Engineering a Greener School

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Environmental problems are engineering problems. Learn how to use age appropriate engineering problem-solving approaches to help your students design ways to make your schoolyard wildlife friendly (K-2), and your schoolyard less polluting to water (3-5).

The Engineering Process

Engineering is the use of scientific, economic, social and practical principles and knowledge to solve a problem. A process is a list of steps needed to produce a particular outcome. So the ***engineering process*** uses scientific, economic, social and practical principles and knowledge to figure out the steps needed to solve a problem.

The main difference between science and engineering is the goal. In science the main goal is to find out something new about the universe (including the earth, humans, society, etc.). In engineering the goal is to solve a specific problem. Other than the goal, there is a lot of overlap in the two disciplines, both in the way they are done and in their interdependence. Science depends on engineering to create new tools so scientists can make new discoveries, and engineering depends on science to make new discoveries so engineers can create new tools.

Greener Schools

All schools, even if by accident, engage in practices that are green. These include things like providing a safe and healthy environment for students and staff, providing outdoor activity time for all students, recycling paper or containers, or finding ways to reduce energy costs. All schools also have the potential to take additional steps to become greener.

A Process for Engineering a Greener School

Main Step				
1. Identify Problem	what is the issue?	what specific part is the problem?	identify any constraints or criteria for the solution	
2. Come Up With Solutions	gather facts and theories from what you know, what you look up, what you measure – be sure to measure the thing you want to change!	create a conceptual model of the steps leading to the problem, figure out what other information you need	gather more information, revise model, if necessary, reformulate problem making it bigger or smaller	use the model to generate possible solutions (steps where interventions would change the outcome)
3. Choose a Solution (or Solutions)	estimate tradeoffs between effectiveness, achievability, cost, fairness and sustainability	do more research if needed on tradeoffs		
4. Plan Carrying Out the Solution	who will be responsible	what will it cost and where will the money come from	how will it be done – location, tools, procedures	when will it happen, how often will it have to be repeated
5. Carry Out the Plan	present the plan	get support	carry it out	
6. Measure Results	measure the thing you wanted to change to see if it changed	evaluate the effectiveness of your solution – if effective, see if you can do it more cheaply, if not, see step 1.		

Ways that schools can be greener

http://www2.ed.gov/programs/green-ribbon-schools/index.html

Areas of Green	Easy (probably already doing it)	Moderately Challenging	Challenging
Footprint	– Drinking water meets local, state and federal standards – Program to monitor and control lead in drinking water – Recycling is in place – Hazardous Materials are eliminated or reduced, any existing materials covered by a management policy – Anti-idling policy in place, posted and enforced	– Reduce energy use and greenhouse gases – Reduce water use (gal/sq ft/year) – Convert to a water efficient landscape – Implement green cleaning practices and use green cleaning products – Students use alternative transportation to get to school – Safe and Walkable Routes to school	– Energy Star Certification and Facility Energy Matrix – Alternative energy – Green new construction – Procurement policies for furniture, other supplies and equipment, recycled and/or chlorine free paper, electronics, and/or sustainably or locally produced food
Health	– ASHRE standard or local code for ventilation systems is met – Chemical management policy in place (purchasing policy, inventory, tracking and monitoring and safe disposal – School has 150 minutes of outdoor or PE time per week for each student	– Moisture control program in place – USDA Healthier U.S. School program in place - Sunwise program in place – Policies to monitor and control Radon, CO, Mercury and Tobacco Smoke –Asthma management program in place –Integrated Pest Management (IPM) plan in place	– Ventilation systems for exhausting contaminants from laboratory or shop exercises – Removing CCA treated wood from the facility – Indoor Air Quality Tools
Education	– There is environmental education (integrated across subjects) in at least some grades – Students in at least some grades have a meaningful outdoor experience – Students score proficient or better on science assessments – School is partnering with local academic, businesses, organizations and agencies and/or other schools to help advance their own or another school's progress in becoming green	– There is environmental education (integrated across subjects) in all grades – Students in all grades have a meaningful outdoor experience – Environmental and Sustainability Professional Development for teachers – There are student initiated Community projects – Outdoor classroom that is used	– Students take environmental science or environmental assessments and do well – Number of students enrolled in AP Environmental Science who score 3 or better – An environmental literacy or sustainability literacy graduation requirement – – Scores on civics assessments

