Re-envisioning Bacterial Transformation *for NGSS*

This summer, BABEC hired an NGSS implementation expert and convened a teacher workgroup to explore new possibilities for updating our bacterial transformation curriculum. Below is a summary of what we learned.

Biotech lessons *can* be designed to address the three dimensions of NGSS! It's simple: convert them to become more **student-driven**, with students leading the investigations as they explore phenomena. Shift paradigm from 'learning about' to 'figuring out'

The three dimensions of NGSS, defined: "Engaging in **science and engineering practices** to use **disciplinary core ideas** and **crosscutting concepts** to explain phenomenon or solve problems"

It's all about The Phenomena

- NGSS Definition: "*Scientific phenomena are occurrences in the natural and human-made world that can be observed and cause one to ask questions.*"
- Goal of NGSS: for students to be able to explain phenomena (something observable that stimulates questions)

Model-ING. It's not what we thought it was

- Students make new models themselves, to explain and predict phenomena. They are not *given* models.
- They must be made public, which leads to interaction and iteration. They see how their thinking changes.
- Require students to demonstrate their thinking in new ways that they are not experienced in. They engage in high cognitive demand tasks

The 5E Instructional Model can be used to implement NGSS

- Engage: learners become mentally engaged in the concept, process, or skill to be learned.
- Explore: learners actively explore their environment or manipulate materials.
- Explain: learners verbalize their conceptual understanding or to demonstrate new skills or behaviors.
- Elaborate: through new experiences, learners develop deeper and broader understanding of major concepts, obtain more information about areas of interest, and refine their skills.
- Evaluate: learners assess their understanding and abilities.

What to expect from our new genetic engineering curriculum

- Title: Glowing Organisms – Real Life Transformants
- Phenomenon: Applications of glowing technology
- Question Formulation Technique: I notice… I wonder…
- Grab-bag modeling activities (share, discuss, revise). I used to think… Now I think…
- Opportunities to repeat the experiment; formulate new hypotheses, change variables & design new experiments
- Claim, Evidence, Reasoning (CER) activities: students explain what they *learned*, not what they *did*
- Communication activities, collaboration to apply learning
- An a-la-carte selection of activities that allows you to "plug-in" the curriculum throughout the year
- Incorporates the principles of the 5E Instructional Model
- Different colored "rainbow plasmids" and new protein purification lab activities

The Bacterial transformation curriculum is adaptable

- Has lessons that can be used throughout the year in different units
- We are working on a detailed map of where you can insert the lab into your course outline

ALL Three Dimensions NGSS Can Be Taught Using Our Bacterial Transformation Curriculum:

Science & Engineering Practices	How does the transformation curriculum align?
1. Asking Questions and Defining Problems	It asks empirically testable questions concerning how the phenotype of an organism can be manipulated and changed. Engage with a phenomena: glowing organisms. I notice… I wonder….
2. Developing and Using Models	It creates opportunities for hands-on, iterative modeling of: cell membrane permeability, charge interactions, recombinant DNA technology and genetic engineering
3. Planning and Carrying Out Investigations	It follows a clear procedure, explains the purpose of the main steps in the protocol - using controls - and collects the appropriate data to allow for revision.
4. Analyzing and Interpreting Data	Numerous data outcomes can be analyzed and interpreted: transformation efficiency, the effect of time & temperature, ratios of different colored transformants, role of positive and negative controls, comparison of results between groups and classes, and more.
5. Using Mathematics and Computational Thinking	Students are able to use basic concepts of computational thinking to make broad estimates of transformation efficiency, and to calculate an expected result based upon various inputs such as: # of cells, amount of arabinose, time, incubation temperature, etc.
6. Constructing Explanations and Designing Solutions	It provides tangible, empirical results. Students describe the application of transformation in real world and understand current issues such as antibiotic resistance. They can brainstorm new ways to insert DNA into a cell to solve medical, agricultural and environmental problems.
7. Engaging in Argument from Evidence	Students can make claims regarding the phenotypic change in bacteria (i.e. I changed the DNA), providing evidence from the lab that supports the claim (i.e. it glows), and describe how transformation accounts for the phenotypic change. (i.e. DNA provides ability to glow. i.e. claim – evidence – reason [CER]). Students are able to argue both sides of an ethical/societal issue regarding antibiotic resistance, GMO's, insulin production, etc. and make informed decisions.
8. Obtaining, Evaluating, and Communicating Information	It has multiple opportunities for students to communicate basic scientific concepts: DNA structure & function, genetic engineering technology, standard laboratory techniques, and ethical considerations. Students will research and document their process, data, and interpretations and can present them to their classmates individually or in teams.

