Reviewing Freire's science curriculum submission through the lens of the committee's critique, it is clear that while the *topics* in our 8-12 science courses are demanding and thorough, the *pedagogy* we laid out does not do them justice. More importantly, as currently presented, our courses will not do our future students justice. As our team reviews these documents and the committee's suggestions, we see clearly where we need to go and what we need to change to make our science curriculum reflect the NGSS Framework for teachers and students.

First, in our originally submitted plans, we indicated learning targets that our students would reach, but we did not spell out the particular activities which require our students to "generate ideas, explore questions and problems, consider possibilities." We indicated that we would use a variety of traditional assessments, but did not mention how these assessments would call on students to apply and extend what they learn, using appropriate reading, writing, research and mathematics skills meaningfully.

To address this problem, we now see we need to plan signature activities that use science and engineering **practices** to develop and assess students' understanding of ideas. These practices include asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, and working constructively with these data.

Second, our original scope and sequence documents posed essential questions that were often quite specific and limited-- not necessarily essential. Our questions defined the information to which our students would be exposed, but did not integrate the more interdisciplinary **cross cutting core concepts** that make sense of the natural and designed world, and which apply across fields.

We need to rethink our essential questions so they are more thought-provoking and have broader importance across multiple science disciplines. Good essential questions compel students to think about, explain, or investigate complex ideas and solve problems-- and most critically, they relate to the interests and life experiences of students. We must deconstruct our existing essential questions to articulate the essential notions – e.g., patterns, systems, structure and function, stability and change -- that underlie all scientific thinking and inquiry.

Finally, we need to make better use of the third dimension of the NGSS Framework, **core disciplinary ideas**. These were labeled in the original documents as "Unit Concepts/ Enduring Understandings," and while they were identified, it was not apparent in these original documents how those concepts would be interwoven with active instructional practices and cross cutting core concepts.

What follows is an attempt to more explicitly embed these understandings in presentation of a model unit: the third unit of our 10th grade Biology course. In this revised unit presentation, and the attached document outlining unit project and assessment details, we hope that our intentions are clear: Freire students will not just learn scientific information, but will analyze, evaluate, collaborate, argue, and explain in the service of robust scientific thinking and problem solving.

If this revision shows us heading in the right direction, we see it as a first step in partnering with the State to craft a world-class, NGSS-aligned Science curriculum, and are eager to continue the work.

Freire Charter School Wilmington

10th Grade Biology Scope and Sequence -- Sample revised unit

Unit 3: "The Working Cell: Energy from Food and Sunlight"
Timeline: 4 weeks (55-minute lessons daily)

Theme: This unit explores how organisms release energy stored in food and the process of photosynthesis.

Student (Grade-Level) Learning Targets:

- Students will use a model to illustrate how photosynthesis transforms light energy into stored chemical energy
- Students will construct and revise an explanation based on evidence for how carbon, hydrogen, and oxygen from sugar molecules may combine with other elements to form amino acids and/or other large carbon-based molecules.

NGSS	Core Disciplinary Ideas	Essential Questions	Cross Cutting Concepts	Signature Activities & Assessments
HS-LS1-5 HS-LS1-6 HS-LS1-6/HS-LS1-7	The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen The sugar molecules thus formed contain carbon, hydrogen, and oxygen: their hydrocarbon backbones are used to make amino acids and other carbon-based molecules that can be assembled into larger molecules (such as DNA and Proteins), used for example to form new cells. As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form	How does food power our bodies? In what ways does energy come from sunlight? How does the sun make life on earth possible? Why do plants matter to the energy flow of an ecosystem? Why do plants matter to us?	• Patterns • Systems & Systems Models • Energy & Matter (Flows, Cycles, Conservation) • Structure & Function	Energy Drink group project Transfer of Energy individual construction project Final unit test including open ended response section re: analysis of photosynthesis data table and sea slug article. *For details and NGSS Framework details, see attached document*

HS-LS1-7	different products. As a result of chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of food molecules and oxygen molecules are broken and new compounds are formed that can transport energy to muscles. Cellular respiration also releases energy needed to maintain body.			

Energy Drink Project

Do energy drinks really provide useful energy? Students work in teams to research and analyze Energy drinks (Monster, RedBull, Rockstar), and then design the formula for their own energy drink that provides useful energy and is a healthy alternative. Team members will collaborate in the research and then take on specific roles (formulator, logo design, marketing) to create and "sell" their new product. Each team will present their drink to the class, using a prepared script, props and posters.

NGSS Framework

Practice: Collaborating, research, analyzing and evaluating claims, creating an original formula presenting

Cross cutting concepts: Energy and matter conservation, Structure and function

Core disciplinary ideas: As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

As a result of chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of sugar molecules and oxygen molecules are broken and new compounds are formed to produce energy that is then transported for use in many parts of a living organism.

CCSS connections

CCSS.ELA-LITERACY.RST.9-10.4
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 9-10 texts and topics.

CCSS.ELA-LITERACY.WHST.9-10.1.B
Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form and in a manner that anticipates the audience's knowledge level and concerns.

