

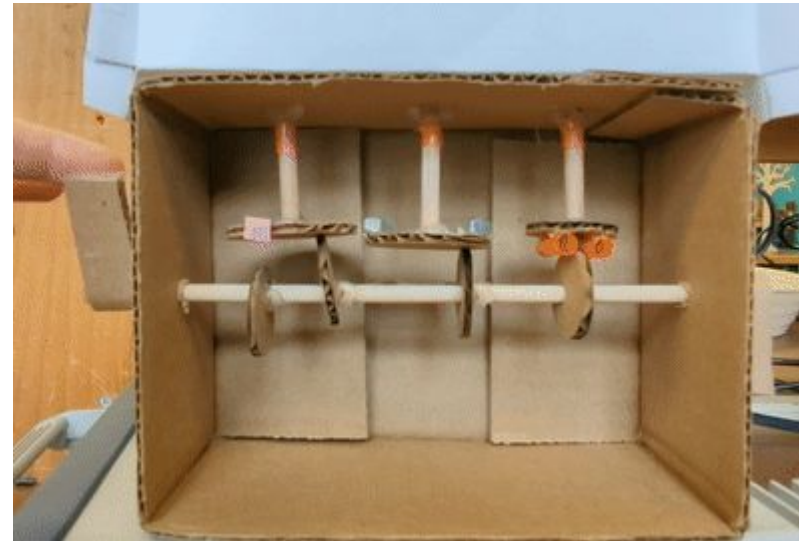
Box Automata

Maker Project

Build a robust hand-crank automata model with simple materials and tools



front



back

Use this project in any academic area

Mathematical Relationships

Natural Cycles and Systems

Civics

Personal Growth

Gender Roles in Society

Historical Events

Storytelling

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This tutorial shows how to

- Design a sample hand-crank automata that shows 3 easy mechanisms
- Build it from a small cardboard shipping box and common classroom materials
- Complete it in about an hour and a half

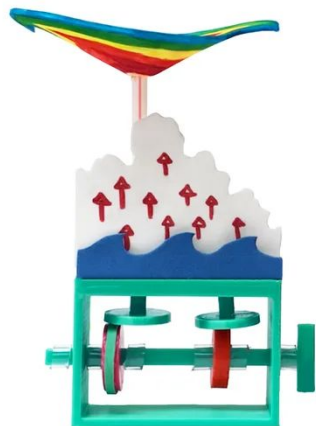


Box Automata Materials and Tools

- Wood dowels, 1/4" diameter, about 24" total
- 1 plastic straw, 1/4" inside diameter (Dunkin Donuts large straw size)
- Small cardboard shipping box or shoe box
- Pencil, standard size
- Cardstock or sturdy paper
- Craft materials to (create the characters and scenery)
- Scissors
- Hot glue gun and glue sticks
- Cutter such as diagonal cutter or wire snips
- *Optional: Utility/craft knife*

Box Automata Resources

Check out these resources to explore common automata motions, see how they happen, and brush up on tool safety.



Automata samples

- See two videos here: k12maker.mit.edu/create-projects

References for automata mechanisms:

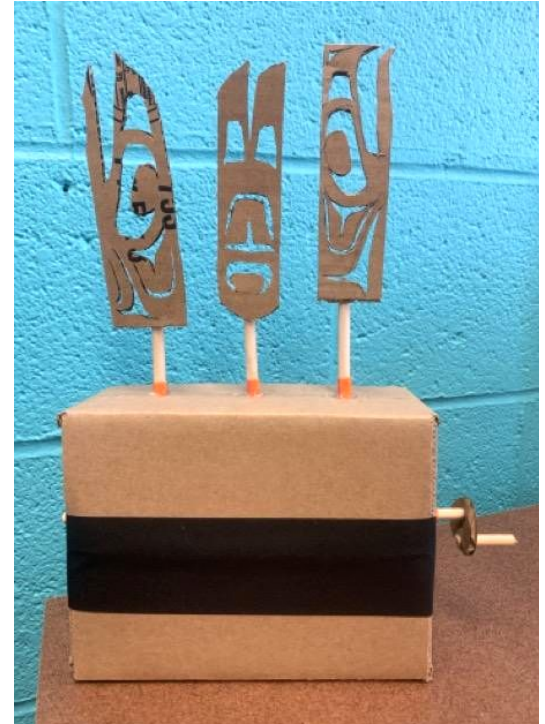
- See videos of mechanisms for Up and down, Side-to-Side, Spin Around at [instructables.com/Mechanical-Cam-Toys](https://www.instructables.com/Mechanical-Cam-Toys)

Cutters Guide

- k12maker.mit.edu/training-and-supervision

Box Automata Steps

1. Prepare the box
2. Make the mechanisms: followers, drive shaft with cams and gears
3. Make the drive shaft
4. Create the moving objects/characters, and background
5. Test, Evaluate, Improve



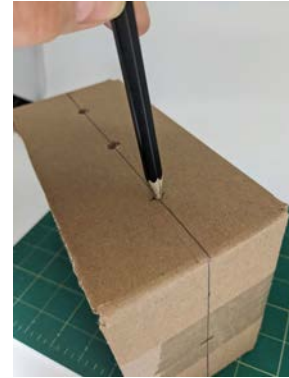
Step 1 - Prepare the Box

- Remove the flaps
- Mark a line along the top panel of the cardboard box, align it to the center as best you can. Continue it down both sides of the box
- Mark spots on the top for the vertical rods.
 - Make sure there is at least 2" (5 cm) between the dowels.
- Mark spots on each side panel for the horizontal rod about half way up.
 - Measure up from a flat surface and pick a height about half way up the side.
 - In mechanism terms the horizontal rod is called “drive shaft”.



Step 1 - Prepare the Box

- Poke holes at the marks on the top and sides of the box with a sharp pencil.
- Use a sharp pencil and push it all the way through to make a hole slightly bigger than $\frac{1}{4}$ " (6mm).
- Add guides for the vertical rods, in the top holes only.
 - Cut 1" pieces of the $\frac{1}{4}$ " diameter straw and insert them halfway through the top holes.
 - Fasten the straws in place with hot glue.
 - In mechanism terms the straws are known as "bushings"



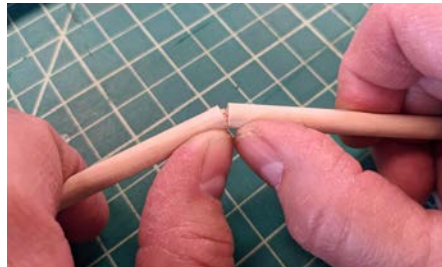
Step 2 - Make the Mechanisms

Make the mechanisms: followers, and drive shaft with cams and gears

Cut a circle of cardboard for each vertical rod. Make the circles about 1½ to 2” diameter. They do not have to be very round.

Cut wood dowels about 4” long. If the wood is not too hard, it can be cut with a utility/craft knife.

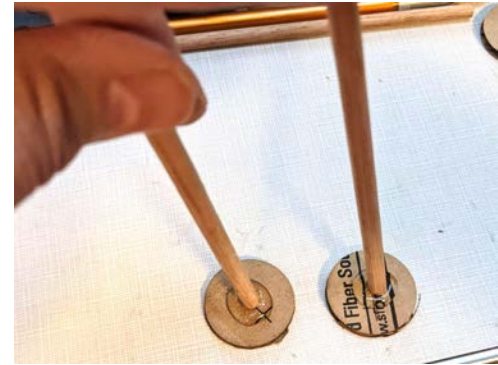
- Roll the rod while pressing down with the knife at the desired length to create a score line.
- Slowly break the rod at the score line



Step 2 - Make the Mechanisms

Fasten the wood dowels to cardboard circles with hot glue

- In mechanism terms these dowels are called “followers”. They will move according to the motion of the cams below them.



Insert the followers in the guides (bushings)



Step 3 - Make the Drive Shaft

Cut a piece of ¼” wood dowel for the drive shaft.

Make it 2” longer than the width of the box



Make the cams

Create cardboard discs by cutting round circles of cardboard (these can be laser cut or hand cut)

Mark one for a center hole and 3 for off-center holes

If possible, use a craft knife or utility knife to mark a cross hole. If that is not possible use a push pin or very pointy screwdriver

Poke holes most of the way through with a pencil - the cams should fit snugly on the drive shaft. (These holes are not as big as the holes on the box.)



Step 3 - Make the Drive Shaft

Assemble discs on drive shaft and install it in the box.

