Delicious and Nutritious Chemicals: A unit for engaging 10th grade Chemistry students in the study of biological molecules

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Abstract

Science Leadership Academy at Beeber is a project-based learning magnet school in West Philadelphia. In this three-week unit, tenth grade Chemistry students will learn the chemical composition of four macromolecules: carbohydrates, lipids, proteins, and nucleic acids. After learning the chemical structures and formula for each of the macromolecules, students will launch an inquiry-based investigation on the effects of these macromolecules on fruit flies. An emphasis on laboratory skills with fruit flies will be a main focus of this unit.

Content Objectives

In my current role as a 10th grade Chemistry teacher at Science Leadership Academy at Beeber, I constantly look for ways to integrate inquiry-lab based learning into my teaching. Fortunately, the Cancer Biology and Technology seminar with the Teachers Institute of Philadelphia models exactly the kind of teaching I wish to incorporate next school year. As a fellow in the Cancer Biology and Technology seminar, I've had the experience of working with fruit flies as a model to apply what I've learned in the seminar lectures. Real science is all about building, carrying out, and interpreting experiments, and I hope to apply what I've learned in the TIP seminar to create an authentic science experience for my high school students.

Science Leadership Academy is a special admission public school in West Philadelphia that specializes in project-based learning (PBL). PBL is a style of teaching that focuses on inquiry, group work, and authentic demonstration of learning. Instead of lectures and traditional tests, students are given more open-ended opportunities to demonstrate their learning. PBL naturally aligns well with the practice of science, where scientists ask a question and can investigate that question creatively through projects and experimentation. However, in my experience, PBL can be challenging to implement within the constraints of traditional schooling methods. For example, large class sizes make it difficult to create inquiry-based lab experiences for my students due to a shortage of materials. Additionally, district mandates and required content standards limit the amount of time I can dedicate towards exploring a certain subject. Public education traditionally tries to incorporate too much content with little depth of exploration, which

makes PBL difficult. With the challenges of large class sizes, limited materials, and limited time, implementing authentic PBL and inquiry based learning in my science classes remains challenging; however, the TIP seminar has inspired me to try new things next school year that may help overcome these challenges.

One of the Next Generation Science Standards (NGSS) for life sciences that is critical to understanding biotechnology is the following:

HS-PS2-6. Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials. [Emphasis is on the attractive and repulsive forces that determine the functioning of the material. Examples could include why electrically conductive materials are often made of metal, flexible but durable materials are made up of long chained molecules, and pharmaceuticals are designed to interact with specific receptors.]*

Currently, students in my chemistry classes demonstrate an understanding of the general concept of the molecular structure, but show lack of understanding of how that structure relates to a chemical's function. For example, my chemistry students can draw a Lewis structure, interpret a VSEPR diagram, and identify intermolecular forces, but they have less understanding of how a chemical's structure aids its function, or how altering a chemical's structure can be a valuable tool in biotechnology. The problem with high school chemistry is that the curriculum covers too much content with too little depth. This leads me to ask, for example, why students would be required to draw a Lewis structure without first understanding its meaning. It would be valuable to incorporate a curriculum unit in my chemistry classes that demonstrates the relationship between structure and function in a real and functioning laboratory setting.

My curriculum unit will strive to accomplish the following - 1) Give students an opportunity to explore the impact of chemicals on living things; 2) Help students understand the relationship between a chemical's structure and its function; and 3) Provide students with in-depth authentic inquiry-based opportunities to engage in scientific thinking. The unit, which is tentatively titled "delicious and nutritious chemicals," will use fruit flies as a model organism to explore the impacts of three macromolecules (carbohydrates, lipids, and proteins) on living things. Currently, my students know the definitions of carbohydrates, lipids, and proteins, but they lack understanding of how those chemicals serve as the foundation for life and how those chemicals impact diet and health. After gaining a baseline understanding of what carbohydrates, lipids, and proteins are from a biological perspective, students will understand what these three macromolecules look like from a chemical perspective. Not