CCSS.ELA-LITERACY.WHST.9-10.7
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

CCSS.MATH.PRACTICE.MP3 Construct viable arguments and critique the reasoning of others.

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Modeling the Transfer of Energy Project

How can you represent the transfer of energy from the sun's light energy as it is converted to stored chemical energy, and eventually becomes energy humans can use? Students will work independently to create a physical model (e.g., using toy train tracks), or a model using computer graphics to show how energy is transformed from light energy to energy in stored chemical energy in food, and then to ATP in humans.

NGSS Framework

Practice: Modeling

Cross cutting concepts: Energy and matter conservation, Structure and function

Disciplinary Core Ideas: The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen

As matter and energy flow through different organizational levels of living systems, chemical elements are recombined in different ways to form different products.

As a result of chemical reactions, energy is transferred from one system of interacting molecules to another. Cellular respiration is a chemical process in which the bonds of sugar molecules and oxygen molecules are broken and new compounds are formed to produce energy that is then transported for use in many parts of a living organism.

CCSS connections

CCSS.ELA-LITERACY.WHST.9-10.7
Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.

Test: Analyze data and apply your knowledge

Part 1: What produces the faster rate of photosynthesis? Read the teacher-provided data table detailing various weights of plants before and after they were kept under lights of differing colors (green light, blue-red light, blue light). Assume all other variables are constant. Determine which color light produces the fastest rate of photosynthesis and why.

Part 2: Based on the article "Making the Most of a Meal" below, answer this question: Is it possible for animals to use photosynthesis to produce their own food? How does this change our definitions of plants and animals? Support with textual evidence, quoting accurately from the text and your scientific investigations.

Making the Most of a Meal

Citation: Ornes, Stephen. "Making the most of a meal." *Science News for Students*, Web 11 Feb 2014. <https://student.societyforscience.org/article/making-most-meal/>.

For decades, people have been telling each other, "You are what you eat" — meaning that the nutrition in a person's diet affects his or her health. It doesn't mean, for example, that if you eat a plant, you become a plant.

At least, not for people.

For a certain kind of sea slug, however, those words are more than just a reminder to eat well. The *Elysia chlorotica* is a sea slug that looks like a leaf and eats by sucking the insides out of strands of algae. (Yum!) These algae, like plants, get their food by using sunlight to help make sugar.

At a recent meeting of scientists, a biologist named Sidney K. Pierce reported a surprising observation in these algae-eating sea slugs. Pierce does his research at the University of South Florida in Tampa.

Pierce already knew that these sea animals, just like plants, have the right chemical tools to turn sunlight into food. Surprisingly, now he's learned that the sea slugs aren't simply stealing what they need to do this from the algae. They've also stolen the recipe for how to make chlorophyll, a chemical that is vital to the process, and can make chlorophyll themselves. In other words, they have started to behave like their food.

"This could be a fusion of a plant and an animal — that's just cool," John Zardus told Science News. Zardus is an invertebrate zoologist at The Citadel in Charleston, S.C. Invertebrates are animals that don't have backbones (like slugs), and zoology is the study of animals — so Zardus studies animals without backbones.

Inside their cells, plants have tiny structures called chloroplasts. These chloroplasts turn carbon dioxide and water into sugar using sunlight and a chemical called chlorophyll. (The first part of the word comes from the Greek word chloros, which means "green" —chlorophyll gives green plants their color.) The process of the chloroplasts using chlorophyll to make sugar is called

photosynthesis.

Like plants, the algae that get eaten by the sea slugs also use photosynthesis. When Pierce's slug eats algae, it separates out the chloroplasts. Instead of digesting and excreting the chloroplasts, the sea slug absorbs them inside its own cells. Pierce and his colleagues already knew that once a slug has chloroplasts inside its cells, it can use photosynthesis to make food — which means it may not even have to eat for the rest of its life (about a year). Other animals, like coral, have been known to stash cells containing chloroplasts and use some of the food they make.

But the chloroplasts use up the chlorophyll during photosynthesis, and a fresh supply is needed. Where does it come from? One idea was that when an animal absorbed the chloroplasts, they came with a lifetime supply of chlorophyll. But as it turns out, that's not the case with these sea slugs. Pierce and his colleagues found that unlike other animals, sea slugs can make their own chlorophyll — which means that they have stolen more than just the chloroplasts.

Deep inside almost every living cell are genes, which function like recipes for how to make what the organism needs. A plant has genes, for example, that contain the instructions for chlorophyll. As it turns out, so do sea slugs — as Pierce and his colleagues are discovering.

So sea slugs not only ingest the chloroplasts — they've also "adopted" part of these genetic instructions from their food. In other words, these sea slugs are truly becoming what they eat. Even stranger — it's the first time the worlds of algae and animals have seemed to overlap like this.

NGSS Framework

Practice: Analyzing data from charts and graphs, evaluating variables, elaborating on findings, applying understanding to new scenarios and phenomena

Cross cutting concepts: Energy and matter conservation, structure and function, scale, proportion and quantity, patterns

Disciplinary Core Ideas: The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen