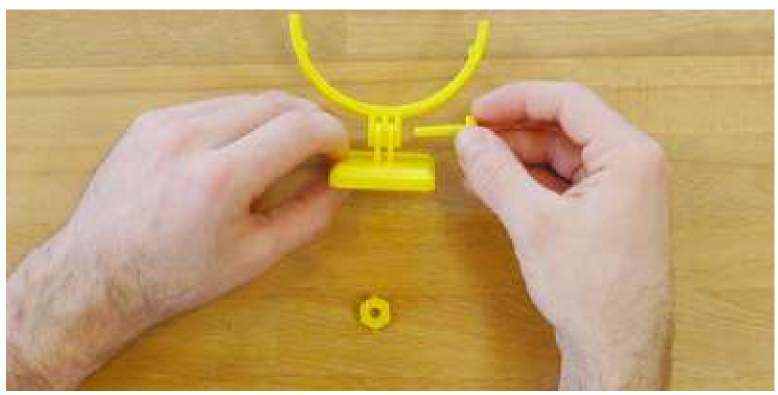
› Insert the **support bar bottom** into a **support base** and line up the holes. Insert a **nut** and **bolt** to keep the parts together.

› Insert the **support bar top** into a **case clamp** and align the holes. Insert a **nut** and **bolt** to keep the parts together.

› Insert a **case clamp** into a **support base** and line up the holes. Insert a **nut** and **bolt** to keep the parts together.

› Attach the **support base** parts to the bowls using dual lock.





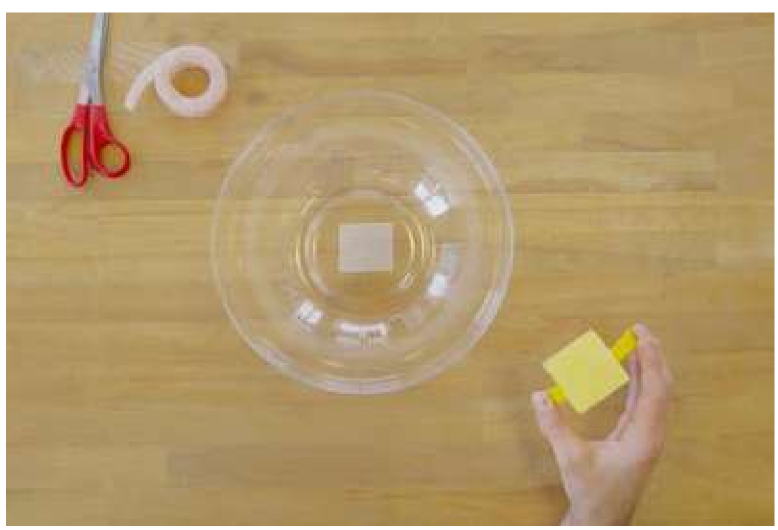
E. Final Assembly:

› Snap the case assembly onto the **case clamps**.

› Insert the blade assembly into the case by inserting the **bottom adaptor** into the **bottom case bracket**.

› Place a **case bracket** onto the top of the case by slipping it over the protruding **blade connector** and aligning it to the **case connectors**.

› FInally, slip the **crank** onto the **blade connector** and fill the bottom bowl with your material.



TEACHER PREPARATION

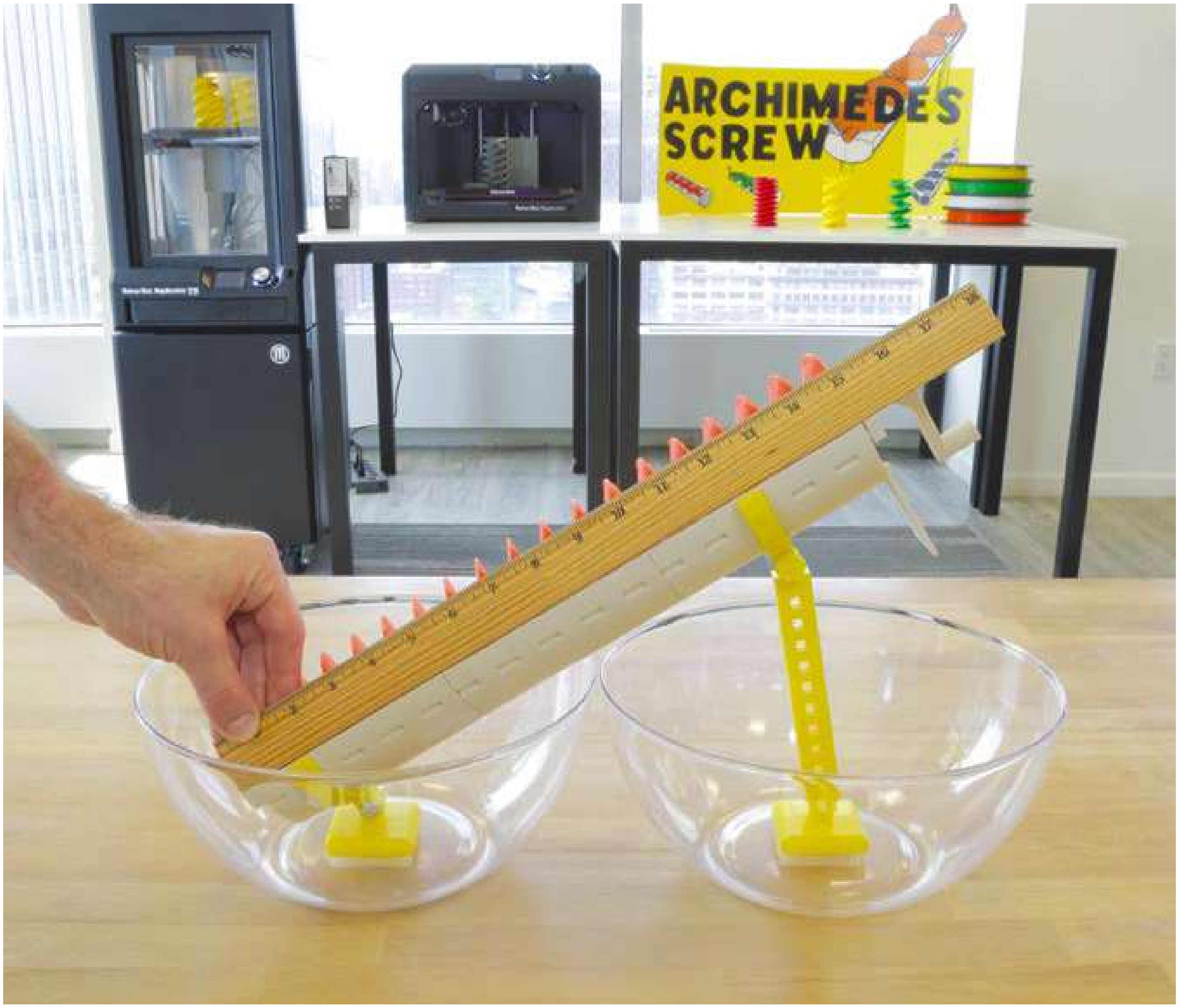
F. Demonstrate the sample screw design to students. Explain that their task is to make a more efficient screw design that fits into the case.

