Geering Up UBC Engineering & Science for Kids
101-2275 East Mall, Vancouver V6T 1Z4
604-822-2858 | geeringup@apsc.ubc.ca
www.geeringup.apsc.ubc.ca

ICED17

ICED17 Design Fair and Expo

International Conference on Engineering Design 2017

The ICED17 Design Fair and Expo is an opportunity for students to interact with design professionals from around the world, present projects completed in the area of resource-sensitive design, and explore what other groups are doing in this field within Vancouver and beyond.

This lesson plan provides one project that you/your class could complete and bring to the Design Fair. For more information on participating in the ICED17 Design Fair, please see: https://mech-iced17.sites.olt.ubc.ca (temporary site)

Water Filtration System

Topic Areas	Time	Grade Levels	Complexity
· Technology · Sustainability · Resource Limitations · Environmental awareness · Engineering Design Cycle	Teacher Instructional time: 1-2 hours Project design time: 15+ hours	8-11	Moderate to advanced

Learning Outcomes

Theme- *Resource-Sensitive Design*:

- *Design to advance resource-limited societies:* Designing products that will work well in communities that have issues like no roads for getting materials, equipment or fuel into the community, have limited or no access to electricity or clean water, or have cultural preferences that impact how well products are accepted.
- *Design to protect critical resources:* Designing products that use less of our limited resources (like oil or clean water) when they are made, and/or do not damage those resources (such as by creating water pollution).

Adapted from the NASA Water Filtration System lesson outline

- *Design to embrace resource limitations:* Instead of seeing limited resources as a problem, using the limitations as a motivation to create simple, elegant and functional designs.

(taken from the ICED 2017 Design Fair and Expo Guidelines)

Focal Points:

- *Using fewer resources* (measured as the weight of the device per flow rate)
- *Using fewer consumable* resources e.g. how often must the filter be changed after cleaning the water- reflects supply chain issues to low-resource areas)
- *Using sustainable resources* – i.e. perfectly recyclable versus downcyclable or non-recyclable (no PVC, styrofoam, does not harm the environment) *see page 6 for a breakdown of materials' categorizations

Objectives:

- Students will design and build a water filtration device
- Test the device, make observations, and collect data
- Collaborate and analyze the results in an attempt to identify the best filter media to use
- Based on the analysis and on the study of other filtration devices, students will make modifications to their model and repeat the process in an effort to produce the most effective filtration apparatus possible
- Compare team results within the classroom and communicate those results to the larger community

Example Materials (for class of 30)

For the class:

- 2-3 Scales
- 2-3 Conductivity testers (*if available)
- 1-2 Graduated cylinders
- 3-4 pH strips per team
- 6-8 Plastic cups
- Newspaper
- Markers

For each conductivity tester: (example of how to use conductivity tester in water samples: https://www.youtube.com/watch?v=-QF27bncXAQ)

- Digital multimeter
- 9-volt battery
- Battery snap connector

- Black electrical tape (15 cm)
- Wire stripper
- Alligator clips (optional)
- Light bulb (optional)

For each filtration device:

- Plastic water bottles
- Rubber bands
- Cheesecloth segments (10-by-10-cm)
- Plastic wrap strips (10-by-10-cm)
- 10-by-10-cm section window screen (optional)
- Filtered waste container
- Utility knife
- Masking tape
- Paper clips
- Additional materials (see Materials' Categorizations on page 6)

Filter media (per team):

- 10-15 cotton balls
- 6 coffee filters
- 200g activated carbon
- 200g gravel
- 200g sand
- 100g uncooked macaroni

For the simulated contaminated water:

- 400 mL vinegar
- 1-2 drops of food colouring
- 50 g sand
- 1 tbsp salt
- Handful of hair (if available)
- Handful of dust
- 2 litres of tap water
- 2-litre beaker
- Stirring device

Miscellaneous for each team:

- Poster board
- Markers
- Scissors
- Glue or tape

Lesson plan

Safety – remind students of the importance of classroom and lab safety. Review the rules for smelling (wafting) in the science lab. Students should wear eye protection during this activity. Materials Safety Data Sheets (MSDS) are required for this experiment. You can find MSDS at http://www.msdssearch.com/msdssearch.htm. This activity requires proper clean up.

