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Environmental Science and Sustainable Development: Educating Students about It

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ABSTRACT- The United Nations World Commission on Environment and Development (WCED) in its 1987 report 'Our Common Future' defines sustainable development as: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Under the principles of the United Nations Charter 'The MillenniumDeclaration' identified principles and treaties on sustainable development, including economic development, social development and environmental protection.Broadly defined, sustainable development is a systems approach to growth and development and to manage natural, produced, and social capital for the welfare of their own and future generations..Issues of sustainability are inherently complex and constantly changing. It is therefore crucial to address these issues from an interdisciplinary perspective also. Courses should be designed to broaden the students' perspective on questions and challenges related to sustainable development, and at the same time provide opportunities to deepen knowledge in relevant fields. Students should also learn how to use relevant analytical tools for studies of environmental change concerning sustainable development. They should know how can the contribution of Science & Technology to sustainability be improved? They should also know if science is so useful, why we don't invest more of it in this aspect of development. This paper aims to achieve this byproviding material on relevant and practical activities that engage students in sustainability in his classroom thus paving the way for a sustainable future and its green aspects.

Keywords: Environmental Sciences, Sustaiable Develpoment, Teach,

Introduction

Sustainable development is a society project, and a political one, that cannot be defined and implemented without science, both because science has to play a huge role in the choice of technical solutions and because science is not disconnected from society. Science is an organised & dynamic process of finding solutions to technological problems. Science is heritage of all and integration between science, technology, education and development, technology as application of science to changing reality, technological development as part of learning process is essential for sustainable development so the students should be able to recognize that "development is built not merely through the accumulation of physical capital and human skill, but on a foundation of information, learning and adaptation…"and that relevant knowledge for that remains under produced, underutilized and unevenly distributed. They should also know that development is impossible without learning process including science & technology.

But learning process ignores role and needs of human beings and concept of participation in education is at its nascent stage only. So theeducational materials should be organised around developing 'capabilities' not disciplines.

Sustainable Development not just as a subject of Science Education

All the dimensions of sustainable development can be addressed in a multidisciplinary way by the scientific approach method itself which can stimulate the same level of demand in the reasoning in this regard**.**Inquiry-Based Science Education (ESD) can provide inputs to education for sustainable development both on contents and methods. ESD is tackling issues that have been identified mostly on the basis of an environment/ nature-oriented issue (climate change, biodiversity, water…), and thus to situations and phenomena that are the usual inquiry field of scientific process towards knowledge. This method can also be used to provide a much more and cohesive way to address sustainable development issues against the compartmentalisation tendency -linked to the school subject- which may appear easier to implement.

Teaching Chemistry for Sustainable Development

In this paper teaching and assessment support for chemistry related subjects are given with .the content on wide variety of teaching methods, from lesson-style teaching, to problem based learning. To address the requirement of education for sustainability this paper contains Activities, Ideas, StudentHand Outs, Summary, Homework Ideas on sustainablechemical innovations.

The part one is on ‘Green Chemistry’ followed by three parts. Green Chemistry principles that scientists and engineers can use to move towards sustainable development are discussed in it.

In Part two on Greenhouse Gases therole of Green Chemistry in helping to mitigate climate change by reducing greenhouse gas emissions and by removing greenhouse gases from the atmosphere is discussed. We briefly discuss the types of greenhouse gas (GHG) emissions and existing chemistry innovations in sequestering and mitigating them.

In part three on Reducing Toxicitythe concept of ‘benign by design’ is introduced, where products and services are designed so that they don’t use or produce toxins in the first place.

And in part four the topic of making better batteries students are educated on the issues and possible opportunities within the field of batteries, as well as the role batteries will play in enabling sustainable development. The opportunities in hybrid-electric and electric vehicle applications, biodegradable batteries, and batteries that can support reliable renewable energy supply in particular are highlighted.

Part-1

The activities suggested do not cover extensive amounts of chemistry theory; rather they provide an application that demonstrates how theory learnt in class can be used to develop sustainable solutions to real world problems.

