LESSON PLAN 8:

BIOSYSTEMS DESIGN CHALLENGE

PART I

Curriculum: Introduction to Biodesign
Unit: 3—Biosystems
Grade Level: 10th-11th

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TO FIND MORE LESSON PLANS AND TO READ MORE ABOUT THIS CURRICULUM VISIT: BIODESIGNMAKERSPACE.ORG

Background Information For Teachers

Overview of this lesson:

In Lesson 8, we think about how the interconnected, efficient characteristics of natural systems might be applied to human design. We call this "systems thinking"—an approach to design that considers the many people, organisms, and ecosystems that will be affected by our design decisions, long and short term, and seeks to design with this interconnectedness in mind. Systems thinking seeks to "close the loop" on linear systems. For an exam ple of a linear system, think of the way most cities and communities manage and dispose of waste is a linear system—waste is produced, ultimately dumped somewhere, and sits there in perpetuity or until something is done with it. In closing this loop, we would ask: is there a way this waste could serve as a nutrient for another part of a larger system? This is how systems function in the natural world.

So what does a "closed loop" system look like in the human world? We center this lesson on a now-somewhat famous example of "systems thinking": the Cardboard to Caviar Project. Graham Wiles, a man living in Yorkshire in the UK, developed a work rehabilitation program for recovering addicts with a single "linear" waste stream that he saw an opportunity to close. Wiles began by collecting, for a fee, the massive number of cardboard boxes that restaurants in his area needed disposed. He then brought these to a horse farm, which used the cardboard for bedding, which once soiled, Wiles collected again to use in a vermicompost (worm compost) system, that in turn produced more worms. These worms were fed to Siberian sturgeon, which produced caviar, which were sold back to the restaurants where Wiles began this cycle. Over time, he found opportunities to create more networks in this closed loop system—finding, for example, opportunities to employ veterans and recovering addicts in this system as a form of work rehabilitation. Wiles was able to look at problem in his community, and begin to tackle it by designing a system inspired by the natural world's efficiency and interdependence.

In this lesson, which we call the "Biosystems Design Challenge", students make their own "Cardboard to Caviar" Biosystems. This Design Challenge is broken into two lessons: in this first one, Lesson 8, students focus only on coming up with an idea for their system. In the following lesson, the focus is on creating an organized and persuasive poster and proposal for these Biosystems that students present to an imaginary city council. We gave each phase of lesson two hours, but as always, more time usually means more polished and robust ideas. Timing is up to you!

Standards, Objectives, & Supplies

Grade Level: 10th-11th

Duration: 2 hours

Lesson Concept: We can take inspiration from nature's cyclical systems and use these systems as an analog for solving human problems, as in "cardboard to caviar".

Lesson Objectives/Learner Outcomes:

1. Understand the principle of applying ecosystem cycles and input mapping to align with better organized human systems.

2. Design a cyclical system based on a local problem and arrange all components into a visually pleasing graphic.

Instructional Support Materials (if needed):

- Powerpoint with necessary images + journal prompts.
- LCD projector/smartboard
- Access to youtube video: https://www.ted.com/talks/michael_pawlyn_using_nature_s_genius_in_architecture/transcript?language=en

Materials + Supplies:

- Newsprint or big scrap paper for planning posters (24" by 36" or around that size, two to three for each group)
- Post-it notes for planning posters (a pad for each small group of students, preferably different colors)
- Pens (one for each student)
- Pencils (one for each student)
- Sharpies or markers (a handful for each group)
- Scissors (one for each group)
- Tape (a roll for each group)

Science / Art Standards

SCIENCE (Next Generation Science Standards):

LS 2A Interdependent Relationships in Ecosystems - Organisms and populations are dependent on their environmental interactions both with other living things and with non-living factors, any of which can limit their growth. Competitive, predatory, and mutually beneficial interactions vary across ecosystems but the patterns are shared.

LS2B Cycles of Matter and Energy Transfer in Ecosystems - The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem. Food webs model how matter and energy are transferred among producers, consumers, and decomposers as the three groups interact within an ecosystem.

LS2C Ecosystem Dynamics, Functioning and Resilience - If a biological or physical disturbance to an ecosystem occurs, including one induced by human activity, the ecosystem may return to its more or less original state or become a very different ecosys tem, depending on the complex set of interactions within the ecosystem.

ART (National Core Art Standards):

VA:Cn10.1.iiia: Synthesize knowledge of social, cultural, historical, and personal life to create meaningful works of art or design.

VA:Cr2.3.8: Select, organize, and design images and words to make visually clear and compelling presentations.

