Subject Matter “D” Evidence: Unit 6, Alternative Proteins

Contents

Executive Summary

Sponsored by Genentech, Futurelab+ brought together a coalition of partners to develop an innovative, modular, 2-year biotechnology curriculum, along with instructional materials, to expose students and educators to the breadth of education and career pathways across biotechnology. To increase adoption and access to such curricula in California and beyond, the modular curriculum was designed to align with the California Career Technical Education Model Curriculum Standards for Biotechnology, meet at least one year of the University of California (UC) science (D) subject requirement, and incorporate some of the three-dimensional learning innovations of the Next Generation Science Standards (NGSS). The 2-year biotechnology curriculum has four core units per year; each core unit has nine lessons and a lab that each take approximately one week to complete (9–10 weeks for the full unit). In total, the biotechnology curriculum has 72 lessons and eight labs that span two full instructional years. Because the Futurelab+ biotechnology curriculum is modular, teachers can select specific units and materials to design biotechnology courses that are relevant and appropriate for their students and teaching environments, whether they are classroom based, virtual, or hybrid.

Because teachers and schools can choose which portions of the curriculum to include in their final course designs, this report series provides evidence of where each unit meets specific criteria for the UC science (D) subject requirement and, when incorporated into a full year-long course, where the curriculum could meet 1 year of the UC science (D) subject requirement as interdisciplinary coursework, contingent upon review and approval by UC. Subsequently, the evidence provided herein can be used by teachers for submitting Futurelab+ course materials for UC science (D) subject approval.

The purpose of this report is to provide evidence for alignment of Unit 6 of the Futurelab+ Biotechnology Curriculum with the UC science (D) subject requirement. To help educators submit their final courses for UC science (D) subject review, the American Institutes for Research® (AIR®) also wrote sample unit and lab summaries, which follow the guidelines for writing a UC science (D) course (March 17, 2021), to provide language to teachers as they write their full course descriptions.

Specifically, AIR reviewed each unit for evidence of the extent to which the unit meets the eight Course Content Guidelines for the UC science (D) subject requirement. This report provides specific examples to demonstrate where and how materials satisfy these criteria. Based on our review, we believe there is a strong body of evidence that will likely translate to Unit 6 meeting 1 year of the UC science (D) subject matter requirement as interdisciplinary coursework. **This review was completed on materials received May 16, 2022, and has not been updated to reflect any revisions made to materials since then.**

University of California A–G Course Requirements

To be eligible for admission into the California State University or the University of California (UC) systems, high school students must successfully complete (with a grade of C or better) the UC A through G (A–G) course requirements. The A–G course requirements encompass 15 year-long courses, including (A) 2 years of history/social science, (B) 4 years of English composition and literature, (C) 3 years of mathematics, **(D) 2 years of science**, (E) 2 years of language other than English, (F) 1 year of visual and performing arts, and (G) 1 year of a college preparatory elective. Teachers, parents, and students want high school courses to meet A–G requirements. To increase adoption of the Futurelab+ biotechnology curriculum, the modular curriculum was designed to meet at least 1 year of the UC science (D) subject requirement as interdisciplinary coursework.

Futurelab+ and UC Science (D) Subject Requirement

The modular, 2-year Futurelab+ biotechnology curriculum consists of four core units each year. Each unit has nine lessons and a lab. A lesson consists of more than one class period of learning to allow students the opportunity to develop their knowledge and understanding more fully. Lessons and labs take approximately five 45-minute instructional periods to complete. In its entirety, the biotechnology curriculum has 72 lessons and eight labs.

The 2-year Futurelab+ biotechnology curriculum was designed to be modular. Teachers can select specific units and materials to design biotechnology courses that are relevant and appropriate for their students and teaching environments. For example, a school or individual biotechnology teacher can create a course that consists of four Futurelab+ units—two units from Year 1 of the curriculum and two units from Year 2 of the curriculum. Meanwhile, a different school or individual biotechnology teacher can create a course that consists of two Futurelab+ units in conjunction with other materials. Each course would have unique course descriptions because the materials are different.