G. Create an Onshape account.

H. Distribute the sample Onshape file to students. The link to the file is in the Thingiverse Education post (*thingiverse.com/thing:1769714*).

STUDENT ACTIVITY

STEP 01:
PLANNING

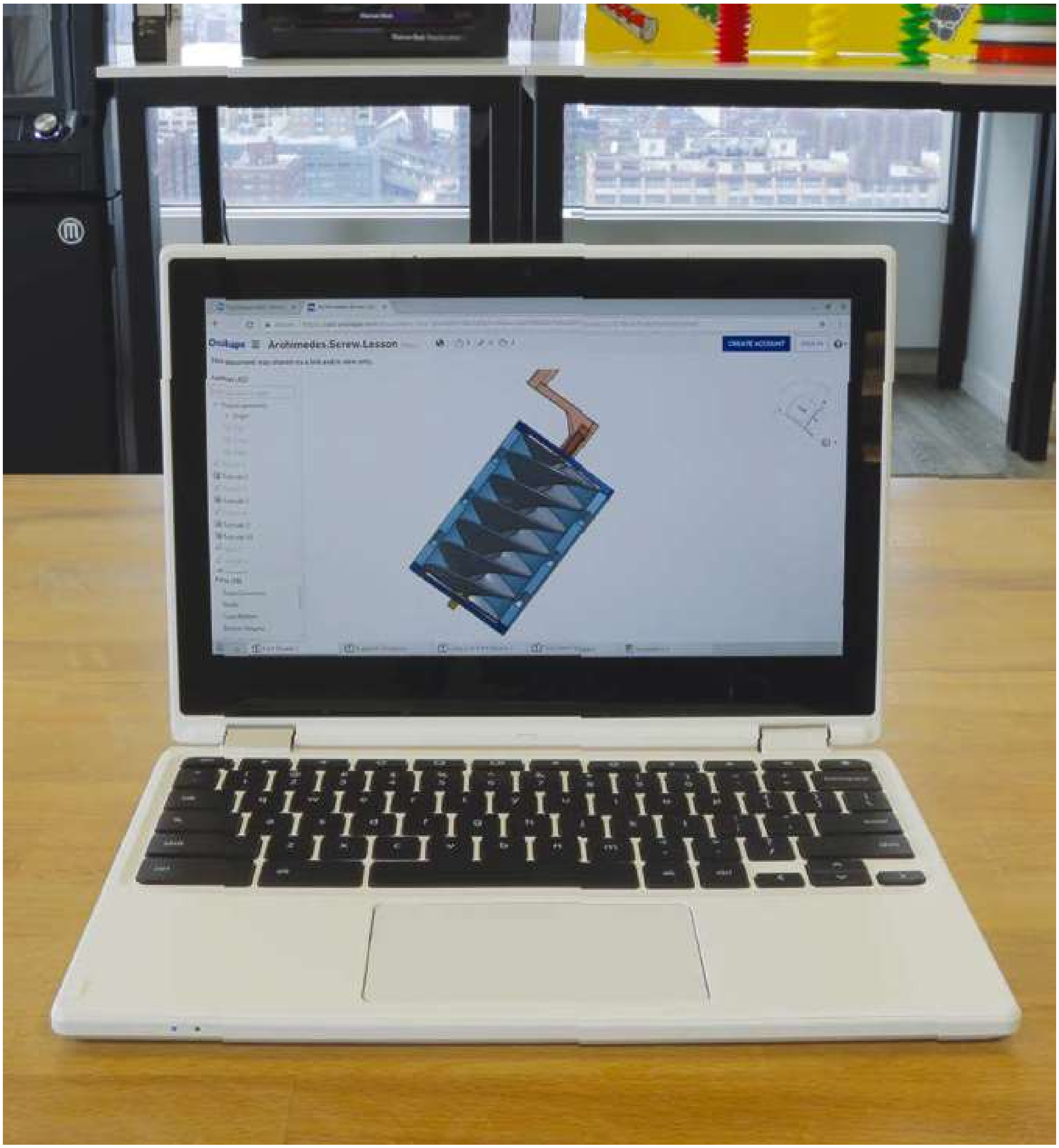


A. Measure the bowls, case, transport distance, and material before beginning to plan your screw design.

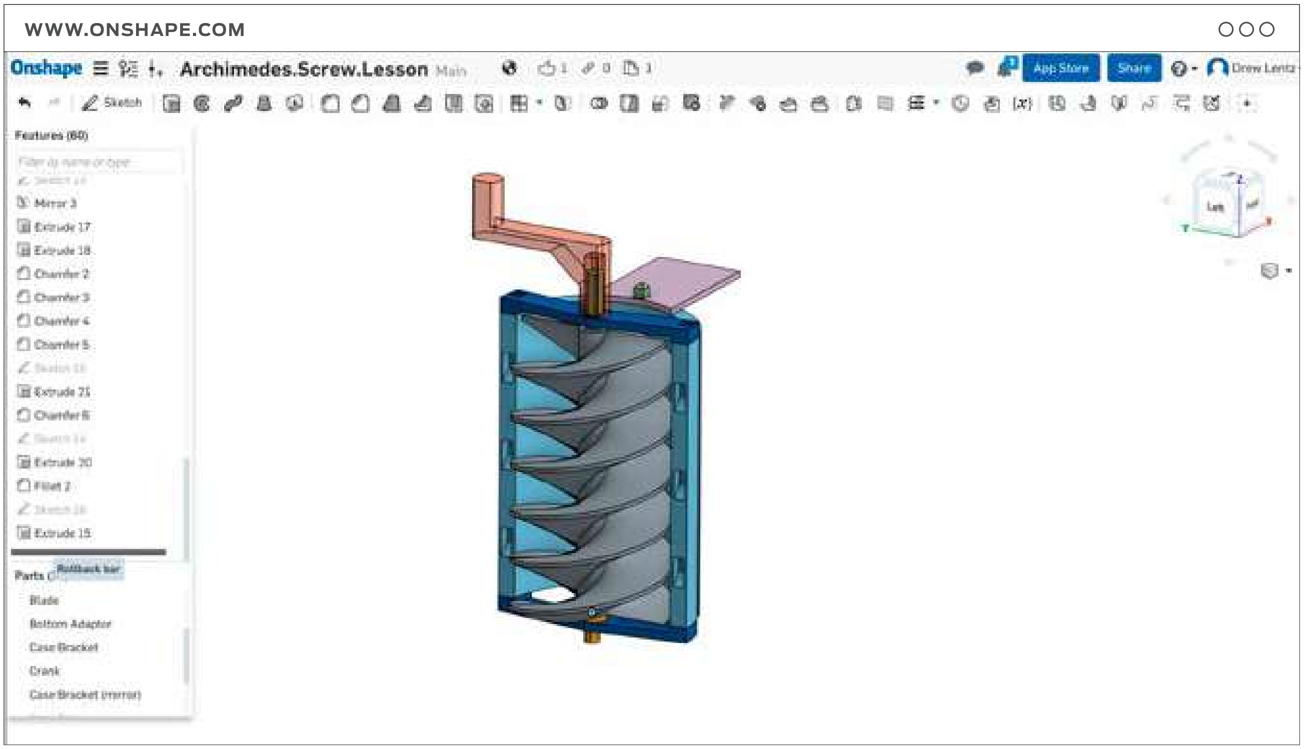
B. Analyze the printed sample screw and take notes of possible improvements.

STEP 02:
REVIEW SAMPLE CAD DESIGN