Activity 1 – Experiment: Biosynthesis of Ethanol from Molasses[1]

In this activity, the teacher (in a demonstration) or students (in groups) use chemistry laboratory skills to apply three green principles (the use of renewable resources, catalysis, and design for degradation) in a biosynthesis reaction. This experiment has been adapted from a ‘Greener Education Materials for Chemists’ publication.

(Note that part of this experiment needs to be prepared a week in advance!)

Key Learning Point:

Green chemistry principles can be applied to all kinds of chemical reaction processes, to lessen the environmental impact of reactions.

Resources:

Students should be briefed about the 12 principles of green chemistry and Green Engineering.

Materials (per demonstration): 70ml molasses, 70ml water, 0.5g yeast, $Ca(OH)_2$ (to make
Lime water)

Equipment (per demonstration): 250ml Erlenmeyer flask, One-hole rubber stopper, containing bent glass tube, Test tube, Simple Distillation Equipment, Fractional Distillation Equipment.

Teacher Preparation:

Whoever is undertaking this experiment (i.e. as a demonstration or in student groups) will need to have sound chemistry knowledge and skills in distillation. The principles applied in this lab (the use of renewable resources, catalysis, and design for degradation) are described in detail in the student hand out.

Activity Description:

The first part of the experiment (the fermentation) must be performed a week prior to the
Distillation (boiling)

Procedure 1: Week 1

1. Mix 70 ml of molasses with 70 ml of water in a 250 ml Erlenmeyer flask.
2. Add about 0.5 g of yeast to the flask and stir gently until well mixed.
3. Stopper the flask with a one-hole rubber stopper containing a bent glass tube.
4. Attach a short rubber hose to the bent glass tube and insert a short straight section of glass tube into the other end of the rubber tube.
5. Dip the straight glass tube into a test tube two-thirds full of limewater, $Ca(OH)_2$ solution. The test tube of limewater serves as a one-way vapour lock, keeping air from entering the flask while allowing the carbon dioxide to escape. If air were to enter the flask during the reaction, the ethanol produced would be further oxidized to acetic acid (vinegar).
6. Store this apparatus in a lab cabinet (in darkness) for one week while the fermentation reaction occurs.

Procedure 2: Week 2

1. Prepare a simple distillation, decanting the ethanol solution into a 250 ml round bottom (Florence) flask.
2. The simple distillation can be done fairly rapidly (one drop per second) and the alcohol fraction should be collected until just below the boiling point of water, 100ºC.
3. Prepare a fractional distillation, placing the mixed alcohol product from the simple distillation in another round bottom flask. Distil the ethanol slowly; record the temperature range for each fraction collected - stop collecting at 90ºC.
4. Fractions are identified by a rapid change in temperature and a concurrent increase/decrease in distillate production.
5. Determine the density of each fraction by massing a 10 ml sample collected with a volumetric pipette. If the collected fraction is less than 10 ml, use the available pipette that is closest in volume to the fraction.
6. Use the Table below to determine the alcohol content in each fraction.
7. Record your volume of "pure" ethanol collected and add your ethanol to the collection container.
8. Discuss with students the benefits of conducting chemical processes without the production of toxic by-products or the use of significant energy.

Determining the Aqueous Alcohol (EtOH) Content:

Density g/ml	% EtOH by wt.	% EtOH by vol.	g EtOH per 100 ml	Density g/ml	% EtOH by wt.	% EtOH by vol.	g EtOH per 100 ml
0.989	5	6.27	4.95	0.856	75	81.30	64.17
0.982	10	12.44	9.82	0.843	80	85.49	67.48
0.975	15	18.54	14.63	0.831	85	89.48	70.63
0.969	20	24.54	19.37	0.828	86	90.25	71.23
0.962	25	30.45	24.04	0.826	87	91.02	71.84
0.954	30	36.25	28.61	0.823	88	91.77	72.43
0.945	35	41.90	33.07	0.821	89	92.53	73.03
0.935	40	47.40	37.41	0.818	90	93.27	73.62
0.925	45	52.72	41.61	0.815	91	93.99	74.19
0.914	50	57.89	45.69	0.813	92	94/72	74.76
0.903	55	62.89	49.64	0.810	93	95.44	75.32
0.891	60	67.74	53.47	0.807	94	96.11	75.86
0.880	65	72.43	57.17	0.804	95	96.79	76.40
0.868	70	76.95	60.74	0.789	100	100.00	78.90