Glossary of Problem Solving Terms

aesthetics	the creation and appreciation of beauty; in designing solutions, considering the appeal of the product, process or system to those who will use it, carry it out or have to sustain it
alternate solution	a solution different from the one everyone thinks of first, multiple alternate solutions should be developed and compared to find the most effective, achievable, cheap, fair and sustainable solution
brainstorm	an individual or group creative exercise involving free association between words or ideas
conceptual model	a model made up of concepts (abstract generalizations) that can be mental or an image
constraint	a physical, social or financial limit to what can be achieved
engineering	the use of scientific, economic, social and practical principles and knowledge to solve a problem
environmental impact	how new products, processes or systems will affect the environment (public health, other species, biogeochemical cycles and processes)
ethics	concepts of right and wrong conduct; e.g. fair distribution of the costs and benefits of a proposed project
feasibility	the potential of a proposed project to be successful
interdependent	when the outcome of one event is dependent on other conditions or events; in some cases the other conditions or events may not be controllable and/or the interdependent relationship is unknown
iteration	repeating a process to achieve a goal using the results of one run through as the starting point of the next run through
model	a simplified representation of a thing, process or system used to make predictions about it; a model may be physical, mathematical or conceptual
process	the steps needed to create (or recreate) a particular outcome given particular starting conditions
reliability	the ability of a product, process or system to repeat its performance under the same conditions with minimal variation
reverse engineering	extracting knowledge or design information from an existing product, process or system and using it to create something similar
risk	the potential of losing something of value – money, time, life, health, sense of identity, the respect of others, a feeling of security, etc.
social impact	how new products, processes or systems will affect individuals and groups
sustainability	the ability of a process or system to continue indefinitely within its larger system; e.g. grocery stores within the U.S. economy, pollination within an ecological community, classroom learning within a school
synectics*	a creative technique using analogy and metaphor to place oneself directly in the problem or issue one is trying to address to ensure that even apparently trivial aspects are considered: e.g. putting yourself in someone else's shoes; imagining the path in which water, energy or a commodity would flow
system	a set of interacting or interdependent components forming an integrated whole
tame problem	a problem where all the possible outcomes can be mapped, interdependence is minimal, requirements are fixed and the need or wants of relevant parties don't matter; e.g. chess, math problems, puzzles, some engineering problems
trade off	a situation that involves losing one quality or aspect of something in return for another quality or aspect, if one thing goes up, the other must go down
trigger word	a creative technique using a word or phrase to bring to mind other words or phrases
wicked or messy problem	a problem that resists resolution because of incomplete information, complex interdependencies, changing requirements and/or the conflicting needs and wants of relevant parties; e.g. environmental problems, social problems

Engineering a Greener School: Teacher
K – 2nd Grade: Where is the Wildlife?

This lesson introduces students to the living organisms that share their schoolyard and explores why (or why don't) they live there.