Learning Plan

Stage 1: Motivation

1. Introduction Lecture: Cardboard to Caviar—How can we translate biological systems into human systems? Review with students the content covered in the last class, namely, biosystems and aquaponics. Remind students that our goal in the previous class was to look at how nature's systems (or nature's technologies, as we also call them) might be very directly applied to our built environment. We tried to imagine how an aquaponics system might be useful in a classroom or an apartment building, for example. Now, we are transitioning into looking at how the efficiency and interconnectedness of biological systems might serve as inspiration in designing for larger human systems. We are no longer just thinking about how a single aquaponics system might serve a single person or family, but rather how "systems thinking" might better serve communities or entire cities. To do this, we take inspiration from the cyclical, interdependent nature of an ecosystem. So what could **this** look like? Show or explain to students Graham Wiles' "cardboard to caviar" project, in which a Yorkshire man decided to "close the loop" one type of waste in his community. He began collecting from restaurants, for a fee, cardboard boxes that were being thrown out and needed them to be taken away. He then sold the boxes to a local horse farm where they were used as bedding. When the cardboard was soiled, he turned it into vermicompost, which produced more worms, which were fed to **sturgeon,** which produced caviar, which they then sold back to restaurants. Wiles then sought to expand this system, employing recovering heroin addicts who were then both employed and were benefitting from being outdoors and engaging with natural systems. He continued to add more and more elements to this cycle, always seeking to create a closed loop where there was an "opening" or source of waste.

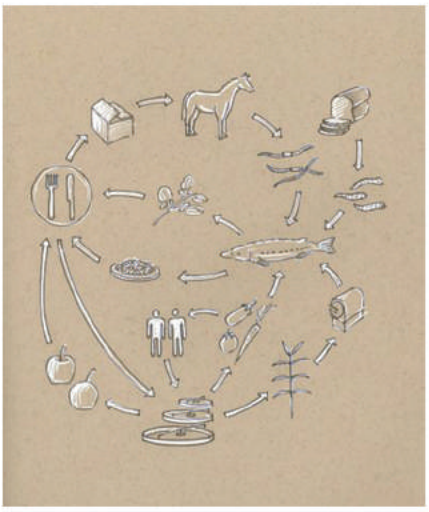

Image: An illustration of Graham Wiles' Cardboard to Caviar Project (source: Pinterest. illustrator: unknown)

Show students a part of the TED talk on this topic: "Michael Pawlyn: Using Nature's Genius in Architecture." This is a fifteen minute long video, all of which is pertinent to Biodesign, but the "Cardboard to Caviar" project is discussed from minutes 4:00-5:34. *(10 minutes)*

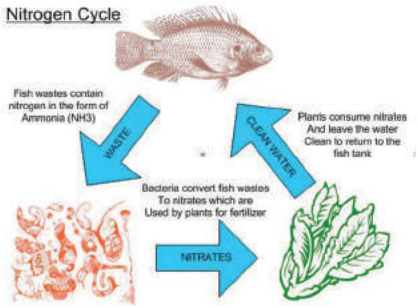

Image: In past classes, students have already become familiar with closed loop systems, as in aquaponics (source: Pinterest. illustrator: unknown)

2. Introduce activity: Biosystems Design Challenge. Explain to students that for the concluding project of this unit, they will be tasked with applying systems thinking in their communities. The challenge: In small groups, students will come up with a "system", (like in the Cardboard to Caviar Project) to "close a loop" in their community. They will not have

to build this system in real life, so these ideas can remain hypothetical. While these can be more complex than students can feasibly make in real life, they should try to keep these systems somewhat realistic. For example, it's perfectly fine to imagine a system that might take a great deal of organization and time to actualize in real life, in which underemployed people in the community are employed to operate an aquaponics system in the former gymnasium of a local school, but to imagine a **system** that turns water into milk that is then turned into milkshakes and sold to local schools is a little less likely because that water-to-milk technology does not exist. Be ambitious, but make sure ideas are grounded in systems that are already tested and in use! In our class, these systems had to include an aquaponics system, which students learned about and built in the previous class. Students will break up into small groups and brainstorm what their cycle might look like, first answering the questions on the Biosystems Brainstorm Worksheet (see end of PDF) and then beginning to map out their system, using Biosystems Mapping Worksheet if helpful (see end of PDF). Students should expand to bigger paper if it is helpful. This is a collaborative project, so that students can work together to generate ideas and knowledge about their community and what their community is in need of and envision solutions, rather than tackle complex problems alone. *(5 minutes)*

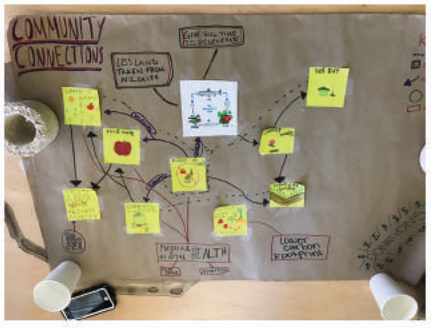

Image: One of our student group's planning document for their biosystem. This group was interested in creating opportunities for work and child care for young mothers and worked this into their biosystem.

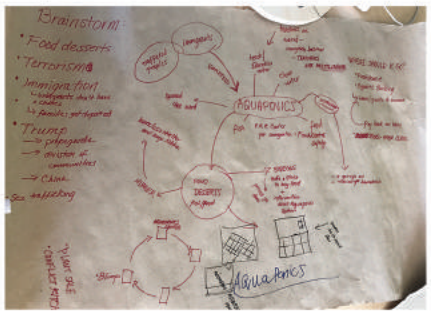

Image: A different group was interested in food deserts in their community. They also were concerned about the current political environment, especially issues concerning refugees and immigrants.

