

**MIDDLE SCHOOL**

**Green Chemistry**

**Lesson Three: Life Cycle**

**Background:** How do we know a technology is truly sustainable? Green chemistry, an area of science that is considered to be pollution prevention at the molecular level, provides multiple tools for evaluating how “green” a product is. There are three criteria that determine whether something can qualify as a green chemistry technology: cost, safety, and performance. A green chemistry technology must be comparable in cost or cheaper, must be safer for human health and/or the environment, and must perform just as well or better than existing products. Additionally, there are 12 Principles of Green Chemistry that are used in technical research to help guide the process of developing a green chemistry technology. These criteria and principles help scientists and engineers design truly sustainable products and combat the use of “green washing” marketing, in which advertisers exaggerate environmental product claims.

In this lesson, students will take part in a very important task typical of any scientist or engineer: reviewing and revising their experimental procedure. The given procedure for students involves extra wasteful and unnecessary steps. In groups, students will evaluate the given procedure, rewrite each step, and justify the changes they are making. Together, their changes will highlight the three criteria important for green chemistry technology, which allows for discussion of the sustainability of their mycelium cell phone case.

**Objectives:** Students will…

* Understand the 12 Principles of Green Chemistry
* Define *life cycle*
* Apply their understanding of life cycle to identify the manufacturing process of both a renewable and a nonrenewable product
* Revise a lab procedure to increase efficiency and reduce waste.

**Key terms**: life cycle, renewable and nonrenewable resources

**Materials:**

* Copies of Student Procedure sheets
* Copies of blank Revised Lab Procedure sheets

**Time Required:** 45-class period

**Standards Met:**

**MS-ETS1-1.** Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

**MS-ETS1-3.** Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

**Keys to Success:**

* This lesson focuses on carefully reviewing, analyzing, and revising a given lab procedure. There is no need to purchase materials listed in the student lab sheet for the original procedure, like glitter or cans of soda.
* In the debrief of the life cycle cards, some groups will likely start the mycelium materials life cycle at two different points, either agricultural production with compost or renewable resources from agricultural waste. Either of these starting points will work perfectly well, as the life cycle is really best represented as a circle without a distinct starting point.
* The 12 Principles of Green Chemistry, along with simplified descriptions, are attached at the end of this lesson as resources for the 12 Principles extension discussion.

**Teacher Preparation:**

* Print and cut life cycle cards
* Print Student Procedure and Revised Lab Procedure sheets

**Procedure:**

5E Procedure:

*Engage:*Students will consider the life cycle of polystyrene compared to mycelium materials using their knowledge from prior lessons to set the stage for designing their cell phone case.

* As a class, define *life cycle* as it relates to products. Affirm student answers that help build the accurate understanding that life cycle refers to the very beginning materials a product is made from, through its time in use, until it is no longer useful or desired and is then disposed of.
* Explain to the class that you will be passing out sets of 10 cards. Each set contains two different life cycles, one for polystyrene (Styrofoam) and one for mycelium materials (Ecovative). Working in groups, they will separate the two life cycles from one another and put them in order.
* Divide the class into groups of 4 or 5 students and give them time to complete the activity together.
* Debrief the activity as a class by first going over each life cycle, starting with polystyrene. Either invite volunteers to the front of the class to hold each card in order or tape the cards to the board. The order for each life cycle is as follows:
  + Polystyrene: Non-renewable petroleum sources, multi-step manufacturing process, consumer product, minimal recyclability, landfill
  + Mycelium materials: Agricultural production with compost, renewable feedstocks from agricultural waste, natural growth cycle, consumer product, biodegrades by composting
    - NOTE: The life cycle for mycelium materials can start at any point, as it is actually a *closed-loop life cycle*.
* Ask the class what they think about each of these life cycles. Do they believe that a line is the best way to represent each of these life cycles?
* Hopefully, at least one student group will suggest to move the mycelium materials life cycle into the form of a circle. Have the students holding the cards at the front of the room organize their cards into a circle to represent this shift in thinking, or move the cards taped to the board into a circle.
* Explain to the class that the mycelium material life cycle represents what is called a *closed-loop life cycle*. This means that there is no distinct beginning or end to the product’s life. When products with this type of life cycle are no longer useful or desired for their primary purpose, they can be used to create new useful materials. This type of life cycle is in distinct contrast to the life cycle of polystyrene, which has a clear beginning and end. Once polystyrene goes to the landfill, it will stay there for hundreds of years before it will break down.

*Explore:*Students review the procedure they will use to make their mycelium material cell phone case.

* Explain to the class that they will be taking on the role of the material scientists to build their cell phone case. One of the most important first steps that any scientist will take before they perform an experiment is to carefully read the procedure, ask questions, and make any appropriate revisions.
* Divide the students into the same groups as in Lesson 2 (2 to 4 students) and have them read the procedure and share feedback with each other.
* The students will likely exclaim that some of the steps are “stupid” or “pointless” or ask why certain steps are included.

