Engineering Applications: Solutions to Unique Opportunities

This STEM activity was designed for the LiTHIUMLEARNS HIRED Grant program.

Engineering Applications: Solutions to Unique Opportunities (4th and 5th grades)

Students will design and build a filtration system using household materials to separate a solid or visible substance from an aqueous (water-based) solution. This models real-world processes such as those used in brine processing in Arkansas.

Arkansas Science Standards Alignment (Grades 4–5):

- **5-PS1-3**: Make observations and measurements to identify materials based on their properties.
- **5-PS1-4**: Conduct an investigation to determine whether the mixing of two or more substances results in new substances.
- **5-ETS1-1**: Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **5-ETS1-2**: Generate and compare multiple possible solutions to a problem.

Intro

Arkansas has underground salty water (called **brine**) that contains valuable minerals including **lithium**, used in batteries for phones and electric cars. Scientists are working on ways to filter out lithium without harming the environment. In this lab, students will act as scientists and engineers, designing a filtration system to remove one part of a mixture, just like engineers do when separating lithium from brine.

Engineering Challenge:

You are a team of engineers tasked with cleaning up a dirty water sample by removing as much solid material (e.g., soil or coffee grounds) as possible. Your team will design, test, and improve a water filtration system using common materials.

Materials

- Clear plastic cups or jars
- Water
- Dirt, sand, coffee grounds, or flour (to simulate “contaminants”)
- Paper towels
- Coffee filters
- Cotton balls
- Sponges
- Gravel/small rocks
- Plastic bottles (cut in half to create funnels)
- Rubber bands
- Spoons
- Stopwatch or timer

Procedure:

1. **Explore the Problem:**
    - Show students a "dirty water" sample.
    - Discuss what might be in it and how we might clean it.
2. **Plan Your Design:**
    - In small groups, students draw or describe a filtration system they think will clean the water.
    - They choose from the available materials (limit quantities to add design constraints).
3. **Build and Test:**
    - Students build their filtration system using a plastic bottle funnel or stacked cups.
    - Pour the dirty water through and observe what is removed.
4. **Observe and Record:**
    - Students record what they see: How clear is the water? What materials worked best?
    - They can score their results on a simple “cleanliness scale” from 1–5.
5. **Redesign (if time permits):**
    - Allow students to improve their system using what they learned.

Data Collection:

- What materials did you use in your filter?
- What do you notice about the water after filtering?
- What would you change to improve your filter?

Discussion:

- Which materials worked best and why?
- What properties made them good filters?
- How does this activity relate to what scientists in Arkansas are doing with brine?
- What other mixtures in the world might need to be separated?

Engineering Applications: Solutions to Unique Opportunities (6th, 7th, and 8th grades)

Students will investigate how to separate a component of an aqueous solution using a filtration system. They'll design, test, and refine a filter using household materials to simulate processes seen in Arkansas chemical plants. The lab focuses on **engineering design**, **material properties**, and **real-world resource challenges**.

Arkansas Middle School Science Standards Alignment (Grades 6–8):

- **PS1-MS-4**: Develop a model that predicts and describes changes in particle motion, temperature, and state of a pure substance when thermal energy is added or removed.
- **PS1-MS-2**: Analyze and interpret data on the properties of substances before and after interactions to determine if a chemical reaction has occurred.
- **ETS1-MS-1**: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution.
- **ETS1-MS-2**: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **ESS3-MS-3**: Apply scientific principles to design a method for monitoring and minimizing human impact on the environment.

Intro:

Beneath the ground in south Arkansas lie **brine reservoirs**, salty water that contains **bromine** and **lithium**.

In this lab, you'll simulate this process by **engineering a filtration system** to separate one part of a solution.

Engineering Challenge:

Design and construct a filtration system using limited materials to remove a visible solid contaminant from a simulated brine solution.

Materials:

- **Simulated "brine" mixture**: water + salt + coffee grounds
- Clear plastic bottles or jars
- Paper towels, coffee filters
- Gravel, sand, activated charcoal (optional)
- Cotton balls
- Sponges
- Plastic mesh or screen
- Funnels (or cut plastic bottles)
- Measuring cups
- Stir sticks or spoons
- A conductivity meter (optional for additional analysis)
- Stopwatch
- Student lab sheets

Procedure:

1. Introduction (Whole-Class Discussion):

- Show images or videos of Arkansas lithium brine fields or processes.
- Ask: *Why is brine important? Why does how we extract minerals matter?*
- Introduce the problem: “How can we filter a mixture to isolate useful materials?”

2. Define the Problem:

Students receive a design brief:

"You are working for a clean-tech company developing a sustainable way to filter materials from brine. Your task is to create a system to clean simulated brine by removing solid contaminants while preserving the salt content (to simulate dissolved minerals)."