Given the modular nature of the curriculum and because teachers and schools can choose which units to include in their final course designs, this report series provides evidence of where singular units meet specific criteria for the UC science (D) subject requirement and, when incorporated into a full year-long course, where the curriculum could meet 1 year of the UC science (D) subject requirement as interdisciplinary coursework, contingent upon review and approval by UC. Subsequently, the evidence provided herein can be used by teachers for submitting Futurelab+ course materials for UC science (D) subject approval.

To assist educators in writing and submitting to UC their unique course descriptions that incorporate Futurelab+ materials, each unit report includes a sample unit overview, assignment overview, and laboratory activity summary, as required for A–G course submissions and following the sample provided in the UC Policy Guide. **Appendix A** includes the example UC science (D) subject course description provided by UC. **Appendix B** includes a sample unit overview, assignment overview, and laboratory activity for educators to adapt to their needs.

This summary report provides evidence on how **Unit 6, Alternative Proteins**, of the Futurelab+ curriculum meets the UC science (D) subject requirement.

Methodology

There is strong overlap between the UC science course content guidelines and the NGSS Lesson Screener criteria (see Exhibit 1). As such, AIR staff first conducted an NGSS Lesson Screener review on a randomly sampled lesson from Unit 6.

Exhibit 1. Course Content Guidelines and NGSS Lesson Screener Criteria

There is strong overlap between the UC science (D) subject requirement and the NGSS Lesson Screener criteria. Specific course content guidelines of the A–G Policy Resource Guide are briefly summarized here, with notations about which Lesson Screener criteria include the same or similar requirements.

- Explicitly integrate the eight NGSS Science and Engineering Practices **(Lesson Screener Criteria B and C); this requirement is mentioned multiple times.**
- Draw content generally from the NGSS **(Lesson Screener Criteria B and C)** and Common Core State Standards for Literacy in History/Social Studies, Science, and Technical Subjects.
- Provide opportunities for students to participate in all phases of the scientific process and require students to discuss ideas with other students **(Lesson Screener Criteria B, C, D, and E).**
- Be explicit about formative and summative assessment practices **(Lesson Screener Criteria B, C, and E).**
- Include real-world problems that engage all students in science learning **(Lesson Screener Criteria A, D, and E).**
- Specify minimum mathematics course requirements.
- Reserve at least 20% of class time for teacher-supervised, hands-on laboratory activities.
- Incorporate technology (to the extent possible) to increase access and computer-based skills for students.

Upon completion of the NGSS Lesson Screener, which looked at Lesson 4, AIR staff reviewed the remaining Unit 6 materials for further evidence of the extent to which the unit meets the following UC science (D) subject matter course criteria, outlined in the Course Content Guidelines:

Criterion 1 Integrate the eight NGSS practices of science and engineering

Criterion 2 Consist of content pulled largely from the California NGSS and the Common Core State Standards for Literacy in History/Social Studies, Science, and Technical Subjects

Criterion 3 Provide opportunities for students to participate in all phases of the scientific process

Criterion 4 Employ quantitative reasoning and methods where appropriate

Criterion 5 Hold at least 20% of class time for teacher-supervised, hands-on laboratory activities

Criterion 6 Include explicit formative and summative assessment practices

Criterion 7 Provide real-world problems and applications

Criterion 8 Include the use of technology if possible

Summary of UC Science (D) Course Content Guidelines

Criterion 1: Integrate the Eight Science and Engineering Practices

Subject "D" Course Criterion 1 requires students to engage with the eight science and engineering practices outlined in the California NGSS throughout a year-long science course. **The following bulleted list shows examples of students engaging with these eight practices throughout Unit 6 of the Futurelab+ curriculum.** The examples are reflections of the practice's definition; they are not necessarily reflections of the developmental progressions of the skills in the practice. This list is not exhaustive.

