FLINN STEM

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IMSA Fusion — Synthetic Scorecard STEM Curriculum Module

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Acknowledgements

Synthetic Scorecard: Building the Future of Biology has been a multi-year collaborative venture with the generous support, help, and time of many organizations and individuals.

Dr. Natalie Kuldell teaches at the Massachusetts Institute of Technology in Biological Engineering. She is also founder and president of the BioBuilder Educational Foundation, a non-profit organization that extends MIT's teaching approach in Biological Engineering and Synthetic Biology by providing modular curriculum and professional development for high school teachers. Dr. Kuldell has lead multiple professional development sessions about synthetic biology in which the curriculum team has team has participated, been a resource, and continues in her roles as mentor and advocate for the writers and curriculum.

Dr. Kathryn Hart is a research instructor in the department of biochemistry and molecular biophysics at Washington University in St. Louis. Members of the curriculum team have participated in Dr. Hart's multiple professional development sessions regarding synthetic biology. She continues to share her lab resources, her mentorship, and advocacy for the curriculum and its participants.

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Melinda Huff from Cynmar has graciously supplied a variety of materials so that activities could be tested.

Leigh Brown from BioRad provided many suggestions and alternatives to bring ideas to fruition.

Curricular Objectives

- Develop an awareness of the discipline of synthetic biology.
- Identify applications of synthetic biology.
- Refine skills necessary to carry out procedures related to biotechnology and synthetic biology.
- Engage in and evaluate modeling and simulations.
- Use real world data.

Background Information

Synthetic biology is a young field with promises of finding solutions to issues such as water and environmental pollution, making more nutritional food, treating cancer and other medical conditions, cleaner energy, and improving computer power. Biologists, electrical engineers, and computer scientists merged forces to develop this venture. Taking the approach of design, test, build enables participants to work together to develop methods of standardization, abstraction, and synthesis that are used while engineering biological systems. The genetic code of G, A, T, C can be written and programmed at the cellular level inexpensively with a predictable outcome. In order for this coding to occur, DNA must be able to be sequenced and synthesized.

These processes and others require specialized equipment and protocols that have been shared with biotechnology. All of this has helped to develop a registry of standardized parts available for use in assemblies. This database has been developed through an international effort. http://biobricks.org/about-foundation/ . As the field of synthetic biology expands, so will the parts registry and applications of this technology.

Resource:

Kuldell, Natalie, "Synthetic Biology," *Backgrounders*, SENCER, Science Education for New Civic Engagements and Responsibilities, n.d. Web. 7 April 2015.

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(Science Education and New Civic Engagements and Responsibilities), a national
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Next Generation Science Standards (NGSS)

3-5-ETS1-1 - *Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.*

3-5-ETS1-2 – *Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.*

3-5-ETS1-3 - *Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.*

MS-ETS1-3 – *Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.*

MS-ETS1-4 - *Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.*

HS-LS1-1 - *Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins which carry out the essential functions of life through systems of specialized cells.*

HS-LS1-2 – *Develop and use a model to illustrate the hierarchical organization of interacting systems that provide specific functions within multicellular organisms.*

Next Generation Science Standards Reference:

NGSS Lead States. 2013. *Next Generation Science Standards: For States, By States.* Washington, DC: The National Academies Press.

NGSS Science and Engineering Practices

SEP1: *Asking questions and defining problems.*
SEP2: *Developing and using models.*
SEP3: *Planning and carrying out investigations.*
SEP4: *Analyzing and interpreting data.*
SEP5: *Using mathematics and computational thinking.*
SEP6: *Constructing explanations and designing solutions.*
SEP7: *Engaging in argument from evidence.*
SEP8: *Obtaining, evaluating, and communicating information.*

Common Core State Standards Mathematics

3.NF.A.1 - *Understand a fraction 1/b as the quantity formed by 1 part when a whole is partitioned into b equal parts; understand a fraction a/b as the quantity formed by a parts of size 1/b.*

3.MD.C.6 - *Measure areas by counting unit squares (square cm, square m, square in, square ft, and improvised units).*

4.MA.A.1 - *Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.*

4.OA.C.5 - *Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself.*

4.NF.C.7 - *Compare two decimals to hundredths by reasoning about their size. Recognize that comparisons are valid only when the two decimals refer to the same whole. Record the results of comparisons with the symbols >, =, or <, and justify the conclusions, e.g., by using a visual model.*