Part 2- How to Deal with Greenhouse Gases

The aim of this part is to provide an overview of climate change and 'peak oil', and introduce ways of reducing our greenhouse gas emissions and reliance on fossil fuels like oil as an energy source. In particular, we will consider using energy more efficiently in everyday places like our homes, and using different forms of fuel and technology to power vehicles.

Activity 1 – Discussion: A Family of Greenhouse Gases?

In this activity, students are encouraged to discuss the science around greenhouse gases and their various contributions to atmospheric heating.

Key Learning Point:

It is an important skill to be able to discuss the science behind climate change, with regard to the role of greenhouse gases in affecting atmospheric systems.

Resources:

Overview of the range of GHG Emissions[2]

Depending on the time available to cover this topic, we recommend viewing *An InconvenientTruth*[3]. Hosted by ex-Vice President of the United States, Al Gore, this documentary providesa well considered introduction to climate change. The documentary explains in easy-to-understand terms the latest scientific evidence of global warming and its potential impacts on our civilisation. To learn more about the documentary or to preview the trailer teacher with students should visit www.climatecrisis.net.

Teacher Preparation:
– Depending on the level of understanding about this topic, teachers may want to do some preparatory research, following up on the references provided in 'Brief Background Information' in the student materials.
– Students should be given time to prepare for the activity, and class time should be allocated for the actual discussion.

Activity Description:
1. Divide students into five groups. Prepare a table listing Greenhouse gases, Provide each group with one of the gases listed in the table, not including carbon dioxide.
2. Ask each group to discuss:
a) The natural, and human-derived sources of this gas;
b) The atmospheric lifetime and global warming potential, compared with CO_2.
c) The percentage of Indian and other countries' emissions.
d) An example of where this gas emission is being addressed.
3. After allowing discussion time, ask the groups to – in turn – present their considerations to the rest of the class.
4. After each presentation, or after all of the presentations, bring the various topics together by reconsidering the Key Learning Point above.
5. Highlight the complexity of atmospheric systems, the need to be cautious about any gaseous emissions, and the many opportunities for chemists to reduce the emission of very powerful greenhouse gases to the atmosphere.

Student Hand out – Creating Low Carbon Glue[4]
This activity has been modified from an activity developed by Beyond Benign Biomimicry Matching Activity, considering how we can imagine new possibilities for nature-inspired materials that do not rely on fossil fuels.
The following glues have been inspired by a variety of natural organisms over millions of years. Can you match the inspiration with the glue?
Using the information about various organisms provided on the table above, match the organism to the low carbon glue solution in this table

Glue Innovation	Properties of the Glue
Gorilla Glue	– Expands as it cures, filling gaps – Is waterproof – Takes a few hours to dry so you can reposition things if you need to
Epoxy	– Comes in two parts, resin and catalyst – Is sold in different drying times – Once cured can be drilled, sanded or Painted
Elmer's Glue	– Non-toxic – Can be cleaned up with water – Good for wood and paper gluing
Rubber Cement	– Easy damage free removal – Favored in arts and crafts projects – Will not shrink or swell paper fibers
Superglue	– Fast Drying – Creates an almost invisible bond – Can stick human skin together – Dries out easily if not stored properly
Liquid nails	– Withstands temperatures from -60° to 300°F, indoor & outdoor – Acid free / Low odour – Flexible & shock absorbing – Works on wet surfaces – Can fill gaps up to 1/4" (6mm) – Does not adhere to polyethylene or Polypropylene
Silicone Adhesives	– Reacts with moisture in the air – Used around water as in gasket sealants and caulking – Used in electronics

Part 3- *How to Reduce Toxicity*
The aim of this part is to provide an overview of the challenges that India and the rest of the world are facing with maintaining our most precious resource: water. This lesson will introduce various ways we can use water more efficiently, clean water more effectively, and help major users of water, like agriculture, reduce their reliance on drinking-quality (i.e. potable).