- Send a note home to parents telling them about the project a week or two ahead of time. Include the materials list and ask them to send in materials from this list if available (otherwise materials will have to be supplied by yourself or the school).
- Students will work in teams of three or four and are encouraged to think of their team as a single unit in order to work cooperatively and learn from each other's efforts.
- Discuss the properties of liquids such as cohesion, adhesion, viscosity and surface tension, so students will know what to look for while making observations. (properties of liquids: http://www.livescience.com/46972-liquids.html , surface tension: http://hyperphysics.phy-astr.gsu.edu/hbase/surten.html).
- Review the scientific method (https://www.flocabulary.com/lesson-scientific-method/) and engineering design cycle (http://www.sciencebuddies.org/engineering-design-process/engineering-design-process-steps.shtml#theengineeringdesignprocess). Discuss ways students should have access to research equipment.
- Because resource limitation is always an issue in developing countries, set a weight limit for the filtration device (including filter media).
- Students are encouraged to draft a project proposal (https://people.ok.ubc.ca/rlawrenc/teaching/writingProposal.html), which can be as simple or extensive as they would like, (however a brief ½ page project proposal is all that is required to enter the 2017 ICED Design Fair and Expo) and sumbit it to their teacher for review. Once approved, they can begin constructing their models, testing and modifying.
- Students should have opportunities for small group and whole class discussions at intermediate points along the design process.
- After the filtration devices have been built, tested and modified, hold a competition to see which team has the purest water, (lowest conductivity and most neutral pH) using the least of amount of resources. For an extra challenge, see which team can construct their filtration system using the most renewable materials (highest percentage of their materials in Category 1 – see page 6 for materials' categorizations).
- Suggested timeframe for project:
    - Week 1: Project proposal/commence model construction
    - Week 2: Model construction

- Week 3: Testing (conductivity, pH etc.), modification, re-testing
- Week 4: Poster creation, communicate results to class, filtration competition
- * Each weekly guideline may not take the entire week to complete. Teachers can alternatively introduce the design challenge and then dedicate one day a week of classroom time to constructing the filtration system. Students should still have more than enough time to complete it, and leaves more flexibility on the teacher's part.

Background Information

- **Acid**: Any of a class of substances that yields hydrogen ions (H+) when dissolved in water. The greater the concentration of hydrogen ions produced, the more acidic the substance is. Acids are characterized by a sour taste and the ability to react with bases and certain metals to form salts (students should not taste their filtered water to test for acidity – use pH strips).
- **Base:** Any of a class of substances that yields hydroxide ions (OH-) when dissolved in water. The greater the concentration of hydroxide ions produced, the more basic the substance is. Bases are characterized by a bitter taste, a slippery feel, and the ability to react with acids to form salts (again, do not taste the filtered water – use pH strips).
- **Conductivity:** Conductivity is a measure of a material's capacity to conduct electricity. Conductivity is a standard method to measure the purity of water, specifically the quantity of inorganic contaminants (which conduct electricity). Completely pure water will cont conduct electrical current. Thus, the smaller the amount of current that flows through the treated wastewater, the lower the concentration of inorganic contaminants.
- **Litmus Paper (pH strips):** Indicator used to determine whether a substance is acidic or basic. The pH scale lets you determine the relative acidity of a substance. The pH scale ranges from 1 to 14 where 7 is neutral, greater than 7 is basic, and less than 7 is acidic. Litmus paper will turn red in acidic solutions and blue in basic solutions.

Discussion Questions

- What happened to the water as it passed through the different layers of the filter? What changes occurred to the properties of the contaminated water as it was filtered (pH, appearance, odor)? *Answers will vary.*
- Compare your filtered water to **"**clean" tap water. Did your contaminated water become "clean"? What properties told it was or was not clean? *Answers will vary.*
- Does this data support your hypothesis? Why or why not? *Answers will vary.*

- If you could rebuild a water filtering system by using any of the materials available in or out of the class, which materials would you use and in what order would you layer them? Why? *Answers will vary.*
- Based on your findings, what would you suggest to environmental engineers designing filtration systems and water recycling methods? *Answers will vary.*

Assessment Activities:
Once the filtration systems have been designed, built and tested, instruct the students to discuss the results and what they have learned. You can elect 2 or 3 designs to compete in a "run-off" and have students modify their designs from the data collected. If time permits, students are highly encouraged to create posters about their design and test results, as one of the most important aspects of creating a model in order to solve a problem is communicating your ideas to the larger community.