only will students learn to interpret the Lewis structures of the three macromolecules, but they will also learn how to identify these three macromolecules in foods they eat in their everyday lives. Once students have an understanding of what proteins, carbohydrates, and lipids are from a textbook perspective, I hope to use fruit flies as an inquiry-based lab for further exploration. Students will be assigned a certain macromolecule and asked to design an experiment with fruit flies that explores the question, "How do carbohydrates/lipids/proteins affect fruit flies?". Students will first choose a food that is rich in their assigned macromolecule for their experiment. They will then be trained in how to handle, feed, and quantify the effects of different macromolecules on tumor growth in fruit flies. Students will characterize fruit fly health through both quantitative and qualitative methods. The project will culminate in a mini science conference, where students will make posters and present their research findings to their classmates.

Teaching Strategies

This unit will focus on inquiry-based learning through the use of laboratory experiences and skills teaching. Inquiry-based learning is a student-centered method of teaching where students ask and investigate their own questions. For example, instead of the teacher providing instructions for a lab, students design their own experimental procedure from the provided materials. Inquiry-based learning complements the Science Leadership Academy's focus on project-based learning because, in both inquiry- and project-based learning, students drive their own decisions and investigations. When it comes to science teaching, inquiry-based learning goes naturally with teaching lab skills, since students are given the freedom to design their own experiments and interpret the data they collect.

In this unit, students will be tasked with investigating the question, "How do the four macromolecules of life (proteins, nucleic acids, carbohydrates, and lipids) affect fruit flies?"—but they will not be given specific instructions on how to investigate this question. Of course students will be taught lab safety and basic fruit fly handling techniques, but it will be up to the students themselves to design their own experiment. Students will choose their own macromolecule of focus and decide its source. They will then plan, carry out, and interpret their experimental procedure with the guidance of their group members and teacher. By putting tenth-grade students in charge of their own experiment, they will gain a sense of ownership over their work and an investment in their learning.

Laboratory skills will be emphasized and practiced throughout this unit. Students will learn about safety along with organization and collaboration within a laboratory setting. Students will also learn how to design an experiment, collect, analyze and present

the data. Because tenth-grade students at SLA Beeber have limited laboratory experience at this point in their education, this unit should provide them with new insights and plenty of practice time in a hands-on setting.

The project will culminate in a mock science conference. At SLA Beeber, we strive to give our students practice in presentation and public speaking. By concluding the unit with a celebratory and shared experience like a mock science conference, students will not only get a chance to practice their public speaking skills, but they will also build community with each other and celebrate their work.

Classroom Activities

Week #1: The Macromolecules of Life	
Established Goals: **HS-PS2-6 Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials**	
Understandings: ***Students will understand that…*** The four macromolecules of life (Proteins, Nucleic Acids, Carbohydrates, and Lipids) have chemical structures and formulas The four macromolecules of life can be manipulated through hydrolysis and dehydration synthesis The four macromolecules of life have basic functions in living things that are related to their structures	**Essential Question/Big Idea:** What are the four macromolecules of life? What are their chemical structures and formulas? What roles do they play in living things?

Students will be able to……

Interpret the chemical formulas and structures of proteins, nucleic acids, carbohydrates, and lipids

Explain how hydrolysis turns polymers into monomers

Explain how dehydration synthesis turns monomers into polymers

Identify the major functions of the macromolecules in living things

Learning Plan

Engage- Students will watch a youtube video introducing the four macromolecules and examples of where to find each macromolecule in foods. Class discussion to follow

Explore- Students will record a flipgrid of themselves presenting their favorite source of each macromolecule in their kitchen (carb, protein, lipid). Class will watch each other's flipgrid videos and comment

Explore & Explain- Students will use the gizmo online simulation to explore the four macromolecules and how they are created through dehydration synthesis and digested through hydrolysis.