Activity 1 – Experiment: Toxicology Testing[5]
This activity will introduce students to an environmental monitoring technique called a 'bioassay', using plant material. The activity has been adapted from Environmental Inquiry, a collection of ideas and resources to support student projects on a wide range of topics in the environmental sciences produced by Cornell University through an American National Science Fund grant.

Key Learning Point:
Many household products and common bodies of water contain chemicals that are harmful to plant and animal life. The sensitivity of food crops to common pollutants and products can be tested through simple tests using plant material.

Resources:

– Materials (per group of 4 students): lettuce seeds, bleach, deionized water, petri-dishes, samples of suspected contaminated water, soils, solutions of household substances .

Teacher Preparation:

– For this activity, the teacher will need to become familiar with the process of doing a plant-based bioassay, which involves use of plant material to test for chemical toxicity. For environmental testing, plant bioassays can provide an integrated picture of overall toxicity of an effluent or a sample of water, sediment, or soil from a contaminated site.

– The experiment runs over 5 days, so if the class timetable does not match, the teacher may need to prepare a demonstration experiment 5 days prior to the class with students.

Activity Description:

Preparation:

1. Soak lettuce seeds for 20 minutes in a 10% bleach solution (add 1 part household bleach to 9 part deionized or distilled water). Then rinse five times. This kills fungal spores that can interfere with seed germination. Note: Tap water can be used if you do not have access to deionized or distilled water, but it will introduce more variability into your experiment because of the varied minerals and other compounds it contains.
2. For water samples, place a 7.5-cm paper filter in each 9-cm petri dish. Add 2 ml of water sample to each dish
3. For sediment or soil samples, place 3 grams of sample in the bottom of each petri dish and cover with filter paper. If the sample does not contain enough moisture to saturate the filter paper, add up to 2 ml deionized water as needed.
4. Prepare a control by setting up dishes using 2 ml deionized or distilled water as your test solution.
5. To each dish, add 5 lettuce seeds, spaced evenly on the filter paper so that they do not touch each other or the sides of the dish.
6. Place the dishes in a plastic bag, and seal it to retain moisture. Incubate in the dark at constant temperature (preferably 24.5 degrees C) for 5 days (120 hours).

Measurement:

7. Collect and Interpret the Lettuce Seed Bioassay Data: At the end of the 5-day growth period, count and record how many seeds in each dish have germinated. For each sprout, measure the radicle (the embryonic root) length to the nearest mm. Instruct students to look carefully at the plants to make sure they are just measuring the radicle, not the shoot as well. For example, in the picture below, you would measure just the part between the two arrows, not the shoot and cotelydons to the left.

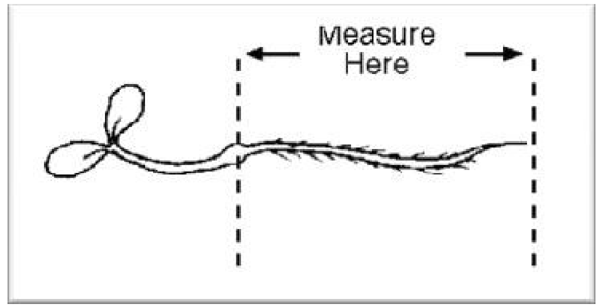

Figure-3: Measurement

8. Compare the data with the Control: Count and record how many seeds in the control dish have germinated. The purpose of the control is to identify how well the seeds will grow without any added contaminants. Would you expect all of the seeds in your control dishes to germinate? Probably not, just like a gardener does not expect all the seeds in a garden to sprout.
   If fewer than 80% of the seeds in the control dishes sprouted, something may have gone wrong in the experiment. Perhaps the seeds were too old or stored improperly, so they were no longer viable. Or maybe something went wrong with the conditions for growth. Did the dishes get too hot, too dry, or contaminated in some way? Did students use tap water for your control, rather than deionized or distilled water? In many cases this works fine, but since tap water is highly variable from source to source, it gives less predictable results.
9. Consider the variability of results: Within each treatment, how much variability did students find in their results? Did the replicate dishes show similar numbers of seeds sprouting, and similar average radicle lengths? If you think the data are much more variable than you would expect, you might want to explore the potential sources of variability for this type of experiment.
10. Relating to toxicology: How might water and soils become contaminated? How can chemists and chemical engineers prevent this from occurring? If soils and water are contaminated, how can we remediate the soils?

