Liquid Lift

A Hydraulic Arm Outreach Activity

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Team Information

Team Name: Data Science & Informatics

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Activity Overview

Outreach Activity Title: Liquid Lift: Build and Operate a Hydraulic Arm

Field(s) of Engineering: Mechanical Engineering, Biomedical Engineering

Grade Range: 6th–8th Grade

Activity Description

Students operate a tabletop robotic arm powered by water-filled syringes and clear tubing. By pushing and pulling syringe plungers, kids control the arm to grab and move small objects in a "rescue mission" challenge, discovering how hydraulic pressure transfers force, the same principle behind excavators, car brakes, and prosthetic limbs.

Student Learning Objectives

Following UF CITT guidelines[1] and Bloom's taxonomy action verbs:

1. Students will be able to **explain** how pushing or pulling one syringe moves another syringe through a water-filled tube (Pascal's Law).
2. Students will be able to **predict and test** how using syringes force changes how far and how strongly the hydraulic arm moves (force vs. distance).
3. Students will be able to **compare** hydraulics, pneumatics (air), and electric motors and describe one reason an engineer might choose each for a real machine.

[1] https://citt.ufl.edu/resources/course-design-basics/analyze-and-design/writing-slos/

Materials and Budget

Item	Source	Qty	Unit $	Total $
20mL Plastic Syringes, 10-pack[1]	Amazon	1	9.99	9.99
Eastman 1/4" Clear Vinyl Tubing, 10 ft[2]	Amazon	1	4.70	4.70
Corrugated Sheets, 12-pack[3]	Zoro	1	26.28	26.28
KTOJOY Natural Wood Craft Sticks, 200-pack[4]	Amazon	1	4.99	4.99
Gorilla Mini Hot Glue Gun Kit + 30 Sticks[5]	Amazon	1	20.99	20.99
Amazon Basics Assorted Rubber Bands, 0.5 lb[6]	Amazon	1	6.36	6.36
ACCO Brass Paper Fasteners 3/4", 100-pack[7]	Amazon	1	7.99	7.99
Liquid Food Coloring Set, 12 colors[8]	Amazon	1	8.99	8.99
ValeforToy Mini Jungle Animals, 54-piece[9]	Amazon	1	9.98	9.98
Pen+Gear Tri-Fold Poster Board, 28"x40"[10]	Walmart	1	3.12	3.12
Scotch Self-Seal Laminating Sheets, 10-pack[11]	Amazon	1	8.52	8.52
Colored Markers Set (12-pack)	Walmart	1	6.99	6.99
Plastic Storage Bins (3-pack)	Dollar Tree	1	3.75	3.75
Paper Towels (1 roll)	Walmart	1	1.27	1.27
Duct Tape (1 roll)	Walmart	1	4.47	4.47
			Estimated Total:	**$109.08**
			Budget Remaining:	*$40.92*