In this step, you'll experiment with changing the variables in each feature of the sample CAD model and observe the impact.



A. Open your browser and navigate to the Onshape link included in the Thingiverse Education post (*thingiverse.com/thing:1769714*).



B. Review the major design steps for each screw part. The sample is by no means the only way to create this model—but should provide an idea for how to construct your own.

The basic steps to modeling this sample are:

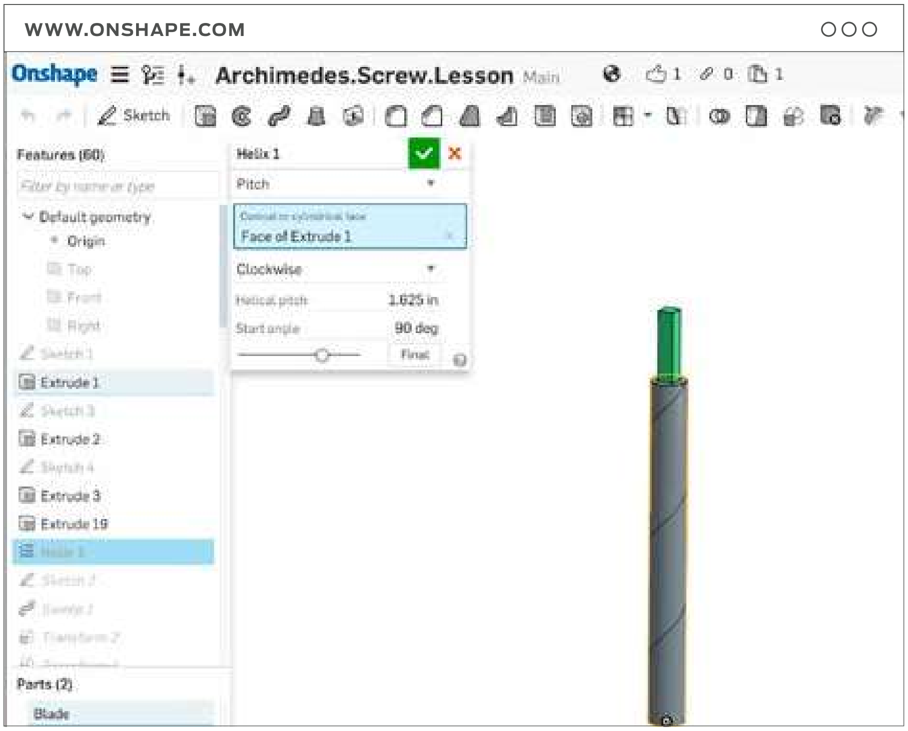
› **Sketch** and **extrude** the center cylinder.