ELA – KW2 Use a combination of drawing, dictating and writing to compose informative texts, KW7 Participate in shared research and writing projects, KW8 With guidance and support from adults, recall information from experiences KL1a Print many upper- and lowercase letters, KL1d Understand and use question words, KL5a Sort common objects into categories, KL5c Identify real-life connections between words and their use, KSL1 Participate in collaborative conversations with diverse partners.
Math – KCC Count to tell the number of objects, KCC 6 Compare numbers
Science – EC1A Understand how seasons could affect organisms, IN1B Measure length using non-standard units, IN1C Compare explanations with prior knowledge, IN1D Communicate observations using words, pictures and numbers, ST3A Work with a group to solve a problem
Social Studies – 4A Identify examples of opportunity cost

Prior Knowledge

- Students should know the major groups of organisms that are visible to the naked eye – plants, animals and fungi, as well as major subdivisions of these groups (see below).
- Students should know that every living thing needs food, shelter and water. It will be helpful if they know the parts of plants.
- Student should know how to estimate length using common objects.
- Students should know how to make simple drawings of objects (for example, by breaking a tree or bird into simple geometric shapes like circles, ovals or rectangles to get a general body shape and then filling in details)

Preparation

- Have copies of the work sheet for each student, a pencil with an eraser, and a "clip board" for them to work on (you can make a "clip board" out of cardboard cut in 9" x 12" sections and a paper clip or bull dog clip). Optional – colored pencils or crayons
- Write a list of common organisms in your area on the chalk board or smart board. You can use the list provided, your own knowledge or ask the students what organisms they have noticed at school or in their neighborhoods.

Priming

- Tell students they are going to work together to make a list of the organisms that live in their schoolyard.
- Prepare students for going outside by making sure that they know the physical boundaries of the area to investigate.
- Set clear rules or guidelines for their behavior outside and rehearse them. For example: Leave and enter the building in a quiet and orderly way. Stay with your group. Stay within the set boundary. Listen for the signal to come together to come back inside.
- Divide students into groups of 2 to 4. Hand each student a worksheet and have them read through it and discuss with each other the **goal** of the field trip. Ask them to close their eyes and picture what they might see in the schoolyard. Have them picture the places they might look – under leaves, in the mulch, on tree trunks, behind the building, on the edge of the schoolyard (but not beyond!). Have them picture making a drawing and adding words to their description.

- Tell them that they need to have a name for their organism, but if they don't know it, they can make one up. It is ok because someone had to make up the name the organism has now. Their made up name will be temporary until the "common" name is found. Let them know that there are so many organisms that even scientists don't know the names of all of them, so they use temporary names or even numbers to tell things apart until they get the "common" name.
- After they make their drawing they should circle what kind of organism it is, circle how big it is relative to things they know and count how many of the same organism they can see. They should fill in all this information on their data sheet.

Go Outside! Collect Data!

Follow Up

- In class, have students in groups compare their drawings and make a list of the things they found. Then have the groups compare their lists and drawings to make a master list. Write this on the board next to the list already on the board. Try to line things up as you write. Use "common" names when they are known and temporary names when they are not.
- Have the students compare the lists to see what the school-yard is missing and/or what is has that is not on the list. Have them count the number of species (kinds of organisms) that could be in the schoolyard and the number they found. Have the students think of reasons things might be absent or present. These include whether the needs of the organism are being met. They can also include the time of year or time of day (opossums and raccoons are out at night, hummingbirds migrate south in the fall, trees are hard to identify without leaves).
- Ask the students if there are any plants, animals or fungi students would like to see in their schoolyard that aren't there? If they suggest some things, discuss why those things don't live in the schoolyard and what could be done to change the schoolyard so they could live there.

Assessments

- Have each student write a short report about an organism they found that includes a picture, where they found it, what they think it needs (food, water, shelter), and how many they found. Depending on their skill, they could do additional research at the library to add to their report. For younger students a labeled picture would be sufficient.

Extension

- Students could make a list of organisms that might be able to live in the schoolyard but don't, and research what could be done to make a place for the organisms to live in the school yard.

Common *kinds* of plants, animals and fungi that might be in a Missouri school's grounds.