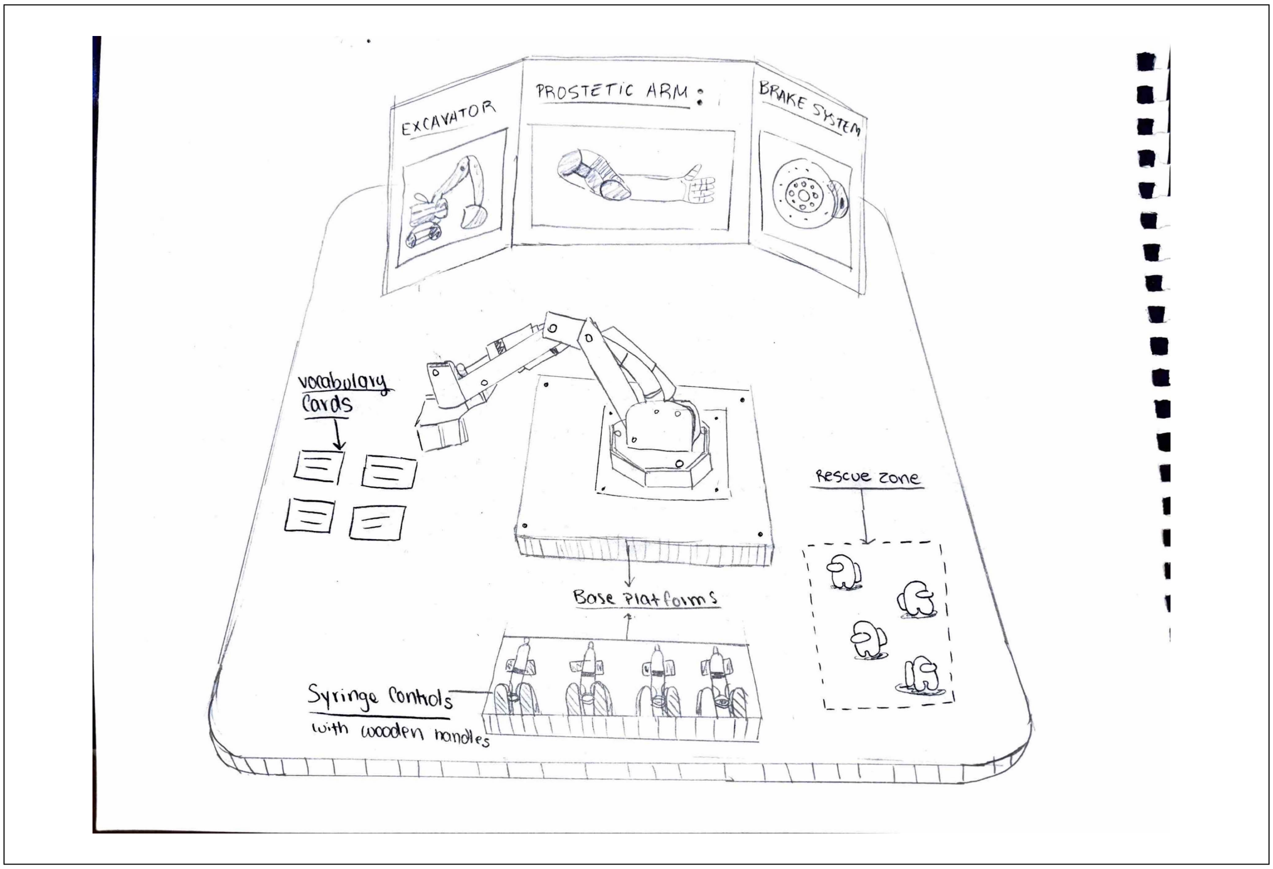
Product Links:

[1] https://www.amazon.com/dp/B0BXL928NN
[2] https://www.amazon.com/dp/B07PY4KM8C
[3] https://shorturl.at/HYVJw
[4] https://www.amazon.com/dp/B07F367TCK
[5] https://www.amazon.com/dp/B07K791YRP
[6] https://www.amazon.com/dp/B074B1KCXD
[7] https://www.amazon.com/dp/B002YK4IHA
[8] https://www.amazon.com/dp/B0B6C25MWY
[9] https://www.amazon.com/dp/B01KYYKECA
[10] https://www.walmart.com/ip/5337847556
[11] https://www.amazon.com/dp/B0013C7V24

Note: All prices verified as of February 2026. Budget surplus of $40.92 provides buffer for price fluctuations and optional enhancements.