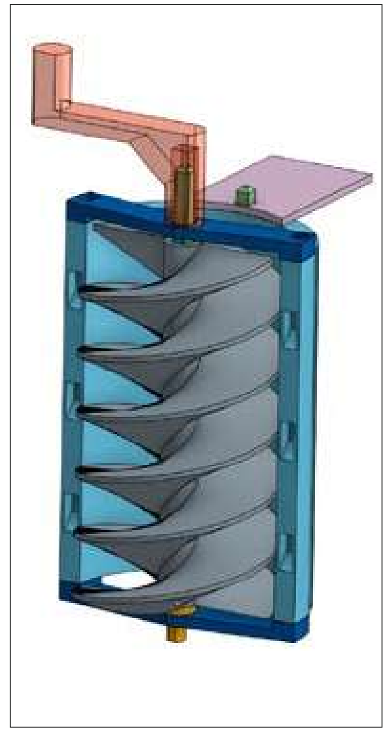
› Use **sweep** tool to create blades.

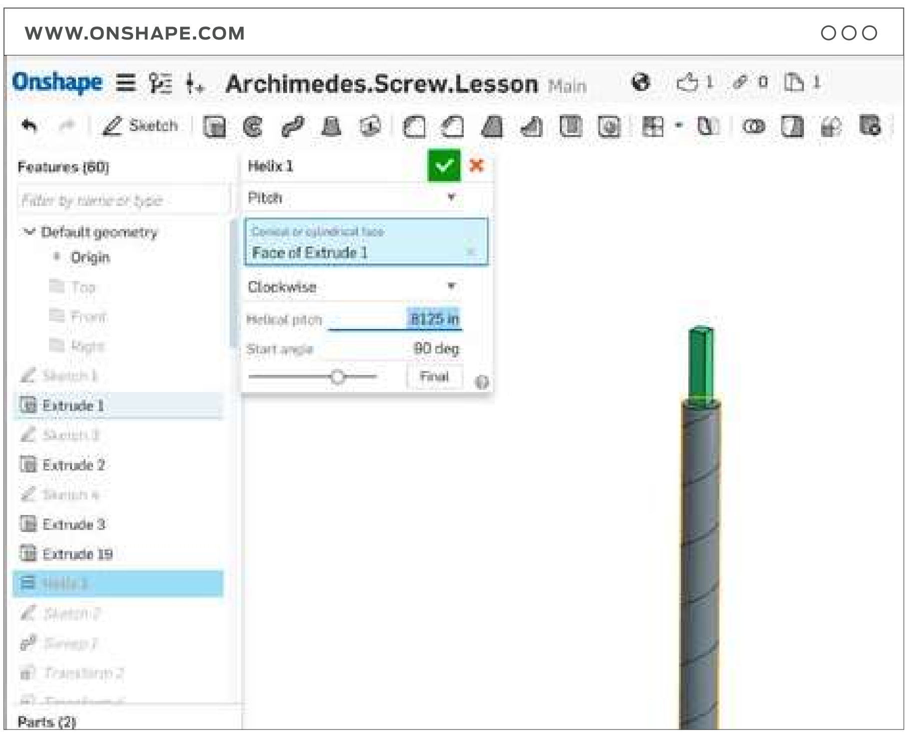
› **Sketch** and **extrude** case bottom, offset from blade. **Mirror** to create case top.

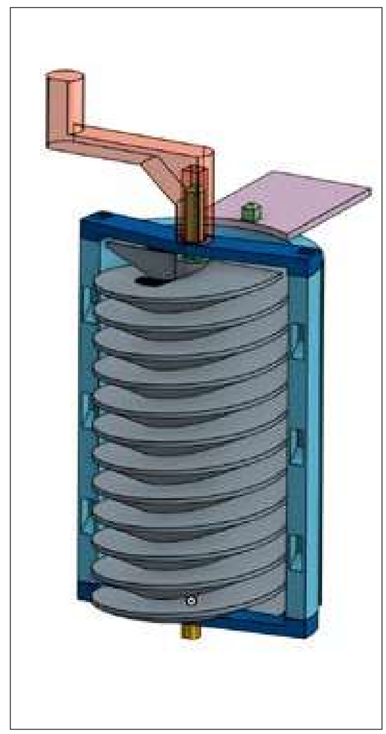
› **Sketch** and **extrude** the adaptors, brackets, crank, and spill plate.

TIP: Use the **rollback bar** in Onshape to go through the timeline and simulate the model being built.