Plants – Major Subdivisions – specific examples

Trees – oak, maple Bradford pear, cedar, elm, tulip tree, redbud, birch, dogwood
Shrubs or bushes – boxwood, azalea, Forsythia, barberry, rose of Sharon, juniper, yew, arborvitae
Grasses – tall fescue, fine fescue, Kentucky bluegrass
Flowers – daylilies, chrysanthemums, coneflowers, phlox, yarrow, daisies, asters, bee's balm

Animals – Major Subdivisions – specific examples

Insects & Spiders – butterflies, bees, wasps, caterpillars, ants, beetles, flies, web spiders, wandering spiders, jumping spiders
Reptiles & Amphibians – turtles, lizards, snakes, salamanders
Birds – cardinals, robins, starlings, sparrows, pigeons, woodpeckers, finches, chimney swift, hummingbirds
Mammals– squirrels, rabbits, opossums, raccoons, armadillos

Fungi – Major Subdivisions

Mushroom – a fungus with a stem and a cap
Shelf Mushroom – grows out of a tree or a log like a shelf
Lichen – small, patchy, flattish growth on dead wood or stone (fungal/algal symbiont)

RESOURCES

Missouri Department of Conservation Field Guide - http://mdc.mo.gov/discover-nature/field-guide
Missouri Botanical Garden Plant Finder - http://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx

Where is the Wildlife?

Draw a picture of something living in your schoolyard.

Name ____

What kind? Plant Animal Fungus

How big? thumb hand head body car building

How many? _______________

Engineering a Greener School: Teacher
3rd to 5th Grade: How Does the Water Flow?

This lesson allows students to apply the concepts of impervious and pervious materials, measuring area, and calculating fractions or percentages; and introduces the concept of storm water run off and the effect on stream flow. Students will be able to apply learned skills in an authentic context that helps them make sense of the world around them.

ELA – 3 W2 – Write informative/explanatory text, 3L Demonstrate command of the conventions of standard English, 3 L6 Acquire and use accurately a range of domain-specific words
Math – 3 NF - Develop understanding of fractions, 3 MD - Understand concepts of area and relate areas to multiplitation and addition, 3 G – Reason with shapes and their attributes
Science – IN1 A – Pose questions, IN1 B Make observations using simple tools, IN1 B Measure length to the nearest cm, compare measurements, IN1 C Evaluate reasonableness of explanation, analyze whether evidence supports explanations, ST3 A Identify a problem that could be solved
Social Studies – 5 EG A Read and construct maps, 6 RI C Take part in a constructive process for resolving a problem, identifying alternatives, judging alternatives

Prior Knowledge

- Students should know about impervious and pervious materials. Impervious materials do not let water through, so water from rainstorms flows off in a downhill direction, just the way a raincoat sheds rain. Pervious surfaces do let water soak into them, so water does not run off, just the way a sponge soaks up water.
- Students should know about structures used to control the flow of water. See the list on the worksheet.
- Students should know how to measure the area of something. This includes things that are not perfect geometric shapes.
- Students should know how to calculate fractions.

Preparation

- Have copies of the work sheet for each student, a sheet of scratch paper for calculations, a pencil with an eraser, and a "clip board" (you can make a "clip board" out of cardboard cut in 9" x 12" sections and a paper clip or bull dog clip). Students or groups of students will also need yard sticks, tape measures, string marked in meters or similar measuring tools.
- Depending on your students, enlist one or more responsible persons to help wrangle them when you are outside.
- Pick out an area of the school yard that would allow them to make their measurements in about 15 or 20 minutes.

Priming

- Tell students they are going to map the materials and structures that cover their school-yard to see which ones let water run off and which ones let water soak into the ground. This is important because more impervious surface increases storm water flowing into streams when it rains. Because the water ran off in the storm, it did not soak into the soil and is not able to provide water for plants or for streams during the drier parts of the year. It is better for plants and streams if storm water does not run off, but soaks into the soil.
- Prepare students for going outside by making sure that they know the physical boundaries of the area to investigate.