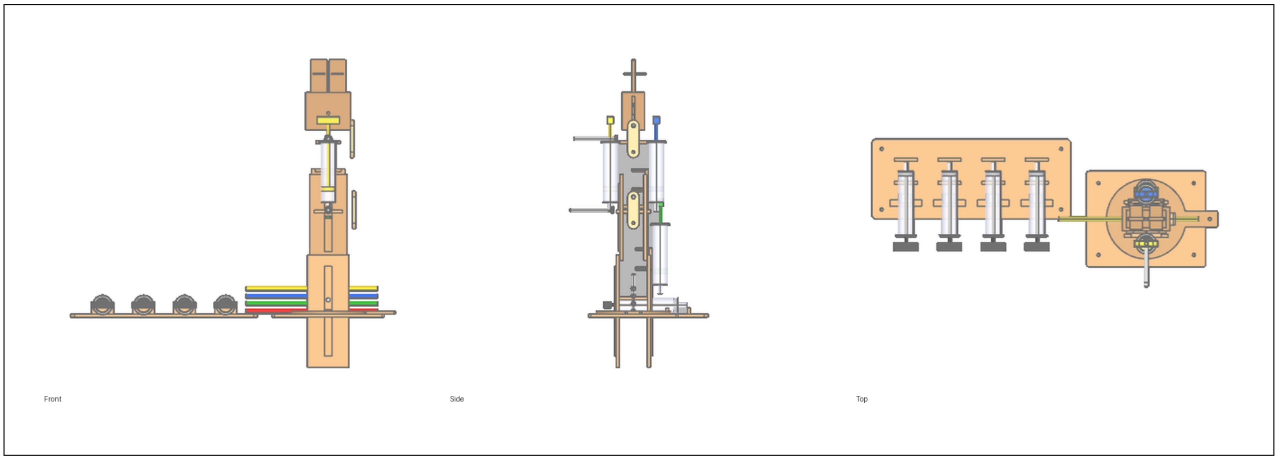
Concept Sketches

Sketch 1: Tabletop Layout (Bird's Eye View)



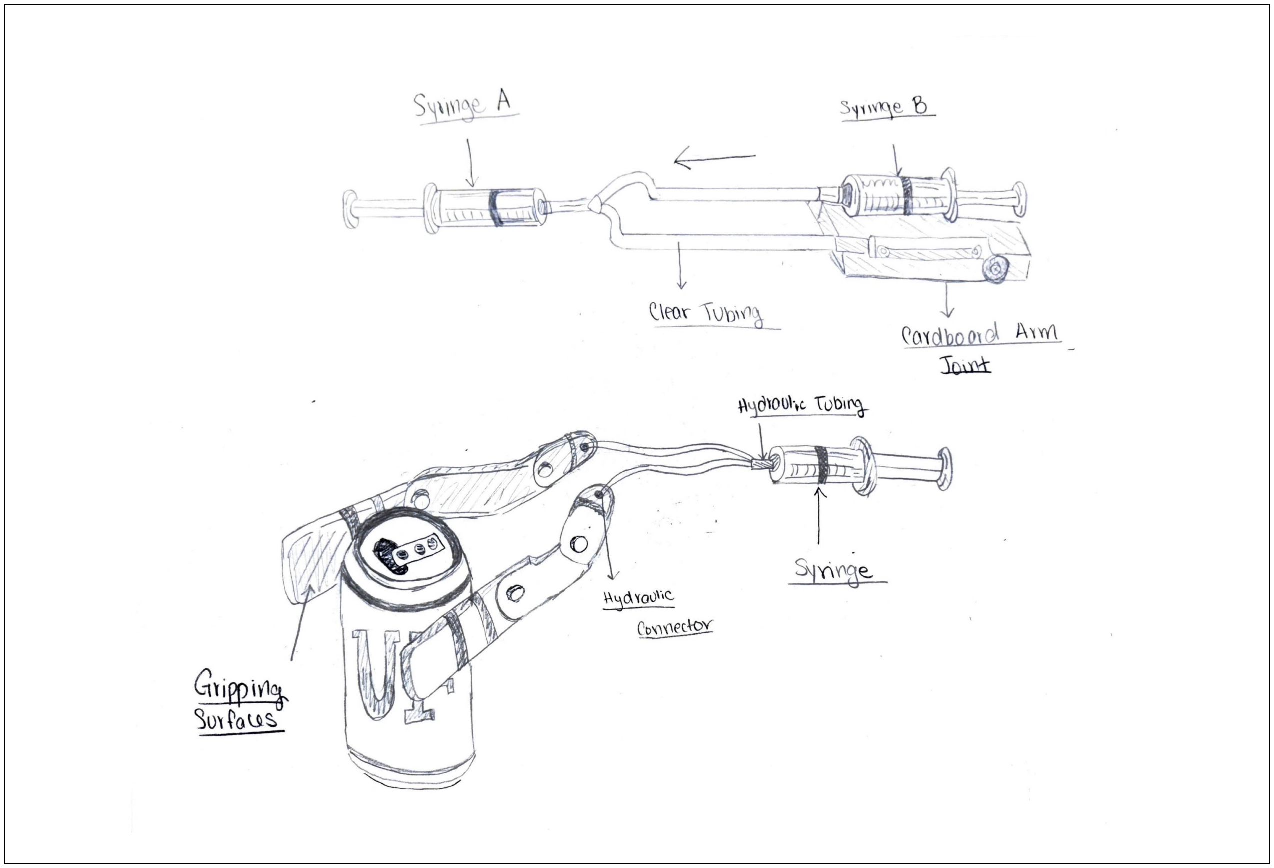
Description: Bird's eye view of the full tabletop setup. The tri-fold poster display stands at the back showing real-world hydraulic examples (excavator, prosthetic arm, car brake system). The hydraulic arm sits center-table, with the four syringe control pairs facing the student at the front edge. To the right is the "rescue zone," a marked area with small plastic toys the student must pick up and move. Laminated vocabulary cards are placed to the left for reference.