3. Plan:

- Students sketch possible designs and list materials they think will work best.
- Criteria: Remove solids as completely as possible.
- Constraints: Limited materials, one redesign allowed, 30-minute construction time.

4. Build & Test:

- Construct filters using selected materials.
- Test by pouring simulated brine through the filter and collecting the filtrate.
- Record clarity, flow rate, and salt retention (qualitative or by taste test if allowed or conductivity meters if available).

5. Analyze & Improve:

- What worked? What didn’t?
- What properties of the materials made them effective or ineffective?
- Redesign and retest if time allows.

Data Collection:

- Initial and final clarity (1–5 scale or turbidity observation)
- Time to filter 100 mL
- Materials used and order in system
- Whether salt was removed or not
- Observations on how well the filter worked and what they would improve

Discussion:

- Which materials were most effective and why?
- Could your filter isolate lithium, which is **dissolved**, not just floating solids?
- What real-world constraints might lithium engineers face (cost, energy, waste)?

Engineering Applications: Solutions to Unique Opportunities (High School)

Students will apply knowledge of solution chemistry and engineering design to build and test a **filtration system** capable of separating components from an aqueous solution. Students will explore the limitations of physical separation methods in relation to **brine processing** and propose enhancements that mirror real-world environmental and industrial challenges in Arkansas.

Arkansas High School Science Standards Alignment:

- **PS1-2**: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of chemical properties.
- **PS1-3**: Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.
- **PS1-4**: Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy.
- **PS1-5**: Apply scientific principles and evidence to provide an explanation about the effects of changing the temperature or concentration of the reacting particles on the rate at which a reaction occurs.
- **ETS1-1**: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- **ESS3-3**: Create a computational simulation to illustrate the relationships among management of natural resources, the sustainability of human populations, and biodiversity.

Intro:

Arkansas's **Smackover Formation** holds vast underground brine resources containing **dissolved lithium**, a key element in **rechargeable batteries** for electric vehicles, phones, and renewable energy storage. Unlike traditional mining, **Direct Lithium Extraction (DLE)** uses specialized membranes or sorbents to separate lithium from saltwater—more sustainable but still challenging. The process involves **selective ion separation**, **membrane technologies**, and **physical/chemical filtration steps**—some of which you'll simulate in this lab.

Engineering Challenge:

Design, build, and evaluate a multi-stage filtration system using common materials to remove solid and suspended particles from a lithium-brine simulation, without removing the **dissolved salt (simulating lithium)**. Then, analyze why additional techniques would be needed to isolate lithium ions from solution.

Materials:

- Salt (NaCl) to simulate lithium salt
- Soil or coffee grounds to simulate suspended solids
- Water
- Beakers or clear containers
- Funnels or cut plastic bottles

- Coffee filters, paper towels, cotton balls, activated charcoal
- Sand, gravel, sponges
- Conductivity meters or multimeters (if available)
- Stopwatch
- Balance (to measure mass of recovered filtrate/solid)
- Student lab sheets

Procedure:

Part 1: Simulate Lithium Brine

1. Mix **water, salt**, and **solid impurities** (soil or coffee grounds) to create a cloudy lithium brine simulation.

Part 2: Engineering Design & Testing

Phase A: Planning

- Define criteria: Maximize clarity, retain salt (i.e., dissolved "lithium").
- Define constraints: Limited materials, 45 minutes build time, 1 redesign allowed.

Phase B: Build & Test

- Students construct a **multi-stage filter**.
- Filter 100 mL of "lithium brine" through their system.
- Record:
    - Clarity (visual or turbidity scale)
    - Volume of recovered filtrate
    - Time taken
    - Salt retention (qualitatively or with conductivity if available)

Part 3: Analyze Limitations

- Students test salt concentration in filtrate.
- Reflect on whether **filtration alone** can isolate lithium from water.
- Introduce real DLE technologies (ion exchange, solvent extraction, nanofiltration).

Part 4: Propose Improvements

- Research existing lithium extraction methods (e.g., Standard Lithium, EnergyX).
- Students revise their designs or propose a conceptual membrane/chemical treatment step for ionic separation.
- Optional: Present findings in a design report or pitch.

Data Collection:

Table (Sample)

Trial	Filter Materials	Time (s)	Clarity (1–5)	Salt Presence (Yes/No)	Observations
1	Gravel, cotton	75	2	Yes	Slow flow
2	Charcoal, filter	62	4	Yes	Some odor removal

Discussion:

1. What materials were most effective at removing solids?
2. Why couldn’t you remove dissolved salt (i.e., lithium) with simple filtration?
3. How do ion exchange or membrane technologies solve this?
4. How could you improve your system for real-world DLE applications?