Practice 1: Asking questions and defining problems

Students engage in elements of *Practice 1, Asking questions and defining problems*, in the following instructional activity:

- **Ask questions that arise from careful observation of phenomena, or unexpected results, to clarify and/or seek additional information.** In *Identifying GMOs*, students ask other student teams clarifying questions during a gallery walk. Students are given several prompts for asking questions, including "Can you expand on______?" "How does _______ support your claim specifically?" and "Can you further explain your reasoning about_________?" (Teacher Section, p. 16).

Practice 2: Developing and using models

Students engage in elements of *Practice 2, Developing and using models*, in the following instructional activity:

- **Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.** In *Golden Rice,* students create a flow chart that illustrates and describes in detail how Golden Rice is manufactured and commercialized (Student Section, pp. 39–40).

Practice 3: Planning and carrying out investigations

Students engage in elements of *Practice 3, Planning and carrying out investigations*, in the following instructional activity:

- **Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.** In *Detecting Genetically Engineered Crops,* students first choose a food product containing corn and extract its DNA. They then use Polymerase Chain Reaction (PCR) and gel electrophoresis to detect the presence or absence of the Bt gene *cry1Ab* in the DNA sample. They also perform a lateral flow test to detect the presence or absence of delta endotoxin proteins, one of which is encoded by the *cry1Ab* gene, that are responsible for the pest-resistant property of Bt-corn (Teacher Section, p. 1).

Practice 4: Analyzing and interpreting data

Students engage in elements of *Practice 4, Analyzing and interpreting data*, in the following instructional activity:

- **Analyze and interpret data to provide evidence for phenomena.** In *Detecting Genetically Engineered Crops,* students analyze the data they collected to make a claim about whether their food product contains Bt corn (Student Section, p. 30).

Practice 5: Using mathematics and computational thinking

Students engage in elements of *Practice 5, Using mathematics and computational thinking*, in the following instructional activity:

- **Organize simple data sets to reveal patterns that suggest relationships.** During *Ad Campaign—Commercialization*, students develop graphs of survey data to gain a better understanding of their community's current views toward the use of genetically modified organisms (GMOs) and genetically engineered (GE) products (Student Section, p. 4).

Practice 6: Constructing explanations and designing solutions

Students engage in elements of *Practice 6, Constructing explanations and designing solutions*, in the following instructional activity:

- **Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade-off considerations.** In *Project Rollout*, students brainstorm three novel GE products to solve a local community issue. Then, working in groups, they assume the role of community liaison, industry expert, genetic engineer, or concept designer for the remainder of the unit as they gather community input and other data to select one of those GE product ideas and build a website explaining how the product addresses the community issue (Student Section, pp. 1–9).

Practice 7: Engaging in argument from evidence

Students engage in elements of *Practice 7, Engaging in argument from evidence* in Unit 6, including in the following instructional activity:

- **Construct and/or support an argument with evidence, data, and/or a model.** In *Identifying GMOs,* students make a claim about whether they would purchase a GMO product. They must use evidence from their investigation to support their claim and explain their reasoning (Student Section, pp. 9–10, 16–17).

Practice 8: Obtaining, evaluating, and communicating information

Students engage in elements of *Practice 8, Obtaining, evaluating, and communicating information*, in the following instructional activity:

- **Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.** In *DNA to Alternative Proteins*, students review a variety of sources to gain an understanding of the various techniques and alternative proteins used to develop GE products and GMOs (Teacher Section, p. 1).

Criterion 2: Content Largely From the California NGSS

As previously noted, the Futurelab+ curriculum was designed to be aligned to the California Career Technical Education Model Curriculum Standards for Biotechnology. These standards, adopted in 2013, include an Academic Alignment Matrix (p. 32) that explicitly indicates content overlap with the NGSS and the Common Core State Standards for Literacy in History/Social Studies, Science, and Technical Subjects. For feedback about incorporation of specific three-dimensional learning and instructional shifts, see the accompanying **Unit 6, Lesson 4 NGSS Lesson Screener** report.