Sketch 2: Hydraulic Mechanism (CAD Prototype)



Description: Parametric CAD prototype of the full hydraulic arm system (front, side, and top views), including the base platform, rotating stage, upper arm, forearm, gripper, control station, and color-coded tubing paths. The color tubes are intentionally left disconnected at key interfaces so students complete the final hydraulic circuit during setup, making assembly part of the learning activity. Each component was modeled as a 3D-printable solid and checked at the assembly level for fit, clearances, and motion. The design files can also be open-sourced to support reuse, classroom replication, and future improvements by other teams.

Sketch 3: Gripper Mechanism (Close-Up)



Description: Side-view cross-section showing the core hydraulic mechanism. Syringe A connects via clear tubing filled with colored water to Syringe B (mounted at a joint on the arm). Arrows indicate water flow direction. Close-up of the gripper (end effector) at the tip of the arm. Two popsicle-stick "fingers" are joined at a pivot point with a brass fastener. A syringe plunger pushes a crossbar that spreads or closes the fingers. When the student pushes the control syringe, the gripper opens; when they pull back, rubber bands snap the gripper closed around the object.

Brief Script of Activity

Introduction (30 seconds)

"Have you ever watched a construction excavator lift a ton of earth with one smooth motion? That arm isn't powered by motors at each joint, it's powered by pressurized fluid. Today you're going to operate a robotic arm that works on the exact same principle, and I'll show you the physics behind it."

Explain the Concept (1 minute)

"This arm runs on *hydraulics*, the science of using pressurized liquid to transmit force. See these syringes connected by tubing? They're filled with colored water in a sealed system. When you push this plunger [demonstrate], the water can't compress, so it transfers your force through the tube and pushes the other plunger out. That's *Pascal's Law*, pressure applied to a confined fluid is distributed equally in all directions."

Point to the poster: "Now here's what makes this powerful for engineers: if you change the syringe sizes, you change the mechanical advantage. A small syringe pushing into a large one multiplies your force. That's how a 150-pound operator can control an excavator arm lifting thousands of pounds. Same principle shows up in car brake systems and prosthetic limbs."

Hands-On Challenge (3–5 minutes)

"Your turn. This is a precision retrieval challenge, use the arm to pick up objects from the hazard zone and place them in the safe zone. You have four hydraulic control pairs:"

- "This pair **rotates** the base left and right"
- "This pair **raises and lowers** the arm"
- "This pair **opens and closes** the gripper"

"Pay attention to how much force you need on each syringe and how far the arm moves. Notice that the gripper syringe pair has different sized syringes, that's intentional. Think about why an engineer would design it that way. Try to retrieve as many objects as you can."

Wrap-Up (30 seconds)

"So what did you notice about the gripper vs. the arm controls? [Let student respond.] Exactly, the gripper trades speed for grip strength because of the size difference in the syringes. That's mechanical advantage in action. Engineers make these trade-off decisions constantly. If this kind of problem-solving interests you, look into mechanical engineering or biomedical engineering, they design everything from factory robots to prosthetic hands using these exact principles."

Give the student a vocabulary card to take home.

Teacher Handout

Liquid Lift: Build and Operate a Hydraulic Arm

Students explore how hydraulic systems transfer force using water-filled syringes connected by tubing. They operate a robotic arm to complete a "rescue mission," discovering the engineering behind real machines like excavators and prosthetic limbs.