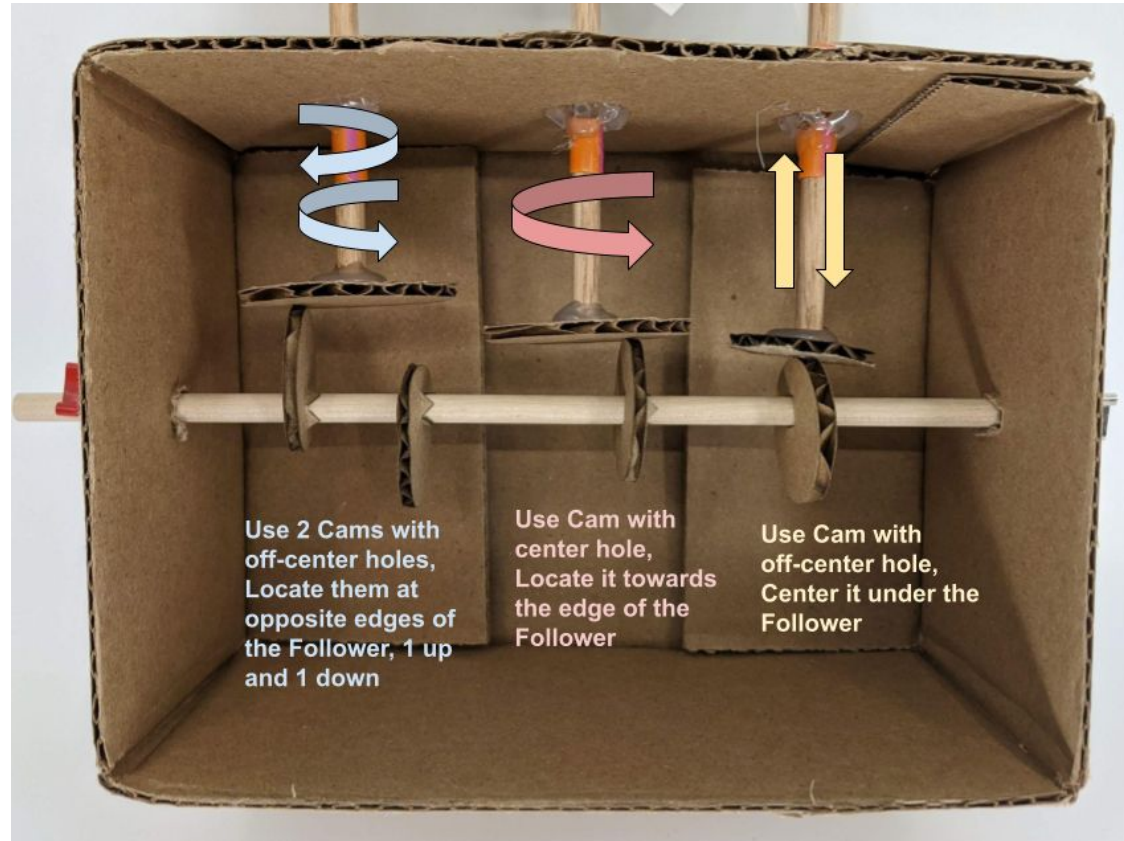
Keep the drive shaft in place horizontally by putting fasteners on the outsides of the box.

- These can be PVC tubing, small cardboard discs, rubberbands, tape, binder clips, zip ties, etc.
- In mechanical terms these are called “thrust bearings”

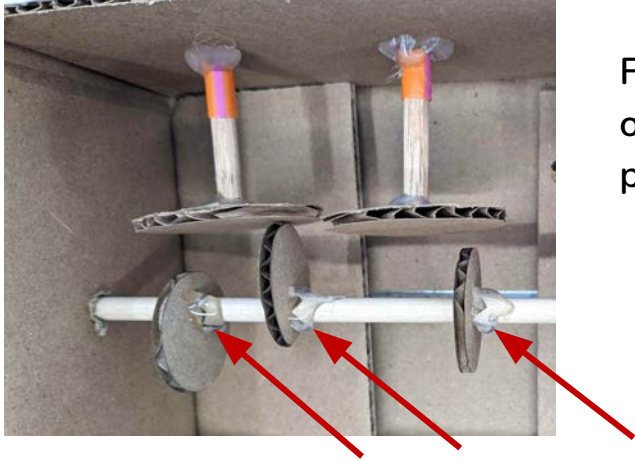


Step 3 - Make the Drive Shaft

Adjust the cams such that they are perpendicular to the drive shaft and line up appropriately under the followers