Cross Cutting Concepts	How does the transformation curriculum align?
1. Patterns	Micro: Formation of bacterial colonies (location & spahe), growth on plates with and without ampicillin. Macro: global bacterial resistance
2. Cause and Effect	It uses empirical evidence to 1) link the phenotypic change of bacteria to transformation, and 2) to explain why bacteria grow and/or glow under certain experimental conditions.
3. Scale, Proportion, and Quantity	Students are able to explain the size and quantity relationship between individual cells and colonies of bacterial cells, and can see the replationship between altering the amount of cells, amount of plasmid, temperature, and time.
4. Systems and System Models	It uses bacterial transformation as a model for the systems of gene expression, and for the manipulation of systems (i.e. interacting cell organelles; biochemical interactions) that allow for genetic engineering.
5. Energy and Matter: Flows, Cycles, and Conservation	The procedure for making cells competent involves adding energy into a system (the heat-shock step) and manipulating ionic charge to alter matter (the cell membrane)
6. Structure and Function	It explains how genetic engineering capitalizes on the specific structure of DNA and proteins to manipulate phenotypes (function). Students are able to explain how differences in phenotype are due to differences in genotype of bacteria.
7. Stability and Change	The concept of antibiotic selection can be used to teach how different environmental conditions alter living organisms. Cell competency can be used to explain how changing heat and charge can destabilize a cell membrane.

Disciplinary Core Idea	Components that align to the transformation curriculum?
LS1: From Molecules to Organisms: Structures and Processes	
LS1.A Structure and function	All cells contain genetic information in the form of DNA molecules. Genes are regions in the DNA that contain the instructions that code for the formation of proteins, which carry out most of the work of cells.
LS1.B Growth and development of organisms	Cellular division and differentiation produce and maintain a complex organism
LS1.C Organization of matter and energy flow in organisms	As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.
LS1.D Information Processing	This DCI is NA for grades 9-12
LS2: Ecosystems: Interactions, Energy, and Dynamics	
LS2.A Interdependent relationships in ecosystems	Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite.
LS2.B Cycles of matter and energy transfer in ecosystems	Bacteria/algae form the lowest level of the food web. At each link upward, only a small fraction of the matter consumed at the lower level is transferred upward, to produce growth and release energy in cellular respiration at the higher level.
LS2.C Ecosystem dynamics, functioning, and resilience	anthropogenic changes (induced by human activity) in the environment—including habitat destruction, pollution, introduction of invasive species, overexploitation, and climate change—can disrupt an ecosystem and threaten the survival of some species.
LS2.D Social interactions and group behavior	Group behavior has evolved because membership can increase the chances of survival for individuals and their genetic relatives
LS3: Heredity: Inheritance and Variation of Traits	
LS3.A Inheritance of traits	The instructions for forming species' characteristics are carried in DNA. All cells in an organism have the same genetic content, but the genes used (expressed) by the cell may be regulated in different ways.
LS3.B Variation of traits	Environmental factors also affect expression of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors.
LS4: Biological Evolution: Unity and Diversity	
LS4.A Evidence of common ancestry and diversity	Genetic information provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms.
LS4.B Natural selection	Natural selection occurs only if there is both (1) variation in the genetic information between organisms in a population and (2) variation in the expression of that genetic information—that is, trait variation—that leads to differences in performance among individuals. The traits that positively affect survival are more likely to be reproduced, and thus are more common in the population
LS4.C Adaptation	Adaptation also means that the distribution of traits in a population can change when conditions change. Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.
LS4.D Biodiversity and humans	Biodiversity is increased by the formation of new species (speciation) and decreased by the loss of species (extinction). Human activity is adversely impacting biodiversity.