Criterion 3: All Phases of the Scientific Process

Throughout Unit 6, students learn about GMOs and GE products, how they are made, the benefits of GMOs, and some of the arguments against them. They learn how to test for GE products, and they explore a case study on Golden Rice, a genetically modified food product used to address vitamin A deficiency in the Philippines, to learn how GE technology can impact communities. Students then apply their learning by surveying and interviewing members of their community about issues that could be addressed through a GE product. They explain how they would manufacture such a product and then create a targeted community informational campaign to explain the purpose and benefits of the product they developed (Project Notebook, pp. 1–13).

Throughout the unit, students engage in the following activities:

- Sort sample products into "real" and "not real" GMOs and discuss the ethics behind the "real" products.
- Compare nutrition labels, then complete a PCR lab to gather evidence of genetic modification.
- Develop a claim, evidence, reasoning (CER) statement for or against the use of GMOs based on lab data, readings, and research.
- Extract and amplify DNA from a food product to test for the Bt gene.
- Perform a lateral flow strip test on a food product sample to test for delta endotoxin proteins.
- Summarize genetic engineering methods.
- Analyze Golden Rice from the perspective of a sociologist, plant and food scientist, food science technician, and an economist.
- Develop a product life cycle flow for Golden Rice.
- Debate the use of Golden Rice as a way to address vitamin A deficiency.
- Investigate GE industries that exist in their community.
- Create a novel GE product to positively impact their community.
- Develop interview questions to understand community perspectives on their GE product.
- Develop an ad campaign targeted to their community that shares the final product.

Criterion 4: Employ Quantitative Reasoning and Methods Where Appropriate

Unit 6 has several opportunities for students to use quantitative reasoning, particularly during Lesson 10, **Ad Campaign—Commercialization**. During this lesson, students develop graphs of survey data to gain a better understanding of their community's current views toward the use of GMOs and GE products (Student Section, p. 4).

Criterion 5: At Least 20% Class Time for Teacher-Supervised, Hands-On Laboratory Activities

This criterion specifically recommends that at least one scientific investigation be a student-designed project involving a tested hypothesis, and "teacher supervision may be synchronous or asynchronous, depending on whether the learning environment is classroom-based, fully online, or a hybrid."

Names of specific lab activities are noted in the Unit 6 Flow Chart and are as follows, along with their timings:

- Detecting GE Crops (5 days)

- Golden Rice Case Study (4 days)
- Community Outreach (4 days)

Unit 6 includes 13 days, or roughly 29.5% of unit time, of hands-on, teacher-supervised lab activities throughout 44 days of instruction, which meets the 20% requirement. Although this specific unit does meet the 20% requirement, the full year of curriculum a student encounters should be taken into consideration for this criterion.

Criterion 6: Explicit Formative and Summative Assessment Practices

AIR found evidence of several opportunities for teachers to gauge student learning, with both formative and summative assessment practices. Students often are provided the opportunity to demonstrate their learning of a specific topic in multiple ways and provide feedback to their peers.

The Unit 6 Flow Chart provides an overview for teachers about specific instructional activities and resulting student artifacts generated to demonstrate student learning, including claim evidence reasoning statements, DNA extraction and lateral flow lab, summaries, flow charts, and a Socratic Seminar to debate the bioethics of using Golden Rice as a way to treat vitamin A deficiency. Each lesson also includes several graphic organizers and worksheets for students.

Finally, the students spend several lessons applying their learning by surveying and interviewing members of their community about issues that could be addressed through a GE product. Then they explain how they would manufacture such a product and create a targeted community informational campaign to explain the purpose and benefits of the product they developed (Project Notebook, pp. 1–13).

Criterion 7: Real-World Problems and Applications

Unit 6 of the Futurelab+ biotechnology curriculum excels at providing real-world problem and application connections for students.

As noted in several prior criteria, the Unit 6 activities have students learning about GMOs and GE products, how they are made, the benefits of GMOs, and some of the arguments against them. They learn how to test for GE products, and they examine Golden Rice, a genetically modified food product used to address vitamin A deficiency in the Philippines, as a case study on how GE technology can impact communities. Students then apply their learning by surveying and interviewing members of their community for issues that could be addressed through a GE product. They explain how they would manufacture such a product and then create a targeted community informational campaign to explain the purpose and benefits of the product they developed (Project Notebook, pp. 1–13).