Part 4- How to make Better Batteries

The aim of this part is to introduce the significance of waste that comes from our everyday practices, and the extent to which waste-to-landfill impacts on the health of our society and the environment. This part will introduce the benefits of reducing and eliminating waste.

Activity 1- Experiment: Sea Water Batteries[6]
In this activity students (or a teacher in a demonstration scenario) will create a battery using salt water. This activity has been adapted from an activity by Creative Science.

Key Learning Point:
Landfills are complex scientific systems. What we put into landfills affects all parts of the landfill and surrounding land through leaking liquids (i.e. leachate), leaking gases (i.e. off-gasing) and leaking contaminants (i.e. soil contamination). We can improve landfill use by properly designing the landfill, reducing the amount we put in, and sorting the waste before disposal.

Resources:
– Students should have a sound understanding of the chemistry behind batteries (including ionic chemistry, electrolysis and the electrochemical series)
– Materials (for each group of 3-5 students): Salt (NaCl), Ice- cube trays, Flat piece of wood (ply or balsa, same size as ice cube tray) for electrode support, Galvanised screws (about 5 cm long) for each battery, 12 pencil leads (2B or softer), or better still, school lab carbon rods or ones salvaged from old worn out batteries, Tinned copper wire, Alligator Clips, LED lights.

Teacher Preparation: The teacher may wish to create a demonstration model to use with the class.

Activity Description:
A very brief background to the experiment
The voltage created in a battery is due to ionic chemistry. When a metal electrode is immersed in an electrolyte a rather complex dynamic process occurs. Let us assume that the metal electrode is initially uncharged (the atoms from which the electrode is made are neutral - they have equal numbers of electrons and protons). When the metal is immersed in the electrolyte, positive metal ions are formed on the surface of the electrode. These ions pass into solution, making the electrode progressively more negative, as the positive ions move away. There will come a time, however, when the negatively charged electrode will start to attract back the oppositely charged ions. So a dynamic equilibrium is thus formed between those ions leaving and those returning to the metal surface. How far the equilibrium goes one way or the other is dependent on the reactivity of the metal.

A battery must have two electrodes, so meanwhile on the other electrode, a similar process must be taking place. If this second electrode is of the same metal as the first, then each electrode will charge to the same extent (voltage), and there will be no resulting difference between them. There will thus be no attractive force (electromotive force EMF) between them, and so no current will flow.

A pair of electrodes can produce a voltage when immersed in an electrolyte. In the following experiments we use of galvanised (zinc- plated) screws and carbon rods as the electrodes and salt water as the electrolyte. While carbon is a good conductor of electricity, the chemistry that takes place at the carbon electrode is more complicated than would be the case when simply using metals. However, larger potentials are produced with carbon and zinc than with copper and zinc, so it is worth the complication. Carbon is a good conductor of electricity. In these cells the metal (zinc) electrode is negative (-) while the carbon becomes positive (+).

To increase the limited voltage and current of such a simple cell, we can join up cells to make a battery of cells - thereby increasing the power. An effective arrangement will be discussed. Household ice- cube trays are used to hold the electrolyte, and wood supports the multiple pairs of electrodes, a set for each ice cube tray.
Make the battery:
1. Fill each of the ice cube trays ¾ full with salt solution (sea water or a solution of table salt in water).
2. On the wood, mark the divisions of the ice cube tray.
3. In each division, insert one nail and one carbon rod, as seen in the figure:

Figure 2. Tray and Wood

4. Use the tinned copper wire to connect each electrode appropriately. This completes the construction of the battery.

So what is the best way to wire up the 12 cells to get useful power from the battery – in series, or in parallel? Consider a single cell - it can produce a voltage of V volts and a maximum current of say I amps. Wiring a number (n) of these cells in series (one after the other in a sort of daisy chain) will multiply the voltage giving n x V volts. However, the maximum current produced by this arrangement will be the same as that of a single cell - I. On the other hand wiring all the cells in parallel will increase the current n-fold but maintain the voltage equivalent to that of a single cell (i.e. V). Combinations of series and parallel cells with produce combination of possible total V and I.