5.NBT.A.2 - *Explain patterns in the number of zeros of the product when multiplying a number by powers of 10, and explain patterns in the placement of the decimal point when a decimal is multiplied or divided by a power of 10. Use whole-number exponents to denote powers of 10.*

5.MD.A.1 - *Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.*

5.G.A.1 - *Use a pair of perpendicular number lines, called axes, to define a coordinate system, with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates. Understand that the first number indicates how far to travel from the origin in the direction of one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., x-axis and x-coordinate, y-axis and y-coordinate).*

5.G.A.2 - *Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.*

6.RP.A.3c - *Find a percent of a quantity as a rate per 100 (e.g., 30% of a quantity means 30/100 times the quantity); solve problems involving finding the whole, given a part and the percent.*

6.RP.A.3d - *Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.*

Common Core Mathematical Practices

MP1: *Make sense of problems and persevere in solving them.*
MP2: *Reason abstractly and quantitatively.*
MP3: *Construct viable arguments and critique the reasoning of others.*
MP4: *Model with mathematics.*
MP5: *Use appropriate tools strategically.*
MP6: *Attend to precision.*
MP7: *Look for and make use of structure.*
MP8: *Look for an express regularity in repeated reasoning.*

Common Core State Standards ELA/Literacy

SL.6-8.5 - *Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.*

SL.4.2 - *Paraphrase portions of a text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.*

SL.4.4 - *Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.*

SL.5.1 - *Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on* grade 5 topics and texts, *building on others' ideas and expressing their own clearly.*

SL.5.2 - *Summarize a written text read aloud or information presented in diverse media and formats, including visually, quantitatively, and orally.*

SL.5.4 - *Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace.*

SL.8.5 - *Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.*

RI.4.1 - *Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.*

RI.4.3 - *Explain events, procedures, ideas, or concepts in a historical, scientific, or technical text, including what happened and why, based on specific information in the text.*

RI.4.5 - *Describe the overall structure (e.g., chronology, comparison, cause/effect, problem/solution) of events, ideas, concepts, or information in a text or part of a text.*

RI.4.7 - *Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.*

RI.5.3 - *Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.*

RI.5.4 - *Determine the meaning of general academic and domain-specific words and phrases in a text relevant to a grade 5 topic or subject area.*

RI.5.7 - *Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently.*

RI.6.7 - *Integrate information presented in different media or formats (e.g., visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.*

RST.6-8.3 - *Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.*

RST.6-8.4 - *Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to* grades 6-8 texts and topics.

RST.6-8.7 - *Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).*

RL.4.2 - *Determine a theme of a story, drama, or poem from details in the text; summarize the text.*

RL.4.4 - *Determine the meaning of words and phrases as they are used in a text, including those that allude to significant characters found in mythology (e.g., Herculean).*

RL.5.4 - *Determine the meaning of words and phrases as they are used in a text, including figurative language such as metaphors and similes.*

W.4.9 - *Draw evidence from literary or informational texts to support analysis, reflection, and research.*

W.5.1.C - *Link opinion and reasons using words, phrases, and clauses (e.g., consequently, specifically).*

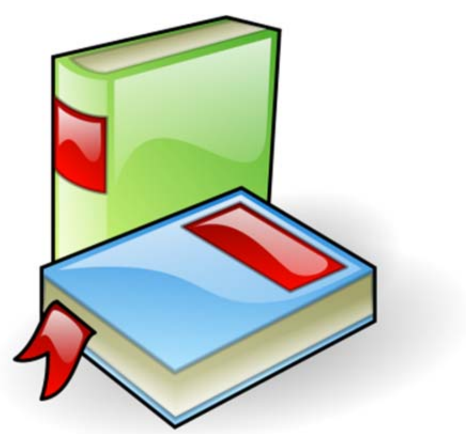
W.5.2 - *Write informative/explanatory texts to examine a topic and convey ideas and information clearly.*

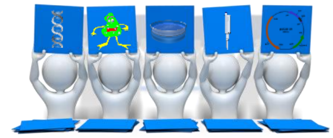
W.5.8 - *Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources.*

WHST.6-8.1 - *Write arguments focused on* discipline-specific content.