Criterion 8: Include the Use of Technology

The Futurelab+ curriculum was designed to be flexible for teachers who may have to alternate between in-person learning, virtual learning, or a hybrid environment. As such, the curriculum includes multiple opportunities for students to use online resources for researching genetically modified products and exploring genetic engineering. As well, students may use online, open-source programs to collect and analyze community survey data about an issue that can be addressed with a genetically modified product and create a public service ad campaign to promote that product.

Resources

Achieve & National Science Teachers Association. (2016). *NGSS lesson screener*. https://www.nextgenscience.org/screener

California Department of Education. (2007). *Career technical* education *framework for California public schools: Grades seven through twelve*. https://www.cde.ca.gov/ci/ct/sf/documents/cteframework.pdf

California Department of Education. (2017). *California career technical education model curriculum standards*. https://www.cde.ca.gov/ci/ct/sf/documents/healthmedical.pdf

Sacramento City Unified School District. (n.d.). *Protocols for culturally responsive learning and increased student engagement*. https://www.scusd.edu/sites/main/files/file-attachments/protocols_0.pdf?1445031253

University of California. (n.d.). *Writing A–G* Courses [UC A–G Course Management Portal]. https://hs-articulation.ucop.edu/guide/update-your-a-g-list/writing-a-g-courses/

Appendix A. Example Science (D) Subject Course Description

The University of California shared the following sample course description to "give course authors a model for how to construct course overviews, unit overviews, and sample assignments" (University of California, "Sample course descriptions."). The following course description can be found here.

Subject Area "D" Sample

Included in this sample is a single course overview, unit, and assignment; this is not a sample of a complete course, nor are all disciplines/courses represented in this sample. The purpose of these pieces is to give course authors a basic sample of how to construct strong course overviews, units, and assignments. Often, when a course is not approved by the UC High School Articulation Team, it is because the UC A-G Subject Area Specific Criteria is not explicitly written into a course submission. We encourage all course authors to consistently review the criteria specific to the subject/discipline under which they are submitting their courses.

Course Title: Biology / **Subject:** Laboratory Science / **Discipline:** Biology

Sample Course Overview:

In this course, students develop an in-depth understanding of the living world by studying structure, function and processes. Students recognize and understand the interactions of chemistry, physics, and earth sciences in the study of biology. Laboratory investigations incorporate procedures and develop the ability to analyze complex information. The main content areas of focus are cell biology, ecology, genetics, evolution, and physiology. Students will continue to develop their skills of reading, writing, discussion, technology, and analysis through lab reports, essays, and individual and group research projects. The ultimate course goal is to demonstrate scientific knowledge and skills as students work toward the school-wide goals of becoming self-directed learners who can identify a task and complete it, complex thinkers who can determine solutions to problems, and community contributors who can work collaboratively.

This course overview demonstrates the following strengths:

- Uses concise language which gives a global view of the course without sacrificing meaning
- Includes a balance of skills and content (merely listing standards to be covered is not sufficient)
- Previews how the course will integrate the following UC laboratory science "D" subject area requirements:
  - All courses approved in the laboratory science subject area should be designed with the explicit intention of developing and encouraging scientific habits of mind important for university-level studies and aligned with the eight practices of science and engineering identified by the National Research Council framework and detailed within the Next Generation Science Standards

Sample Unit: *Cells*

This unit builds upon key lessons introduced in the previous unit, the scientific process, data analysis, investigation and experimentation, by unifying the themes of biology. This unit covers chemical concepts, the differences between carbon-based molecules and proteins, the differences between aerobic and anaerobic respiration, and cell theories related to all living things and how they function. Students begin by understanding basic cellular functions and then move on to compare and contrast different cell types to develop mastery of the processes essential to homeostasis and the proper function of all living cells. Explanation of the properties of water will be applied to diffusion and osmosis across cell membranes. The concepts of chemical energy production and usage, photosynthesis and cellular respiration, will build a foundation for understanding the processes of cell growth and regulation. Enzymatic activity will be connected to the essential cellular processes as they apply to all living organisms. In total, this unit provides students with an inquiry-based approach to applying their knowledge of energy dynamics within cellular organelles while utilizing investigation and experimentation skills mastered in a previous unit.