The ice cube tray used in these experiments has 12 compartments (i.e. 12 holes for ice cubes) and so to get useful power from the battery two combinations of wiring could be
used (see Figure 2).

a) Configuration a) consists of two sets of six cells wired in series and these two sets are then wired in parallel - giving a total of 6 x V and 2 x I.
b) Configuration b) consists of two sets of six parallel cells which are wired in series - giving a total of 2 x V and 6 x I.

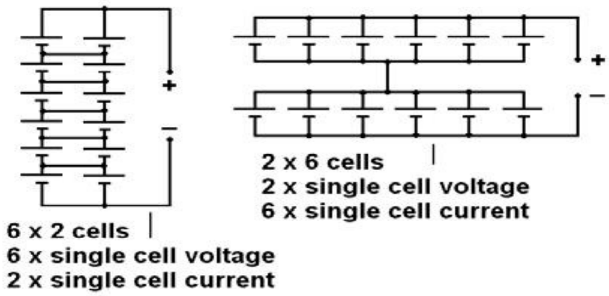

Figure 3. Combination of series and parallel

5. Connect the ends of the circuit to the LED with alligator clips. Remember to check that the device you are powering is correctly wired to the – and + connection of the battery (metal (zinc) = -, carbon = +). We now have a sea water power plant! A pocket LCD calculator, an LED (and series resistor), and possibly a pocket radio, will work well using this arrangement.

   The first battery circuit provides a relatively higher voltage than the second and so it can therefore be used to power devices that need 'higher voltages' but low currents.

   In the demonstrations, you may use a simple flashing LED circuit to dramatically show the battery working. This circuit requires about 3V, but only about 1 or 2 mA to work.

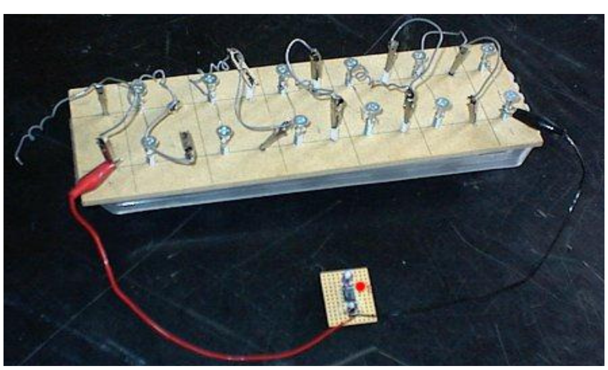

Figure 4. The complete 'high' voltage, 'low' current sea water batteryconnected to an LED flasher circuit

Conclusion

Actions to improve sustainability aim to reduce our ecological footprint while simultaneously supporting a quality of life. Sustainable patterns of living meet the needs of the present without compromising the ability of future generations to meet their own needs. Sustainability is both an individual and a collective endeavour often shared across communities and nations necessitating a balanced but different approach to the ways humans have interacted with each other and with their biophysical environment. Sustainability learning draws on and relates learning across the curriculum. It leads to students developing an overall capacity to contribute to a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations. The material and activities given in this paper are aimed at providing both teacher and students with some ideas on how innovation in education of science, more particularly in education of chemistry, can be used for sustainable development. For this a teacher has to go beyond the curriculum requirements and devise on his own some activities which may or may not be a part of the science text books. Because a more sustainable world is a moving target with new challenges emerging, resources diminishing and human population growing, governments and educational institutions will constantly need to recalibrate their visions and action plans. We have to learn our way forward toward more sustainable societies. A teacher in general and a science teacher in particular can play a pivotal role in it.

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