The Maker's Journey:
Precision in Production

Linkage Lesson

Introduction:

Manufacturing progress has often made use of one foundational idea: **rotary motion is easy to produce and incredibly versatile**. Early factories generated it with water wheels and distributed it through overhead line shafts running the length of the factory. Any machine that needed power—lathes, drills, looms, planers—connected to that rotating shaft using belts and pulleys. When electric motors replaced water power, the source of rotation changed, but the engineering problem did not. Machines still needed a way to turn a spinning input into the precise, repeatable motions required for cutting, shaping, feeding, or assembling materials.

This is where linkages come in. Linkages are mechanical systems that transform the rotary motion into straight-line travel, back-and-forth motion, timed indexing, gripping actions, and more. The motions may look simple, but each one depends on carefully designed mechanical relationships. Modern CNC machines still rely on these same principles—only now the motions are controlled with far greater precision and guided by computer instructions.

What Are Linkages?

Linkages are mechanical systems that transmit motion and force from one point to another to accomplish specific tasks. They consist of rods or levers connected by joints or hinges that allow for movement. Linkages convert input motion into the desired output, enabling machines to perform complex tasks repeatedly, and with precision.

Overview

In this activity, students explore the same engineering principles that powered historic factories and still drive today's advanced manufacturing. By experimenting with how linkages change motion, they learn:

- how rotary motion can be transformed into linear, oscillating, or intermittent motion
- how small changes in geometry affect speed, force, and precision
- how engineers design mechanisms to solve specific motion challenges

This hands-on experience helps students see that behind every automated process—whether a 19th-century drill press or a modern pick-and-place robot—there is a clever mechanical system turning rotation into purposeful, repeatable action.

Materials

- **Part 2 Linkages** Box

  Each box contains enough materials for 10 students to build their own linkage mechanism.

  10 Cardboard bases
  40 Linkage strips
  2 sheets of quick returns (each sheet contains 3 different types)
  4 Bell cranks
  5 Scotch yokes
  Colored index cards
  Brad fasteners and washers, 2 bags
  Dowels and 1” circles, 1 bag
  Paper cups for glue
  Rubber bands

- Materials from Assembly Line Challenge
  - Each student gets: 1 Crank, 2 Guides, and 2 Pivots
- Glue, paintbrushes, scissors, nail and cardboard scrap, tape, ruler from Assembly Line Challenge supplies.
- Example Linkage Diagrams

Outline

1. Introducing the activity:

   Two hundred years ago, if you wanted to punch a hole in a sheet of metal, you used a hammer and your muscles. If you had to do it a thousand times, you’d be exhausted – and likely missed your mark more than once. Then came the linkage. By connecting a few metal bars to a water wheel, we created a machine that was faster, never got tired, and never missed its mark.

   Whether powered by a water wheel or by today’s high-speed motors, the concept of turning rotary (spinning) motion into precise, repetitive movement remains the same for manufacturing. Machines that crush grain, cut wood, weave fabric, or assemble smart phones, all rely on linkages to work.

   Even the most advanced robot is a collection of pivots and guides like you have before you, moved by a motor that – just like the water wheel – only knows how to spin.

Your linkage isn't just moving cardboard; it's a physical program. You are 'coding' with the cardboard components to repeat the same outcome reliably and precisely.

2. Linkage examples

   Use the examples to show some of the many ways the strips, pivots, and guides can be used to control the output.

   Cranks are attached to the boards with a brad fastener. Use the nail and scrap cardboard to safely make holes in the cardboard. TIP: Use a pencil to slightly enlarge the hole so the fastener can spin freely.

   The linkage strips are hole-punched at one end. This will slide over the wooden dowel on the crank. The strips can be cut to any length. However, there is a minimum length needed to make sure the crank can spin all the way around. Connect multiple strips together with brad fasteners. Again, use a pencil to slightly enlarge the nail hole so the linkages easily move past each other and do not stick.

   The bell cranks, scotch yoke, and quick returns can help create specific movements. The larger holes are designed to fit over the pivots, the longer slots typically fit and move over the crank handle, and the smaller holes are for brad fastener connections.

   TIPS:

   - The extra circles can be used as spacers to help support connections or lift linkages higher on pivots.
   - Rubber bands can be wrapped around the ends of dowels to hold components in place or cut and attached between components to restrict motion or act as a spring to move pieces back into place.
   - Test often before permanently attaching pivots or guides. Small changes in the length of linkages or the placements of pivots and guides can create big changes in the output of machine.

3. Build & Design

   Decide which type of mechanism to build and gather the parts. Before attaching components to the board, lay out the pieces to get a sense of how long to make linkages and where cranks and guides will need to attach. Tape guides and pivots to the board until you are sure of their final locations and then glue them on.

Your final movement may remind you of a machine, or something else – a flapping bird, waving flag, or chomping mouth. Use the colored cards to create a final design and bring your mechanism to life!