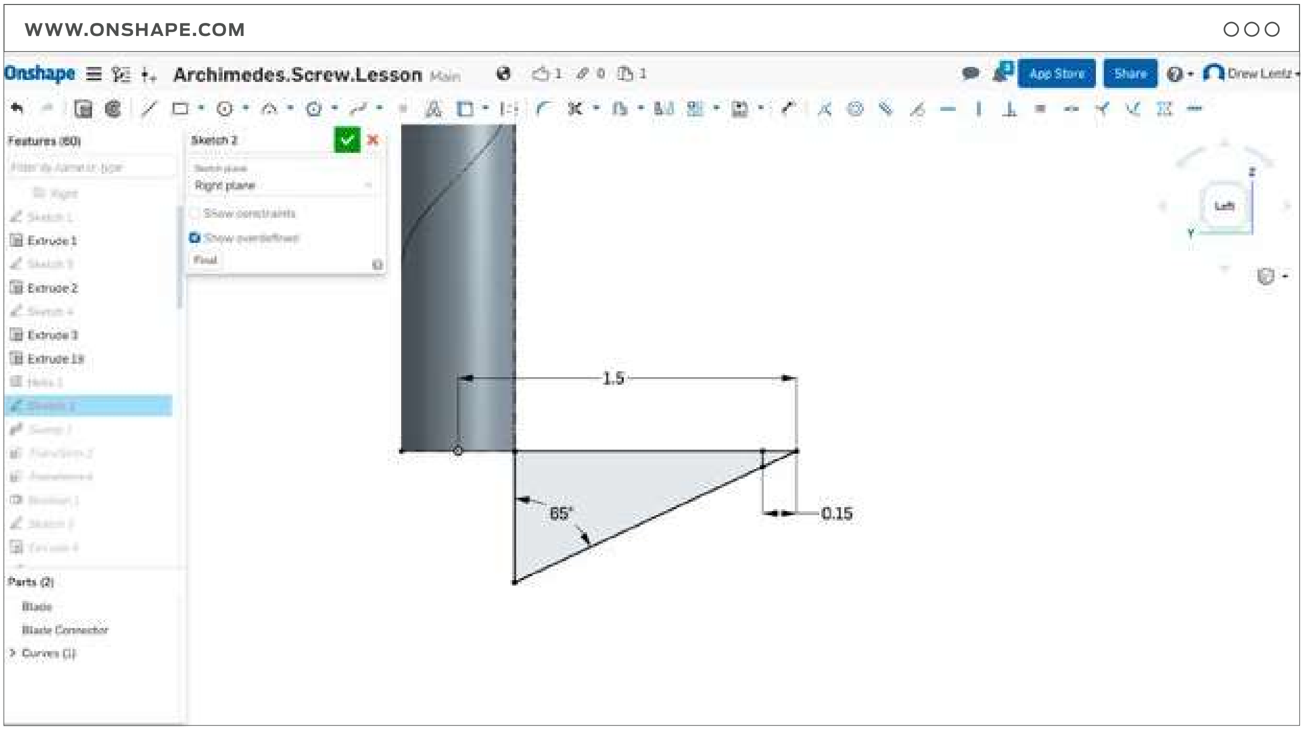


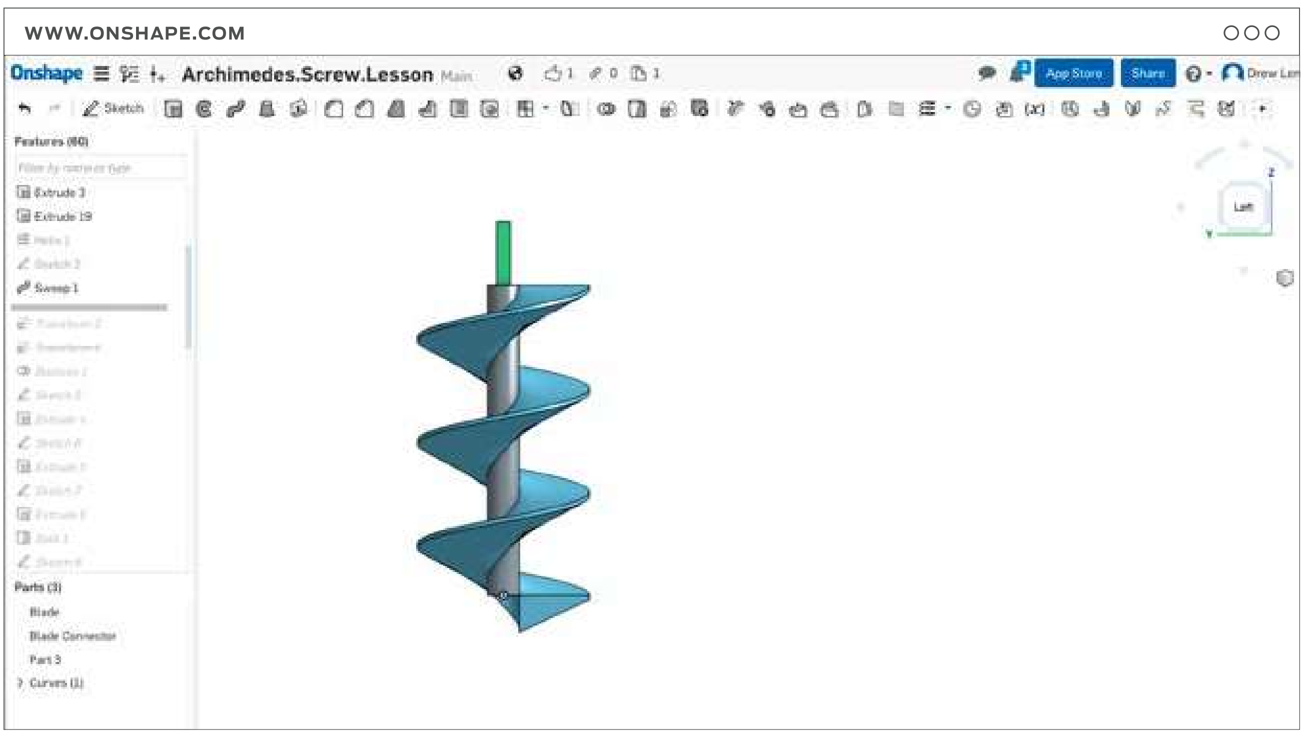




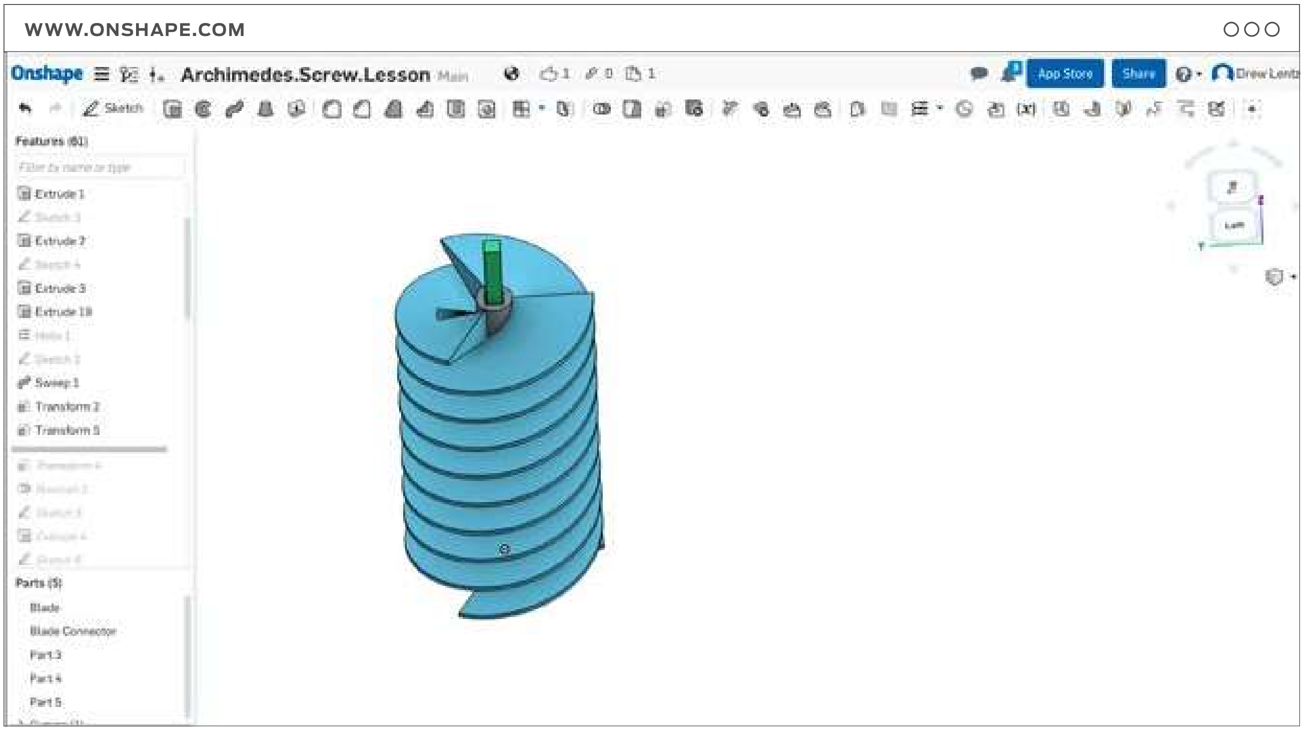


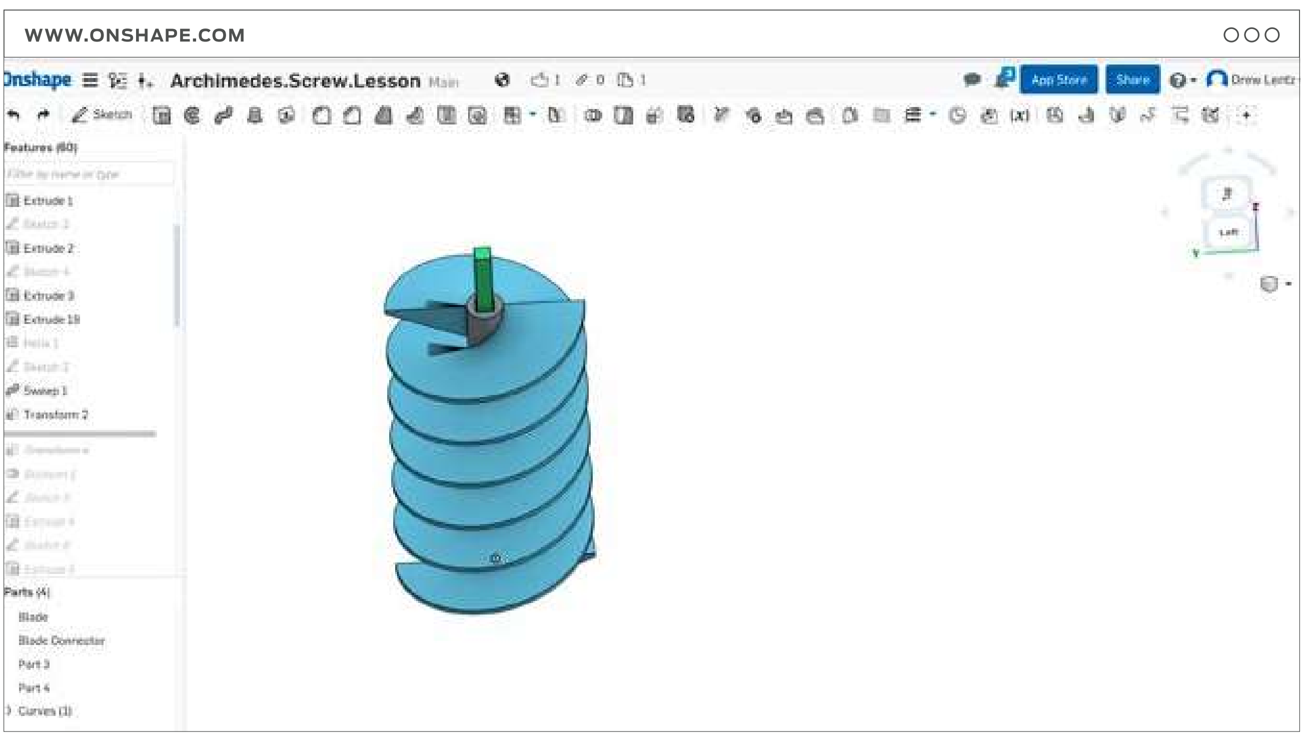
C. Edit the helix sketch: The **helix** sketch defines the pitch of the blade part. Right click to edit and experiment with this number to observe the impact on the blade. This is a quick way to dramatically affect the screw design. In these pictures, the pitch is reduced to create a tighter screw. Later, you will need to calculate an appropriate pitch for your blade.