Enrichment

- Collect and filter other samples of water (e.g. rain water, hand wash water, stream of pond water, etc.).
- Try using other filter media such as potting soil, marbles, and popcorn.
- Ask the students to research how the water in your town is filtered/treated. Maybe take a field trip to the water treatment plant, or check into someone from the water treatment plant visiting to speak to your class.
- Book Engineers Without Borders to visit your class.
- Encourage students to document their work digitally through film and photos. This can then be used to create an electronic diary of the creation of their filtration device and can complement their presentation and poster.
- Investigate other water treatment methods, such as desalination, and conduct classroom experiments using these methods.

Note: This is a general outline for a water filtration activity. Students are by no means required to use all of the suggested materials, nor test their results in the manner provided. Teachers should use their discretion in terms of how much structure to give this design challenge, but often times, the less structure, the more creative the designs. Additionally, in order to qualify for the 2017 ICED Design Fair and Expo, students do not have to constrict themselves to designing a water filtration system; any model that advances resource-limited societies and meets the ICED 2017 Design Requirements will be eligible. It is up to the teacher if they would like to open up the floor to other design areas (e.g. agriculture, health and medicine, sustainable energy) as well.

Materials' Categorizations

Materials will be categorized in the following 3 subcategories:

- **Category 1- Renewables:** directly plant-derived compostable/short-term biodegradable materials such as *wood, cotton, sisal, bamboo, latex* etc. which can biodegrade and are readily plant-derived.
- **Category 2- Infinitely Recyclable Materials and Repurposed Materials:** *metals, glass, virgin polypropylene*, re-purposed finished articles made out of materials in Category 3 (e.g. using a PET bottle as a hull).
- **Category 3- Down-cyclables and single use materials:** Materials that are used in a raw, virgin form to create new articles and are not infinitely recyclable and won't degrade on their own in the biosphere. This includes *PET, ABS, PLA, Acrylic, Polycarbonate, PVC, Polyethylene, Acetal, Polystyrene, Styrene, fiberglass, epoxy, cyanoacrylate, concrete, thermosets, and polyurethane.*

(From M. Fengler)

To qualify for a particular category, at least 80% of the materials by weight on the filtration device must be in that category or higher. For the 2017 ICED Design Fair and Expo, teams can write out their sustainability analysis, reporting the percentage, by weight, of materials in each category, and the category the team believes their design should be classified under.

Rubric

This rubric can be used at the teacher's discretion, as these are the 4 areas that projects submitted to the ICED17 Design Fair and Expo will be judged on:

	Exceeds Expectations (4/4)	**Fully Meets Expectations (3/4)**	**Minimally Meets Expectations (2/4)**	**Does Not Meet Expectations (1/4)**
Theme Relevance	Design fully addresses and encompasses all 3 of the major themes	Design addresses sufficiently all 3 of the major themes	Design addresses some of the major themes or addresses them incompletely	Design does not address any of major themes adequately
Technical Merit	Filtration system produces clean	Filtration system produces	Filtration system produces	Filtration system does not remove

	water with a neutral pH, and conductivity equal to or less than tap water (5-50 mS/m)	relatively clean water with a neutral pH, and conductivity greater than that of tap water	relatively clean water with an acidic or basic pH (red or blue on litmus paper), and conductivity greater than that of tap water	contaminants from water; water has an acidic or basic pH (red or blue on litmus paper), and the conductivity is greater than that of tap water
Innovation	Project proposal incorporates all 3 focal points in great detail	Project proposal addresses most focal points in detail	Project proposal addresses some focal points briefly	Project proposal neglects to address focal points or address them insufficiently
Communication	Project presentation communicates the design and results very effectively and accurately	Project presentation communicates the design and results somewhat effectively and accurately	Project presentation is missing some necessary components and/or the design and results are presented in a confusing manner.	Project presentation is missing several key components and the design and results are not presented in a coherent manner.

Good luck to you and your students!

ICED17 Design Fair and Expo:

ICED17 main site: http://iced17.org/