Key Vocabulary

- **Hydraulics**: the branch of engineering that uses pressurized liquid in a closed system to transmit force and produce motion
- **Pascal's Law**: pressure applied to a confined fluid is transmitted equally in all directions throughout the fluid
- **Mechanical advantage**: the ratio of output force to input force in a system; in hydraulics, achieved by varying cylinder diameters
- **Pneumatics**: similar to hydraulics but uses compressed gas instead of liquid; less precise due to gas compressibility
- **Iteration**: the engineering practice of testing, analyzing results, and refining a design through repeated cycles

Florida Standards Connections (B.E.S.T.)

- SC.6.P.13.1: Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic, and gravitational
- SC.7.P.11.2: Investigate and describe that energy can be transferred from one form to another (potential to kinetic)
- SC.8.N.1.1: Define a problem from the curriculum, use appropriate reference materials, and design and carry out a scientific investigation

Discussion Questions for the Classroom

1. Explain in your own words why pushing one syringe causes the other to extend. What property of water makes this work?
2. If you replaced the water with air, what would change? Why are liquids preferred over gases in hydraulic systems? (Hint: think about compressibility.)
3. When you pushed the syringe gently, the gripper moved a little. When you pushed harder, it moved more. Why does changing how hard you push the syringe change how the arm moves?
4. An engineer designing a prosthetic hand must decide between hydraulic, pneumatic, and electric actuation. What are the trade-offs of each?

Answer Key

1. When you push one syringe, you push on the water inside it. Because the water is trapped in a closed tube, the pressure spreads through the water and pushes on the other syringe. This makes the second syringe move. This due to waters property of not compressing easily.

2. If you used air instead of water, the system would feel soft and bouncy. When you push the syringe, the air would first squeeze before moving the other syringe. Liquids are preferred in hydraulic systems because they do not compress much.

3. When you push harder, you create more pressure in the water. More pressure means more force is sent through the tube, so the gripper moves farther or stronger. When you push gently, there is less pressure, so the gripper moves less. This happens because pressure in a liquid spreads evenly in all directions.

4. Hydraulic systems use liquids and are very strong and smooth, which makes them good for lifting heavy objects. However, they can leak and are often heavy. Pneumatic systems use air and are fast, but they are not as powerful and can feel bouncy. Electric systems use motors and electricity and are easy to control and very precise, but they require power sources and can be expensive. Engineers choose between these systems based on how much strength, speed, control, and reliability they need.

Follow-Up Activity (Next Day, 20 min)

"Hydraulic System Design Challenge": Give each student graph paper and ask them to design a hydraulic machine for a specific task (options: robotic surgical tool, underwater salvage arm, building demolition claw). They must include: (1) a labeled diagram showing syringe placement and tubing, (2) syringe diameter ratios and the mechanical advantage they produce, and (3) a one-paragraph justification of their design choices. Have students present and critique each other's designs.

Take-Home Challenge

Fill two sealed plastic bags, one with water, one with air. Squeeze both against a flat surface. Which transmits force more effectively and why? Write a paragraph explaining the relationship between fluid compressibility and force transmission, referencing Pascal's Law.

Appendix

Why Hydraulics for 6th–8th Graders?

Hydraulic systems provide an ideal intersection of *visible physics* and *real-world engineering application*. Unlike electrical or software-based demos, the cause-and-effect relationship is immediately tangible: push here, movement happens there, and students can *see* the colored water flowing through the tubes. For 6th–8th graders entering Piaget's formal operational stage, this concrete demonstration serves as a bridge to abstract reasoning, students can directly observe Pascal's Law and mechanical advantage before formalizing the concepts mathematically. The precision retrieval challenge adds goal-oriented motivation while encouraging students to analyze trade-offs between force, speed, and control.

Connection to Engineers Week Mission

This activity directly supports NSPE's Engineers Week goals:

- **Inspire the next generation:** hands-on interaction with a real engineering principle
- **Spotlight engineering impact:** explicit connections to excavators, prosthetics, and braking systems show how engineering improves lives
- **Strengthen community connections:** the teacher handout and follow-up activity extend the impact beyond a single interaction into the classroom

Scalability

With the $40 budget surplus, additional arm units could be built to serve multiple students simultaneously. The modular syringe-and-cardboard design is intentionally reproducible, making it feasible for teachers to recreate in their own classrooms using the teacher handout.