WHST.6-8.9 - *Draw evidence from informational texts to support analysis reflection, and research.*

Common Core Mathematics and ELA Standards Reference:
Authors: National Governors Association Center for Best Practices, Council of Chief State School Officers.
Title: Common Core State Standards.
Publisher: National Governors Association Center for best Practices, Council of Chief State School Officers, Washington D.C.
Copyright Date: 2010





Unit Summaries

B + E = SB encourages students to examine their ideas and perceptions about biology and engineering as they predict how these disciplines could possibly work together in the field called synthetic biology. Potential applications of this field are explored in this introduction to the curriculum.

DNA may be small compared to a human, yet compared to an individual cell the amount of DNA contained within the cell is multiple times the length of cell. Experiencing a logarithmic scale ranging from nanometers to kilometers, accompanied with visual cues, will allow students to gain perspective of scale involved in **Come Scale Away**.

Just as programming exists for computers, it also exists for biologic systems. **Scratch Cat Fever** enables students to investigate the concept of abstraction. Through a series of programming experiences they will explore inputs and outputs, programming and sequencing of scripts, and creating a program to obtain a specific outcome.

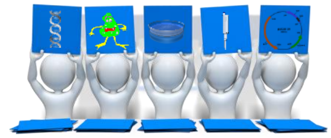
At the heart of synthetic biology is the development of new biologic systems through the insertion of standardized parts into cells to make novel products. Learning to manipulate a database of simulated biological units encourages students to imagine potential products that could be designed. After manipulating the needed building blocks, students will assemble multiple innovative products using this simulation in **Standardized Parts.**

Biotechnology provides the skills needed to complete many of the tasks to carry out the work of synthetic biologists, including the growing of needed cells. In **Streaking**, techniques needed to culture yeast cells will be practiced and employed as students culture samples. Various treatments will be applied to yeast cultures to test for any effects on growth of the yeast cultures.

Cells go through various stages of growth throughout their life cycles. Characteristics help to identify each of these phases. **Pop Culture** provides a variety of activities, both quantitative and qualitative, for students to explore this logistical growth process.

Protein Power introduces students to the abundance, significance, wide range, and critical aspect of proteins at the cellular level through a card game. Making models of proteins furthers the complex and intricate world of proteins.

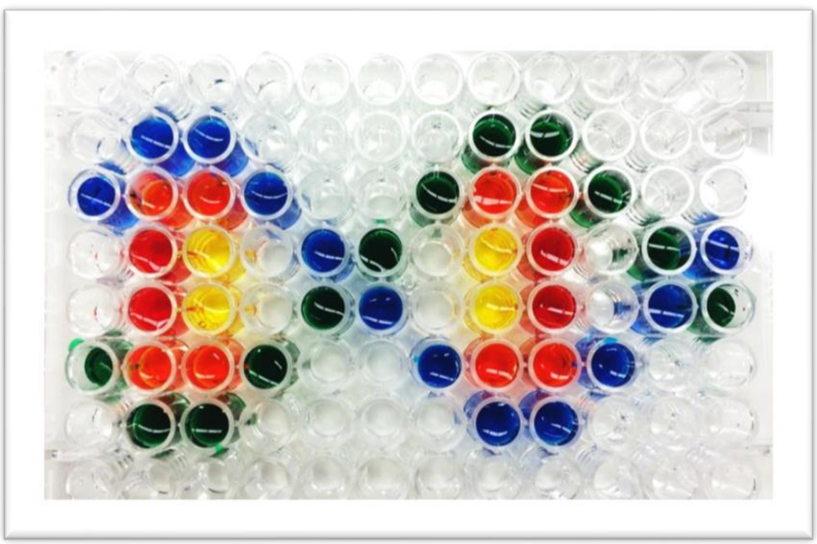
Models are built to gain perspective on how DNA is transcribed and translated. The importance of proteins continues in **TAG…You're It.** Students are introduced to the science behind the proteins: DNA transcription to messenger RNA and translation of the mRNA by ribosomes into the amino acid sequence which form a necessary protein. The importance of the sequencing of the four nitrogenous bases that form the various amino acids is explored through several activities in this unit.

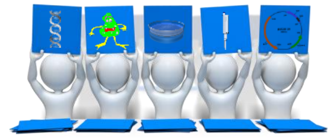


Purification of proteins needs to occur for researchers to use specific proteins. **Separation Anxiety** provides a series of inquiry activities which engage students in a multi-step simulation of purifying for a particular protein. First, students explore tools and the tools' efficiency; second, students practice extracting a protein of interest, and lastly assess the quality of their plan.