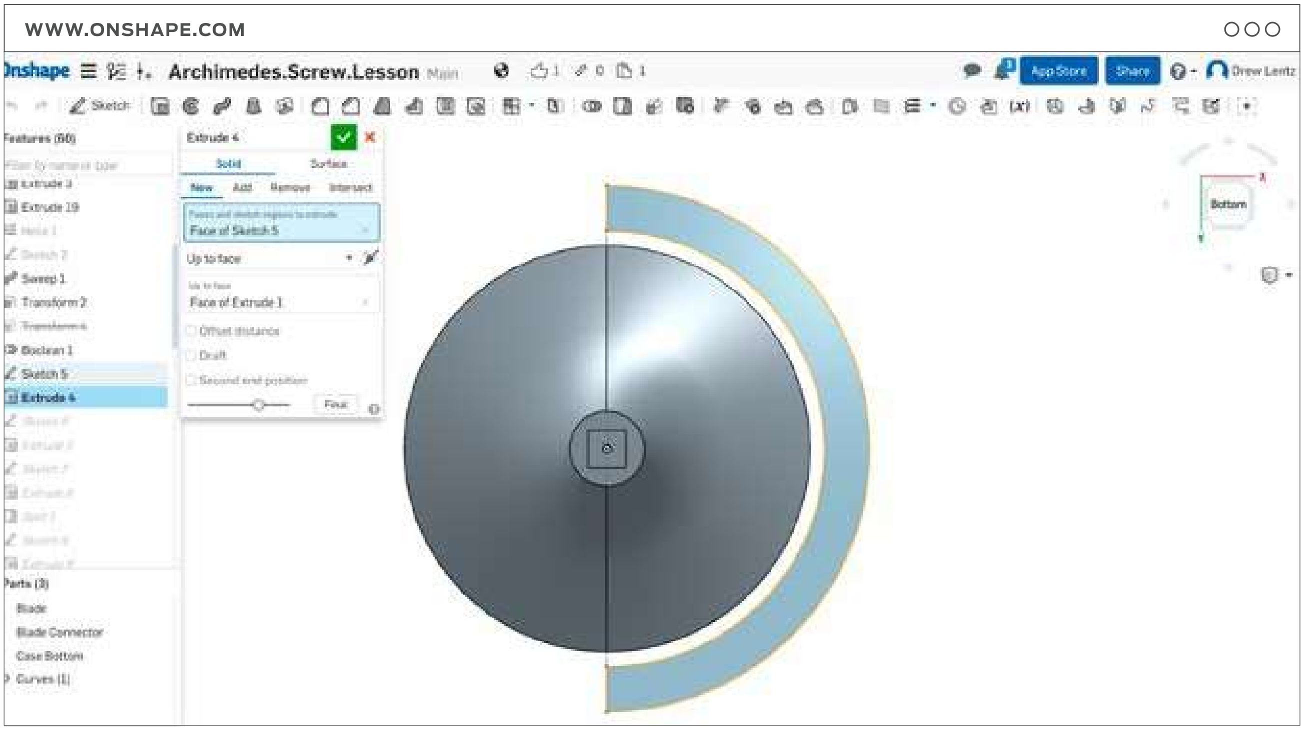
D. Edit the blade profile sketch: Experiment with changing the angle and length of the blade to observe the impact on the blade part. The 65-degree angle allows for 3D printing without the need for support material.