*Explain:*Students discuss their thoughts on the procedure they have just reviewed.

* Ask the class what thoughts they have about the given procedure.
* Tell the class that you agree that some of the steps seem wasteful, unhealthy, or unnecessary.

*Engage/Elaborate:*Student groups revise the procedure to increase efficiency and reduce waste.

* Hand out the Revised Lab Procedure sheet. Instruct the groups to rewrite each step of the procedure on the sheet. Some steps may need to be eliminated, while others can be kept in their entirety. For each change that the groups make, they will need to be ready to justify their revisions.
* When they have revised their procedure, groups should also make the appropriate changes to their materials list.

*Evaluate:* Student groups share the new procedure with the class and discuss the criteria for green chemistry technologies and sustainable innovations.

* Ask student groups to take turns sharing each step of the newly revised procedures. For each step they share, they should justify any changes they made.
* Once students have finished sharing, ask the class if they have noticed any common themes in the rationale behind the changes their classmates have made.
* Summarize student ideas by acknowledging the common themes of improving the procedure with respect to cost and waste. Affirm that cost and waste are closely related.
* Use glitter as an example to talk about both cost and waste. If we add glitter to the mycelium material, we take a biodegradable product and make it so that it can no longer entirely biodegrade. If we eliminate the glitter, we save the cost of an unnecessary addition as well as reduce the waste related to our product.
* Explain to the class that there are three major criteria that are used to consider green chemistry technology, the area of innovation focused on preventing pollution and increasing sustainability at the very beginning stages of product design. Two of these criteria have already been discussed. A green chemistry technology must be cost effective, ideally being comparable in cost or cheaper than existing technology. Additionally, the new product should be safer than the existing traditional product. In this case, the biodegradable cell phone case is safer for the environment because it will not have harmful, lasting impacts like other plastic cell phone cases. However, product safety can also relate to human health.
* Ask the class what the other criteria for green chemistry technology may be.
* Explain that the third criterion is performance. This means that new greener products must work just as well or better than the existing products for them to be useful and competitive on the market.
* Share with the class that green chemistry criteria give us a simple way to evaluate how sustainable a product is. There are many different metrics for measuring sustainability, but cost, safety, and performance keeps things simple while also taking into consideration many aspects of the product.
* To wrap up, share the actual procedure for mycelium material with the class and affirm the students’ efforts.
* Instruct students to save their revised procedures, as they will need them to grow their cell phone case in the next lesson.

**Extension Option:**

* While going over the students’ revised procedures, share the 12 Principles of Green Chemistry with the class. Ask the class to identify which of these principles they addressed in their procedure. Help students to understand the principles by translating them into more common language. If necessary, highlight additional principles that were used by the students that they do not identify themselves. **Life Cycle- Student Worksheet**

**Directions:** Follow the instructions below to make your own biodegradable cell phone cases. You should create two cases, each based on your prototype, with one variable different between them. This variable can be in the forming of the case itself or it can relate to the growth conditions of the case.

**Materials (per student group):**

* Activated mycelium material
* Water
* Guar gum (thickening agent)
* Gloves
* Tape
* Scale
* Mixing bowl
* Baking sheet
* Alcohol prep pads
* Sharp object for making holes
* Cell phone case mold
* Glitter
* Plastic wrap or Ziploc bag
* Can of soda
* Tablespoon measuring spoon

**Procedure:**

1. Put on gloves.
2. Open can of soda and put aside.
3. Sanitize your gloves, work area, and mixing bowl with alcohol prep pads.
4. Throw away alcohol wipes**.**
5. Remove mushroom material from bag and place in clean mixing bowls.
6. Lean over to see if you can hear the mycelium growing.
7. Take what you need for your cell phone case and throw away the rest.
8. Break up material with gloved hands until material is loose (material will lose most of its white coloring).
9. Add one tablespoon of water at a time to dampen material and mix while saying the alphabet backwards.
10. Add guar gum to mixture so that material will start to stick together.
11. Repeat until material has a clay-like consistency.
12. Add glitterto give your cell phone cases a sparkle.
13. Sanitize cell phone case molds/forms with another alcohol wipe and allow to dry.
14. Make 2 cell phone cases based on prototypes. Shape material into desired objects. Sing Mary Had a Little Lamb for 1 minute.
15. Cover surface with plastic to keep material safe from contaminants in the air while it grows.
16. Throw out remaining wrap.
17. Poke 10–20 holes in wrap, 1 inch apart, to allow for respiration.
18. In a clean area, at room temperature and in indirect sunlight, let material grow until fully white again (checking periodically).
19. After 7–10 days, once the cases are fully white, unwrap them and let air dry for 1–3 days.
20. Weigh the cell phone cases and place them on the baking sheet.
21. Determine what 35% of the original weight of each cell phone case would be.
22. Bake the cell phone cases at 200 °F. They will be done when they weigh about 35% of their original weight (check every half hour).
23. Remove from the oven and allow to cool.