- Set clear rules or guidelines for their behavior outside and rehearse them. For example: Leave and enter the building in a quiet and orderly way. Stay with your group. Stay within the school-yard boundary. Listen for the signal to come together.

- Divide students into groups of 2 to 4. Hand each student a worksheet and have them read through it and discuss with each other the **goal** of the field trip. Ask them to think about the materials in the school yard that would be likely to shed water like a raincoat (or are impervious) or soak water up like a sponge (or are pervious). Ask them to think about structures that would slow down or change the direction of water (changing the acceleration or direction of the forces acting on water)
- Have students think about how they are going to measure the area of things that are not exactly rectangular, square, triangular or circular. If they don't think of it themselves, suggest they break odd shapes into different kinds of geometric shapes, measure those shapes and add them together to get the actual shape.

Go Outside! Collect Data!

Follow Up

- In class, make a table on the board with a column for each group + 1 and four rows. In the first column write "Area" in the first row, "Impervious" in the second row, "Pervious " in the third row and "Total" in the fourth row. In the top row, after area, put a number for each group.
- Have the students send a group representative to the board to write the area for each kind of material and the total area. If they are different, briefly discuss why results could differ. If you think they can understand, calculate mean values for each area. Otherwise have them use their group's value for the next step.
- Have them calculate the fraction or percentage of the total area that is impervious surface and the fraction or percentage that is pervious. The lower the impervious fraction or percentage is, the better.
- Have them think about the role of the structures in speeding up or slowing down water in the section of the schoolyard they measured. Ask them to discuss ways the water could be slowed down and diverted to the pervious surfaces so it can soak into the soil.

Assessments

- Have each student write a short paragraph with a recommendation on how to change the flow of water to allow it to soak into the ground. They should use the data they collected to make their case and should illustrate with a picture, map or diagram their suggested recommendation.
- Have each student share their paragraph with another student, compare their recommendations and then make changes in their own recommendation or write a joint recommendation.

Extensions

- On a rainy day, have the students go outside and see if their ideas about where the water goes were correct.

RESOURCES

How to Manage and Control Storm Water Runoff - http://dnr.mo.gov/education/bigriver/how-to-protect-our-water/home-asyst-stormwater.pdf – Section 2 is relevant to this exercise, but the whole document provides useful information on the need to control storm water runoff

How Does the Water Flow?

Water always flows downhill. That includes in your schoolyard! Your goal is to find out how the water flows in your schoolyard and then think about ways to slow it down or stop it flowing.

Draw an outline map of the schoolyard in the space below. If the schoolyard is really large, just draw part of it.

On the map, draw the location, shape and area of different kinds of materials on the surface. The area of a material does not have to be exactly right. You can estimate if it is 1/3, 1/4, or some other fraction of the total area for now. You will measure it later. The materials can be concrete, asphalt, grass, bare soil, mulch, or something else.

Measure the area of each different kind of material. If the area is not a simple shape like a rectangle, then divide it into sections of different simple shapes. Measure the area of each of these simple shapes and add them together to get the area of a kind of material. Record the area of each kind of material on the map and in the table below.

On the map, draw or label the structures which affect the flow of water.

Structures

- street gutter – narrow depression that quickly carries water away
- storm drain – an opening along a street gutter that carries water into an underground pipe and from there to the nearest stream
- rain garden – a low spot planted with flowers and shrubs to hold storm water until it can soak into the ground
- grassed swale – a low spot planted with grasses to hold storm water until it can soak into the ground
- permeable pavement – pavement with large enough holes to allow storm water to soak into the ground
- rain gutter – a narrow trough that collects rainwater running off the edge of a roof and carries it to a downspout
- downspout – a narrow pipe that carries rainwater from a gutter to the ground or to a rain barrel
- rain barrel – a barrel that collects rain water from a downspout

Kind of Material (concrete, asphalt, grass, mulch, other)	Impervious? Check if yes.	Area

Impervious Area ________ Pervious Area ___________ Total Area ___________