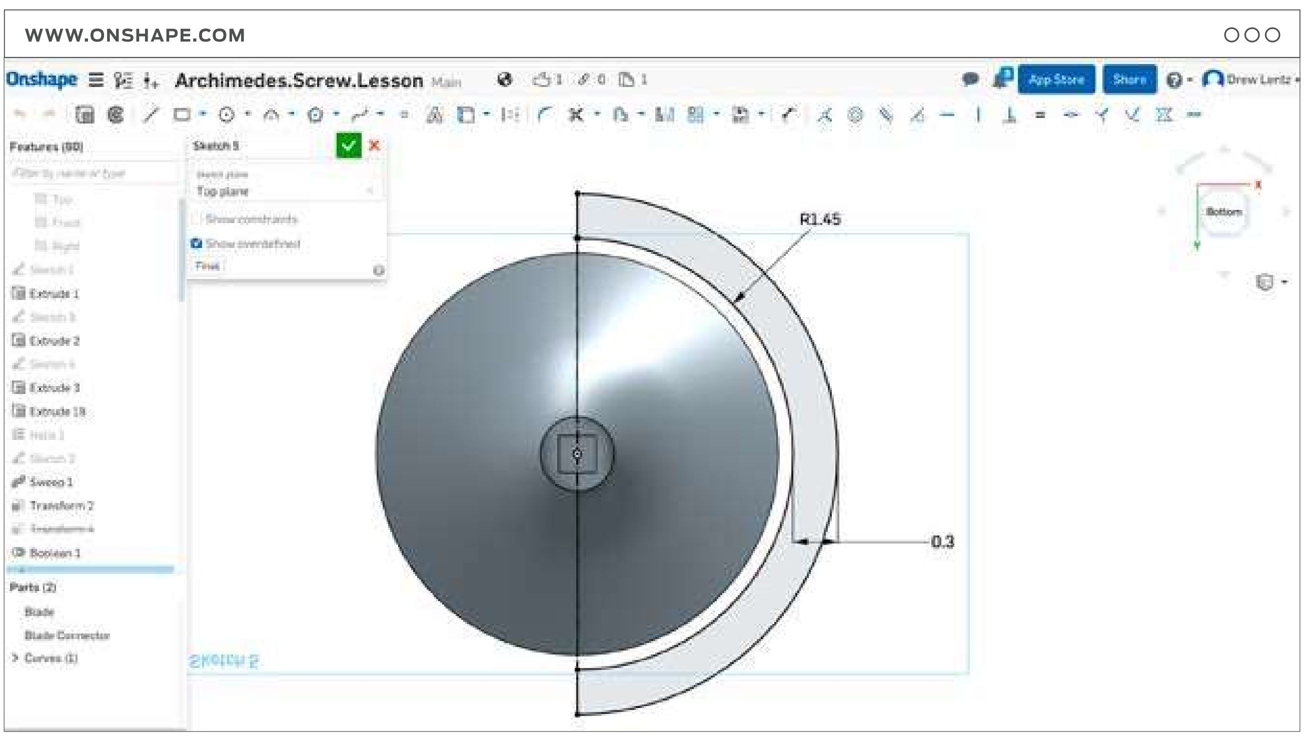




E. Edit the blade part. The blade was created using the **sweep tool** with the blade profile sketch (region to sweep) and the helix sketch (sweep path). To create a second blade using the **transform** tool, duplicate the blade and rotate 180 degrees. Experiment with creating more than 2 blades using the **transform** tool. Once you're done, merge the blade parts with the center cylinder using the **boolean** tool.

TIP: This step is only necessary if you want to create multiple blades.

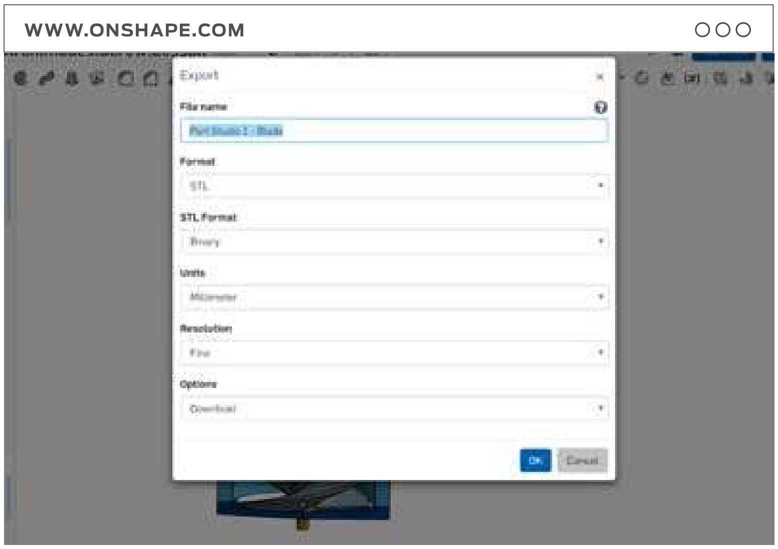




F. Edit the case sketch. This sketch defines the size and shape of the case part. Experiment with the space between the blade and the case (sample is at 0.1"). Shrinking the space will help to minimize material loss but could lead to rubbing between the blade and the case.

STEP 03:
DESIGN, PRINT, TEST, AND ITERATE

This step generally takes 3-5 class periods.



A. Export .STL files from Onshape: Right click on the part in the bottom left hand side and click **export**. Make sure to change the units to millimeters before exporting.

B. Import your files into MakerBot Print ™ and prepare for printing.

C. Print your models:

Print Settings:

Rafts	Yes
Supports	Depends on the model
Resolution	0.2mm
Infill	5%

TIP: Given that these are large prints, test small sections or small scale versions before printing out your entire assembly.

D. Finalize your design, assemble it, and get in any last-minute tests before the official testing.

PROJECT COMPLETE:
GET CRANKIN'!

A. Each group should demonstrate their design by showing how much material they can transport from the lower bowl to the upper bowl in 30 seconds.

B. Record the results for each team, while also taking note of the differences in designs between groups.

C. Discuss the different designs from each group:

› Which worked best?

› Which adjustments proved most effective?

› If you were to redesign, what would you change?

PROJECT WORKSHEET

ARCHIMEDES SCREW BONANZA

STUDENT / GROUP NAME	MATERIAL MOVED (g)	NOTES ON SCREW DESIGN

TO DOWNLOAD: *thingiverse.com/thing:1769714*

GOING FURTHER

A. Provide each group a different material (i.e. water, gravel, cereal, etc.) and have them think about what modifications would need to be made to accommodate these different materials.

B. If you don't want to involve 3D design in this project, there are great Customizer designs on Thingiverse that allow you to create custom screws without needing to actually design them.

TRADEMARKS

SCREENSHOTS

LEGAL