There are other methods of separating materials based on their characteristics, including chromatography and gel electrophoresis. **How Are 'Hue'?** engages students in learning the lab skills needed to successfully carry out these practices, including pipetting, while investigating the composition of various materials.

Chasing Vermeer, about an international art scandal based in Chicago, sets the stage for the culminating activity. Next, students are immersed in solving an art crime. Using biosensors and the lab techniques they have learned, they need to determine, are the paintings real or forgeries? Evidence will be presented to the Museum Board during **The Heist**.





Unit Objectives

B + E = SB

- Generate ideas about the work and roles of biologists and engineers.
- Make inferences about the potential applications for the field of synthetic biology.
- Describe and communicate ideas about synthetic biology.
- Listen to others' presentations.

Come Scale Away

- Analyze a series of objects on the basis of their length from smallest to largest given a set of photos not to scale.
- Explain the meaning of the metric prefixes kilo-, milli-, micro-, and nano-, in terms of powers of 10.
- Model the length of DNA in an *E. coli* bacterium.
- Discuss the use of models including their benefits and limitations.

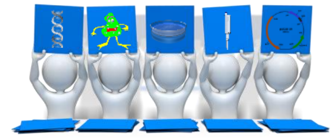
Scratch Cat Fever

- Determine a series of mathematical and other functions by observing a set of input/output values.
- Investigate the sequencing of various computer programming scripts to achieve a desired outcome.
- Carry out a series of directions or procedures.
- Create a computer program using an online visual programming platform to achieve a desired outcome.

Standardized Parts

- Construct a specific set of directions to move a hypothetical robot from one location to another location.
- Identify and explain the relationship between giving directions and developing systems within synthetic biology.
- Use a database to collect information and standardized parts in order to develop synthetic biological units.
- Develop synthetic biological units to be placed within a hypothetical E.coli cell by incorporating the use of plasmids, terminators, promoters, ribosome binding sites, open reading frames, and coding sequences.
- Discuss how the development of these biological units relies upon the arrangement of standardized parts in an effort to perform an intended function.

Synthetic Scorecard



Streaking

- Use models to practice culturing techniques for growing yeast.
- Use techniques to grow yeast colonies.
- Design an experiment to evaluate effects of treatments on yeast growth.
- Predict the outcome of treatments on yeast growth.
- Collect, analyze, interpret, and explain data.
- Measure and quantify colony growth.

Pop Culture

- Describe graphically the growth pattern of kernels of popcorn over time based on auditory data.
- Gather data on kernels popped over time and use the resulting graph to identify different phases of "growth" in number of popped kernels.
- Analyze scientific data on the growth of yeast in a liquid culture medium and compare/contrast to popcorn data.
- Discuss the use of models including their benefits and limitations.
- Identify stages of cell growth.
- Measure, collect, analyze, classify, and interpret data.
- Defend, explain, and communicate ideas based on evidence.

Protein Power

- Interpret, classify and evaluate proteins according to functions.
- Defend their decisions based on evidence.
- Model protein folding.
- Predict the effects of misfolded proteins.

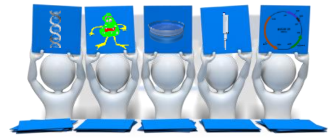
TAG…You're It

- Construct models of the processes of transcription and translation.
- Evaluate the modeling process.
- Describe amino acids.
- Represent and interpret protein chains.
- Identify and evaluate strategies to solve a problem.

Separation Anxiety

- Investigate and test tools for separating proteins.
- Design, test, and refine a plan for separating proteins.
- Collect, measure, analyze, interpret, and communicate results.
- Evaluate models based on evidence.
- Collaborate to determine parameters of evaluating results.

Synthetic Scorecard



How Are 'Hue'?

- Apply knowledge of biotechnology skills and practices by performing electrophoresis to resolve the colored dye molecules within a sample.
- Conduct a scientific experiment by precisely following a multistep procedure and performing technical tasks.
- Identify a location on the coordinate plane by using an ordered pair of values, in reference to perpendicular number lines, called axes.
- Perform biotechnology skills in a simulated application using fixed volume micropipettes and a coordinate grid system.

The Heist

- Read and discuss a piece of fiction.
- Identify key characters and events.
- Describe applications and techniques of synthetic biology and biotechnology.
- Conduct experimentation on samples to generate data.
- Collect, analyze, evaluate, interpret, and compare data.
- Communicate, present, and defend results based on data.
- Develop and present a multi-media presentation plan.