Elaborate- Students will use problem sets and quizlet vocab to practice the terms learned

Evaluate- Students will be assessed via a short in class quiz on the four macromolecules

Week #2: Introduction to Fruit Flies & Laboratory Techniques

Established Goals:

NGSS Planning and Carrying Out Investigations
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Understandings: ***Students will understand that…***	**Essential Question/Big Idea:**
Lab safety involves understanding lab safety rules as well as cooperation with classmates in sharing resources and keeping spaces tidy Fruit flies can be handled, counted, and observed after being frozen	How can we handle and observe fruit flies safely and efficiently?

Students will be able to……

1. Freeze their fruit flies in order to handle them
2. Count and observe their fruit flies
3. Explain the life cycle of a fruit fly
4. Transfer their fruit flies to and from containers with food

Learning Plan

Engage- Students will watch and youtube video about the life cycle of a fruit fly and applications of fruit flies as a model organism . Students will spend time observing their real life fruit flies (without removing them from the container)

Explore-

- **Students will gain practice in freezing their fruit flies, removing them from the container, and putting them back in the container safely**
- **Students will gain practice in freezing their fruit flies, placing them on the microscope, and observing them through the microscope**

Explain- Students will identify roles within their group members as to who will handle each step of the fruit fly observation and care process

Evaluate- Group members will take an oral test to assess their mastery of fruit fly lab techniques

Week #3: Fruit Fly Investigation

Established Goals:

NGSS: Planning and Carrying Out Investigations
Planning and carrying out investigations in 9-12 builds on K-8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.

Understandings: ***Students will understand that…***	**Essential Question/Big Idea:**
Macromolecules have functions in living things A scientific experiment involves asking, testing, and evaluating data surrounding a question	How can we design an experiment with controls, an independent variable, and a dependent variable?

Students will be able to……

1. Identify the independent variable, dependent variable, and control in their experiment
2. Design an experiment that tests the effect of one of the macromolecules on fruit flies
3. Collect empirical and observational data
4. Present their scientific findings publicly

Learning Plan

Engage- Students work in groups to choose a macromolecule and propose an inquiry question using the prompt "How do (macromolecule) affect fruit fly _____"

Explore- Students work in groups to design a controlled experiment with an independent and dependent variable that answers their inquiry question. Students carry out the steps of their investigation over the course of 1.5 weeks.

Explain- Students collect and format empirical data (fertility assay, counting fruit flies) and observational data (can take pictures with the microscopes)

Elaborate- Students present their findings to Ms Tsai for feedback throughout

Evaluate: Students present their data at a mock science fair through a poster presentation or a powerpoint

Resources

Educator resources. (n.d.). Retrieved March 10, 2021, from https://dnadecoded.org/educator-resources.html

https://dnadecoded.org/educator-resources.html

High school chemistry education resources. (n.d.). Retrieved March 10, 2021, from https://www.acs.org/content/acs/en/education/resources/highschool.html

https://www.acs.org/content/acs/en/education/resources/highschool.html

Next Generation Science Standards- H.S. Structure and Properties of Matter [PDF]. (n.d.).

https://www.nextgenscience.org/sites/default/files/HS%20SPM%207.15.13.pdf

Pdb101: Learn: Education corner. (n.d.). Retrieved March 10, 2021, from https://pdb101.rcsb.org/learn/education-corner

https://pdb101.rcsb.org/learn/education-corner

Serendip studio. (n.d.). Retrieved March 10, 2021, from https://serendipstudio.org/biology/

Appendix

https://serendipstudio.org/biology/

- Provides curriculum materials relevant to Week 1 and 2 of this unit (macromolecules of life- proteins, lipids, carbohydrates, and nucleic acids)

https://ecloseinstitute.org/

- Provides curriculum materials and supplies for Weeks 3 and 4 of this unit (fruit fly laboratory techniques, experimental design, supplies)