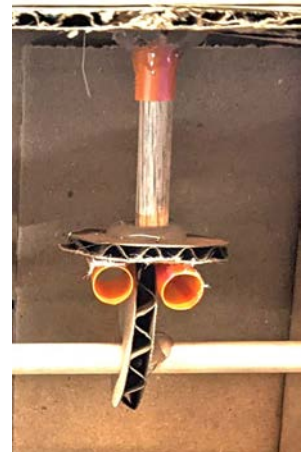


Step 3 - Make the Drive Shaft



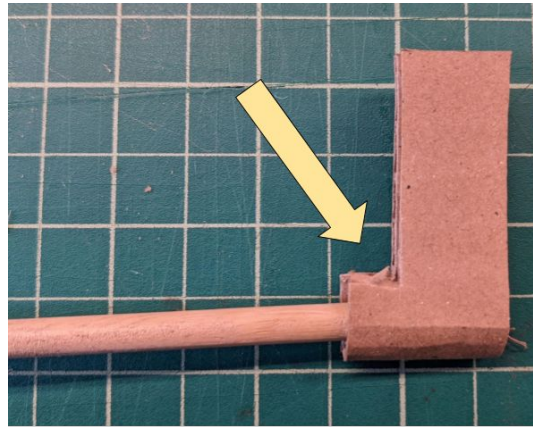
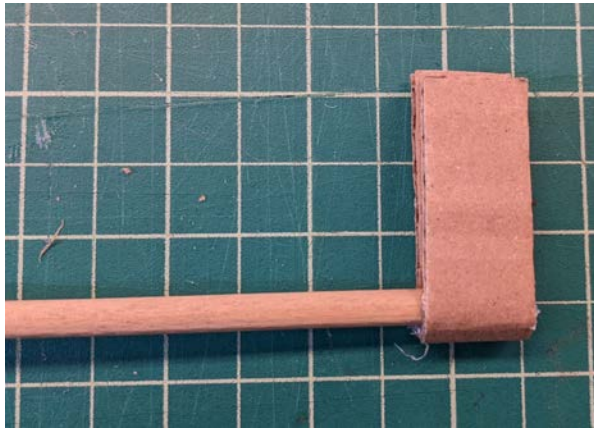
Fasten the cardboard discs (cams) and the outside fasteners (thrust bearings) in place carefully with hot glue.

To keep the Up-Down Follower from unintentionally spinning, add 2 pieces of the plastic straw to the bottom of the follower. Make sure the space between the pieces is wide enough for the cam to slide easily.



Step 3 - Make the Drive Shaft

Make a handle from a strip of cardboard and add it to one side of the drive shaft. The handle shown on the right below is trimmed so less of the handle rubs against the box.



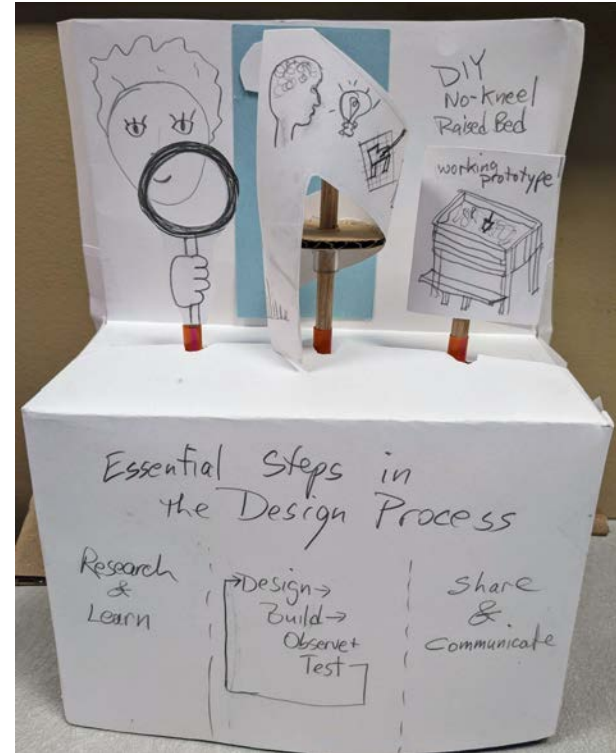
Step 4 - Create Moving Objects & Background

Design the background and moving pieces

If you have not designed the scene yet, take some time to think sketch and refine your thematic goals.

The sample project had technical and thematic goals.

- The technical goal was to show how to build a cardboard box automata with three different reliable mechanisms.
- On the thematic side, the goal was to express the essential steps in the Design Process



Step 4 - Create Moving Objects & Background

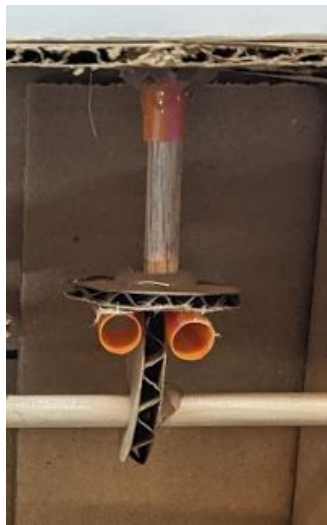
Build prototypes out of simple materials and try them out

- For this prototype, the characters and objects are made from cardstock and lightly glued to the follower rods with hot glue. All graphics are drawn in pencil.
- Fasten the prototypes of the object/characters to the follower rods in such a way that you can adjust them and/or replace them later with the final pieces.
- Check that the pieces do not conflict (bump into each other) when they are moving.

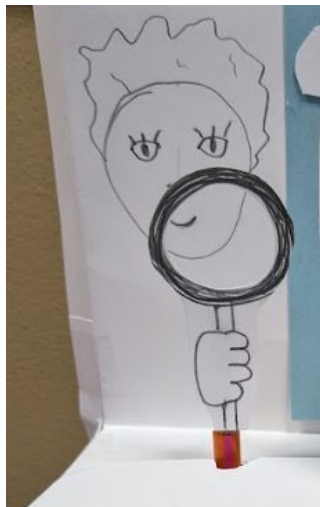


Step 4 - Test, Evaluate, Improve

Common problem: Up-down character/object rotates unintentionally



Attach straws to the follower disc and check that it is aligned with the cam on the drive shaft



Use a background piece to prevent the moving piece from rotating.



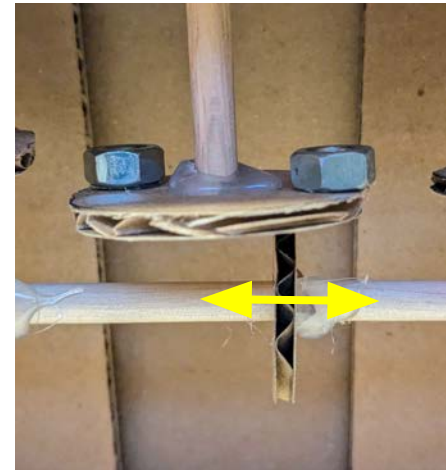
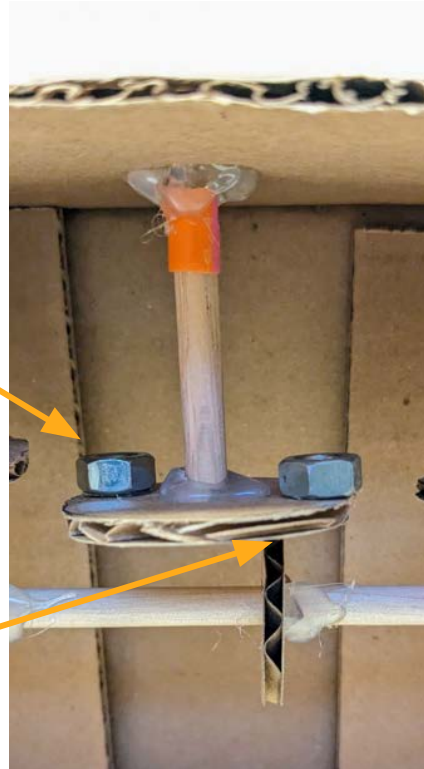
Add a second vertical rod and bushing. Attach it to the main one.

Step 4 - Test, Evaluate, Improve

Common problem: Spinner doesn't spin at all or at desired speed

Increase the traction between the follower disc and the drive shaft disc by adding weight to the follower

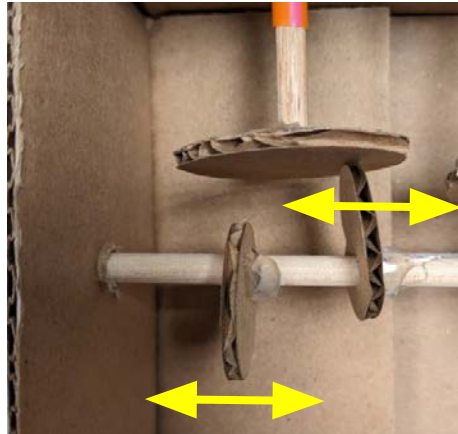
Increase the traction between the follower disc and the drive shaft disc by making the mating surfaces rougher.



Change the rotating speed of the follower by sliding the cam on the drive shaft closer or farther from the center of the follower rod

Step 4 - Test, Evaluate, Improve

Common problem: Side-to-Side rotates too much or too little, or loses alignment with scenery.



Change the rotating distance of the follower by sliding the cams on the drive shaft closer or farther from the center of the follower rod



Use a background piece to prevent the moving piece from over-rotating