**Lesson 3 Revised Lab Procedure**

**Materials:**

**Directions:**

**1.**

**2.**

**3.**

**4.**

**5.**

**6.**

**7.**

**8.**

**9.**

**10.**

**12.**

**13.**

**14.**

**15.**

**16.**

**17.**

**Lesson 3 Teacher Key: Revised Protocol**

**Materials:**

* Activated mycelium material
* Water
* Guar gum (thickening agent)
* Gloves
* Tape
* Scale
* Mixing bowl
* Baking sheet
* Alcohol prep pads
* Sharp object for making holes (both plastic and wooden)
* Cell phone case mold
* ~~Glitter~~
* Plastic wrap or Ziploc bag
* ~~Can of soda~~
* Tablespoon measuring spoon

**Procedure:**

1. Put on gloves.
2. ~~Open can of soda and put aside.~~ This is not used in the procedure, so it is unnecessary and wasteful.
3. Sanitize your gloves, work area, and mixing bowl with alcohol prep pads.
4. Throw away alcohol wipes**.**
5. Remove mushroom material from bag and place in clean mixing bowls.
6. ~~Lean over and to see if you can hear the mycelium growing.~~ Waste of time and energy.
7. Take what you need for your cell phone case and ~~throw away the rest~~ share the leftover material with another group. Prevent waste by maximizing the use of available resources.
8. Break up material with gloved hands until material is loose (material will lose most of its white coloring).
9. Add one tablespoon of water at a time to dampen material and mix ~~while saying the alphabet backwards~~. Waste of energy.
10. Add guar gum to mixture so that material will start to stick together.
11. Repeat until material has a clay-like consistency.
12. ~~Add glitter~~~~to give your cell phone cases a sparkle.~~ Waste of material, also makes the cell phone case unable to be composted.
13. Sanitize cell phone case molds/forms with another alcohol wipe and allow to dry.
14. Make 2 cell phone cases based on prototypes. Shape material into desired objects. ~~Sing Mary Had a Little Lamb for 1 minute.~~ Waste of time and energy.
15. Cover surface with plastic to keep material safe from contaminants in the air while it grows.
16. ~~Throw out remaining wrap.~~ Waste of material.
17. Poke 10–20 holes in wrap, 1 inch apart, to allow for respiration.
18. In a clean area, at room temperature and in indirect sunlight, let material grow until fully white again (checking periodically).
19. After 7–10 days, once the cases are fully white, unwrap them and let air dry for 1–3 days.
20. Weigh the cell phone cases and place them on the baking sheet.
21. Determine what 35% of the original weight of each cell phone case would be.
22. Bake the cell phone cases at 200 °F. They will be done when they weigh about 35% of their original weight (check every half hour).
23. Remove from the oven and allow to cool.

**12 Principles of Green Chemistry**

**1. Pollution Prevention - Create No Waste**

It’s better to prevent waste than to treat or clean up waste after it’s formed.

**2. Atom Economy - Nothing Should be Left Over**

Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.

**3. Less Hazardous Chemical Synthesis - No Toxicity**

Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.

**4. Design Safer Chemicals - Green Products Have to Work as Well as Non-green Products**

Chemical products should be designed to preserve efficacy of function while reducing toxicity.

**5. Safer Solvents and Auxiliaries - Get Rid of All Non-essential Additives**

The use of auxiliary substances (e.g., solvents, separation agents, etc.) should be made unnecessary whenever possible and innocuous when used.

**6. Design for Energy Efficiency - Reduce Energy Usage**

Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.

**7. Use of Renewable Feedstocks - Use Renewable Materials**

A raw material or feedstock should be renewable rather than depleting whenever technically and economically practical.

**8. Reduce Derivatives - Get Rid of as Many Steps as Possible**

Unnecessary derivatization (blocking group protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.

**9. Catalysts - Make Use of a Reusable Method to Speed up a Reaction**

Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.

**10. Design for Degradation - Use Materials That Break Down in the Environment (Biodegradable)**

Chemical products should be designed so that at the end of their function they do not persist in the environment and instead break down into innocuous degradation products.

**11. Real-time Analysis for Pollution Prevention - Check Everything You Do Against the Other Principles**

Analytical methodologies need to be further developed to allow for real-time in-process monitoring and control prior to the formation of hazardous substances.

**12. Inherently Safer Chemistry for Accident Prevention - Safety First**

Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.