Stage 2: Exploration

1. Biosystems Design Challenge Part I: Brainstorm + Mapping: Put several big sheets of newsprint or scrap paper (24" x 36" inches or around that size), sharpies, post it notes, colored pencils and pens on each group's table, plus enough worksheets for each student (or one for the group to share, with one student acting as the scribe). In small groups, students brainstorm and discuss together using the questions on the Biosystems Brainstorm Worksheet (see end of PDF) and begin **planning** for their Biosystems. If it is helpful, students then use the Biosystems Mapping worksheet to begin laying out their systems. Encourage students to use big sheets of paper to get their ideas down on paper. Remind them, these are cyclical systems, so they should close a loop! They will look like circles! *(45 minutes)*

Learning Plan

Stage 3: Reflection

1. Preview of next class, Biosystems Design Challenge Part II: Students clean up and store (and document, if needed) planning materials for Biosystems Design Challenge. Explain to students: "In the next class, we will be creating a poster and a proposal for our biosystems. We will be briefly going over some key concepts in graphic design in order to create informational posters about our systems, then you'll design these posters using a graphic design software. Lastly, you will **develop** a "pitch" to go along with your poster and deliver your poster and proposal to an imaginary local city council." *(5 minutes)*

2. Five-Minute Journaling. Students return to tables to journal for five minutes. Teacher can pick one prompt for all students to respond to, or students can choose from three prompts. *(Writing: 5 minutes, if desired: 5 minute pair share or group share)*

- What is a problem that you would like to see solved in your school, in your neighborhood, or in your home? How might you design a solution that generates no waste? Draw or write a response.
- Imagine a solution for food waste at your high school's cafeteria. Where could this waste go that might ultimately benefit your school and the environment? Can you create a system that closes a loop? Draw or write a response.
- How is "systems thinking" useful in the built environment? Do you see "systems thinking" already happening in your community? Write or draw a response.

3. "So what?" Lesson Recap. Ask students: What did we do today? Why is it important? Emphasize key ideas covered and larger context for today's learning—for example "Most human systems are open loops. We can take inspiration from nature's cyclical systems and use these systems as an analog for solving human problems, as in "cardboard to caviar". We can make open loop systems closed to the benefit of our environment, our economies, and our communities." *(5 minutes)*

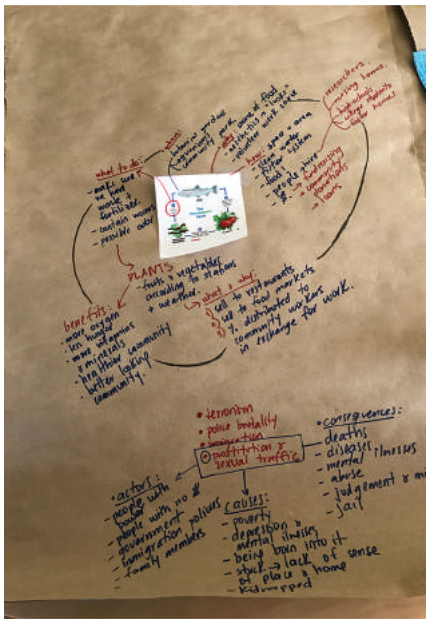

Image: Students needed to have an aquaponics system somewhere in their cycles. This group has pasted a piece of paper with an illustrated aquaponics system on it at the center of their system as they began to work out their ideas.

Biosystems Brainstorm Worksheet

As you begin to think about how to create a biosystem that might solve a problem or close a loop in your community, consider the following questions. Write a sentence or two in response to each. At the end of the brainstorm, look for ways that some of these waste sources or problems might be connected using "systems thinking." Could a source of waste be made useful by something else? Could the solution to one problem help solve another?

1. Where is there waste in my community? (examples might be: food, energy, water, plastic, paper, old cars, machines, home goods or appliances)?

2. What are some problems my community needs to solve? (un-or-underemployment, hunger, food deserts or food inaccessibility, lack of affordable housing, etc.)

3. Where are there unused or underutilized spaces? (examples might be: parks, parking lots, abandoned buildings or buildings that are used infrequently or once a week/month/year)

4. Who could be involved? (examples might be: students who need after-school jobs or opportunities for school credit, underemployed or unemployed people, local or small businesses, etc.)

5. Where are there inefficient or unsustainable systems in my community that could be more efficient? (examples might be: public transportation, school cafeterias, restaurants, stores, social services, etc.)

Biosystems Mapping Worksheet

Your task is to develop an idea for a Biosystem. In small groups, you will come up with a “system”, (like in the “Cardboard to Caviar” Project) to “close a loop” in your community. You will not have to build this system in real life, so these ideas can remain hypothetical and ambitious! You must include an aquaponics system, which you learned about and built in the previous class, somewhere in your system. Use this paper to begin to map out your biosystem, and move to bigger paper as your ideas expand.