Synthetic Scorecard

Unit 1: B + E = SB

NOTES

Objectives:

- Generate ideas about the work and roles of biologists and engineers.
- Make inferences about the potential applications for the field of synthetic biology.
- Describe and communicate their ideas about synthetic biology.
- Listen to others' presentations.

Background Information

Synthetic Biology is a fairly new field that combines biology and engineering practices to produce new genetic systems. According to Dixon and Kuldell (2012) this discipline takes "an engineering approach to the design of novel living systems or the redesign of existing ones." By taking this approach, synthetic biologists are not limited to current genetic systems, thus the possibilities become vast.

In order to accomplish this, synthetic biologists need to use a variety of techniques and equipment. They modify living organisms using DNA. Some examples of this effort are sensor bacteria that will turn a color when they detect various contaminants, such as heavy metals. Another example is malaria, which kills over 500,000 people a year. Artemisinin, the drug used to treat Malaria, from the sweet wormwood is very expensive. Synthetic biology has helped produce an effective synthetic version of artemisinin that is affordable.

So what does each, a biologist and an engineer, bring to the table? The engineer's paradigm for approaching and solving problems is integrated throughout. The cycle of design, build, test is employed while determining solutions to biological problems. Engineering also standardizes practices and tools. Tools used to develop the solutions are derived from biology.

Inquiry Overview

Students will have the opportunity to explore their conceptions about the topics, develop ideas, and share them with their peers.

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Activity

Objectives:

- Generate ideas about the work and roles of biologists and engineers.
- Make inferences about the potential applications for the field of synthetic biology.
- Describe and communicate ideas about synthetic biology.
- Listen to others' presentations.

Standards:

NGSS Science and Engineering Practices: SEP1, SEP6, SEP8
Common Core State Standards ELA/Literacy: CCSS.ELA-Literacy.6-8.SL.5, CCSS.ELA-Literacy.6.RI.7, CCSS.ELA-Literacy.6-8.RST.4

Estimated Time:

- **5 Minutes - Introduction**
- **20 Minutes - Activity**
- **25 Minutes – Sharing of Ideas**
- **10 Minutes - Debrief**

***B + E = SB* Materials:**
for each student:

- Art Supplies
- Rulers
- Student Pages
- 1 - 12"x18" White Drawing Paper

Suggested Inquiry Approach:

Share with students that all of you are going to start a new curriculum. Begin by displaying the provided transparency using a computer with a projector. Propose the question, *"If you could build **ANYTHING** out of biology, what would you build and why?"* to the whole class. Allow time for students to share their answers. You may choose to record comments on the whiteboard or chart paper to reference throughout the curriculum.

Next, distribute the first student page. Ask for a student volunteer to read the first question, "*What kinds of things do biologists do?*" Encourage students to write down their ideas, and draw pictures if they wish. They may share ideas within their groups.

If students need prompting, assist with questions such as:

- **Where might a biologist work?**
- **With what materials might a biologist work?**
- **What problems might a biologist try to solve?**
- **What kind of training/education might a biologist need to have?**
- **What items around your house might a biologist have helped to make/produce?**

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Repeat the same process as with the biologist question, but with the next question, "*What kinds of things do engineers do?*"

After the students groups have had ample time to complete these two questions, host an entire class discussion. Encourage students to write down other ideas that they hear from their classmates.

Continue in the same manner with the following question,
"*What do biologists and engineers have in common?*"

After students have developed their responses and shared within their smaller groups, share as one large group.

Share the next question with the students, "*What should we call the science that biologists and engineers work on together?*" Have students record their ideas independently prior to hosting a class discussion.

Explain to students that there is a science that combines engineering and biology called synthetic biology and that it is a relatively new field of study. Very simply put, synthetic biology is how you make something from biology.

Display the transparency to share the last question with students. Distribute a piece of drawing paper to each student. Encourage students to write and draw their responses. After students have had time to complete their ideas, have them share their ideas and rationales with the class.

Debrief Activity:

- ***What skills do you think one would need to learn to be able to be a synthetic biologist?***
- ***How realistic do you think your idea is?***
- ***What problems do you think synthetic biology might be able to help solve?***

NOTES

Resources

Dixon, J. & Kuldell, N. (2012, February). Mendel's modern legacy. The science teacher, 54-55.

http://techtv.mit.edu/collections/mitmuseum/videos/1684-soap-box-do-it-yourself-biology

What would biology build?