Sample Unit Assignment: *Cells*

Supervised by course teacher, each student will explore how the sugar content of a banana changes as it ripens. Students will formulate a hypothesis as to the amount of sugar and starch content that are contained in samples of green, ripe and overripe bananas. After determining the sugar and starch concentrations of various samples, students will demonstrate their understanding of the process of fruit ripening by comparing their predictions to the data generated. Students will use the data collected from the lab to confirm whether their hypothesis was valid or disproved. Their conclusions regarding the relationship between sugar content, starch content, and the ripening process will be based on these comparisons. After predicting concentrations of sugar and starch in various banana samples, students will perform a test with Benedict's reagent to determine the presence of sugar and a test for the presence of starch using an iodine solution. Students will then use their predictions and collected quantitative data to demonstrate an understanding of the fruit ripening process. Students will be writing a 2 to 3 page lab report that includes that clearly states the hypothesis, experimental methods, collected data, analysis of the data, and conclusion of their findings.

While these single unit and assignment samples do not, nor are designed to, demonstrate all the UC subject area "d" course criteria, they clearly and concisely exhibit the components of the criteria listed below, are well-written, and ultimately answer the question: ***How do this single unit and assignment meet the UC criteria for a college-preparatory laboratory science course?***

This sample course unit and assignment demonstrate the following strengths & course criteria:

- provides rigorous, in-depth treatments of the conceptual foundations of the scientific subject studied based on the appropriate underlying biological, chemical and physical principles
- affords students opportunities to participate in all phases of the scientific process, including formulation of well-posed scientific questions and hypotheses, design of experiments and/or data collection strategies, analysis of data, and drawing of conclusions; they will also require students to discuss scientific ideas with other students, differentiate observations from interpretations, engage in critical thinking and write clearly and coherently on scientific topics
- employs quantitative reasoning and methods wherever appropriate
- includes a teacher-supervised, hands-on laboratory activities that are directly related to, and support, the other class work, and that involve inquiry, observation, analysis and write-up

Appendix B. Sample Unit Overview, Assignment Overview, and Lab Activity

Example Unit Overview: *Alternative Proteins*

In *Identifying GMOs,* students develop a novel genetically engineered product based on community needs and stakeholder input and then create an ad campaign to educate the public about their product. Students begin by learning about genetically modified organisms (GMOs) and how they are advertised by exploring examples, extracting and amplifying DNA from products to determine whether they have been genetically modified, and exploring the technology and protein products that are used to develop a genetically engineered (GE) product. Students investigate Golden Rice and how the product was developed due to a community need and then debate the use of Golden Rice as a solution to address vitamin A deficiency. Students spend the remainder of the unit gathering information from their communities, “developing” a genetically modified product that addresses a need they have identified from their information gathering, and creating an advertising campaign for the product.

Example Unit Assignment: *Ad Campaign— Commercialization*

Educating the local community involves understanding how the community thinks and how community members will receive a novel GE product. Students begin the lesson by analyzing data collected in Lesson 8, **Community Outreach—Developing Knowledge**, from various community stakeholders and use that information to inform the scripts and drafts of an ad series they create about their product.

Lab Activity: *Detecting Genetically Engineered Crops*

In this lab, students first choose a food product containing corn and extract its DNA. They then use PCR and gel electrophoresis to detect the presence or absence of the Bt gene *cry1Ab* in the DNA sample. They also perform a lateral flow test to detect the presence or absence of delta endotoxin proteins, one of which is encoded by the *cry1Ab* gene, that are responsible for the pest-resistant property of Bt-corn. Students then collect class data to determine the prevalence of Bt-corn in the foods they sampled and draw a scientific model explaining what happens inside Bt-corn at the molecular level.

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