Subject Matter “D” Evidence: Unit 5, Solution Seeking Microbes

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 5 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 5 meeting 1 year of the UC science (D) subject matter requirement as interdisciplinary coursework. **This review was completed on materials received May 31, 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 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.

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.

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 5, Solution Seeking Microbes**, 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 5.

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 the Laboratory Investigation, AIR staff reviewed the remaining Unit 5 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 5 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 to clarify and/or refine a model, an explanation or an engineering problem.** In *Design Thinking to Identify Challenges*, students ask other students a series of questions to identify a problem that they will try to solve with a product they want to design. Students are given several empathy prompts for asking questions, including "Tell me about a time when you felt successful in ______?" "What advice would you give another student/person about _______?" and "If you could describe how you feel about_________ in one word, what is it?" (Student Section, pp. 13–15).

Practice 2: Developing and using models

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

- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. In *Superhero Microbes,* students develop a Superhero or Fantasy Creature origin story analogy for a beneficial bacteria of their choosing (Student Section, pp. 8–9).

Practice 3: Planning and carrying out investigations

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

- Make predictions about what would happen if a variable changes. In the laboratory investigation *Yogurt Fermentation,* students predict what will happen when they change a variable in their yogurt fermentation laboratory investigation (Student Section, p. 35).

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 the laboratory investigation *Yogurt Fermentation,* students analyze data from their investigation and those of their peers to decide which yogurt is worth "scaling," or mass producing (Student Section, p. 38).

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 the laboratory investigation *Detecting* Wolbachia*: A Microbial Disease Control*, students review and analyze their results to determine whether they were able to amplify DNA from their insect and if it was infected with *Wolbachia* (Student Section, p. 29).

Practice 6: Constructing explanations and designing solutions

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

- **Apply scientific reasoning to show why the data or evidence is adequate for the explanation or conclusion.** In the laboratory investigation *Detecting* Wolbachia*: A Microbial Disease Control*, students construct an explanation about how infection with *Wolbachia* bacteria can be used to solve problems (Student Section, p. 31).

Practice 7: Engaging in argument from evidence

Students engage in elements of *Practice 7, Engaging in argument from evidence* in Unit 5, including in the following instructional activity:

- **Construct and/or support an argument with evidence, data, and/or a model.** In the laboratory investigation *Yogurt Fermentation,* students make a claim about how changing an independent variable affected the characteristics of their kefir yogurt (Student Section, pp. 39).

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 *Microbes and Food (Menu),* students research information on a career role, then make recommendations on a ”microbe-influenced” version of a food item that could be produced efficiently with microbes (Teacher Section, p. 10).

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 5 Laboratory Investigation: Yogurt Fermentation Lesson Screener** report.

Criterion 3: All Phases of the Scientific Process

Throughout Unit 5, students learn about microbes that are significant to the sustainability of the environment, human health, and food supply, then work toward designing a microbe-influenced solution to a real-world challenge and showcase their design and prototypes at a mock "Micro-Con" (*Superhero Microbes*, Teacher Section, pp. 1–2).

Throughout the unit, students engage in the following activities:

- Act as microbiologists to study an environmentally impactful bacteria, and create comics to showcase their superpowers.
- Take on the role of a food scientist to observe the process of fermentation by making their own kefir yogurt.
- Learn about microbe-produced alternatives to food products and careers in food production.
- Explore antibiotic resistance and phage therapy, and apply this learning to clinical case studies.
- Learn about molecular defenses used by microbes, and how these are used in key biotechnology tools.
- Consider frameworks of ethical decision-making and discuss complex bioethical case studies.
- Perform PCR on an insect's DNA to determine if it is infected with *Wolbachia*.
- Explore how microbes can mitigate global challenges such as climate change.
- Apply the principles of design thinking to develop microbe-based solutions to a community challenge.
- Participate in a mock microbe convention to network, learn from peers, and connect to local scientists.

Criterion 4: Employ Quantitative Reasoning and Methods Where Appropriate

Unit 5 has several opportunities for students to use quantitative reasoning, including during the laboratory investigation *Yogurt Fermentation* where students analyze each other's results to make a recommendation about which yogurt sample to scale for mass production (Student Section, p. 38).

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 5 Flow Chart and are as follows, along with their timings:

- Yogurt Fermentation (5 days)
- Detecting *Wolbachia:* A Microbial Disease Control (5 days)
- Antibiotics Resistance Simulation (1 day)
- Model CRISPR-Cas9 Simulation (1 Day)
- Design Thinking to Identify Challenges (5 days)

Unit 5 includes 17 days, or roughly 37.7% 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 5 Flow Chart provides an overview for teachers on specific instructional activities and resulting student artifacts generated to demonstrate student learning, including claim evidence reasoning statements, fermentation analysis, communications, simulations, interviews, and presentations.

Finally, the students spend several lessons applying their learning by implementing the principles of design thinking to develop microbe-based solutions to a community challenge. Then they participate in a mock microbe convention to network, lean from peers, and connect to local scientists (Unit 5 Flow Chart, p. 1).

Criterion 7: Real-World Problems and Applications

Unit 5 of the Futurelab+ biotechnology curriculum excels at providing real-world problem and application connections for students.

As noted in prior criteria, the Unit 5 activities have students learning about microbes and the role they play in society. In their toolkit, students document what they have learned about microbes over the course of the unit along with the role scientists play in solving real-world challenges with microbes (*Superhero Microbes*, Teacher Section, p. 2).

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 beneficial microbes and their uses in foods. Students also may use online, open-source programs to collect and analyze community survey data about an environmental food production or health community challenge that can be solved with microbial intervention.

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; and
- includes 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: *Solution Seeking Microbes*

In *Solution Seeking Microbes,* students showcase how microbes might be used to solve a real-world problem. They act as microbiologists to study environmentally impactful bacteria, assume the role of a food scientist to observe the process of fermentation, learn about microbe-produced alternatives to food products and careers in food production, explore antibiotic resistance and phage therapy, apply their learning to clinical case studies, consider ethical decision-making, perform PCR on an insect's DNA, explore how microbes can mitigate global challenges, and apply the principles of design thinking to develop a microbe-based solution to a community challenge.

Example Unit Assignment: *Microbes to the Rescue*

In *Microbes to the Rescue,* students participate in a mock microbe convention to network, learn from peers, and connect to local scientists. Throughout the unit, students prepare for this final assignment by investigating the role of microbes in society, interview their peers to determine a design that could address stressors in their lives, design a microbe-based product to address an environmental food product or health community challenge, interview community members about their solutions, and present their microbial solutions at a mock microbe convention.

Lab Activity: *Yogurt Fermentation*

In this lab, students will observe the fermentation process by making their own kefir yogurt. They will begin by observing milk and kefir samples under the microscope, then determine which can be used as a yogurt starter culture using their understanding of microorganisms. Students then will analyze data from published studies describing how different variables influence yogurt production. They will choose one variable to change in their kefir yogurt fermentation experiment. Next, students will collect observational and pH data over a 48-hour period to determine how their independent variable affected the characteristics of their kefir yogurt. Students also will have an opportunity to learn about connections between the microbiome and probiotics, as well as the opportunity to generate their own testable question based on a real-world example from a scientist.

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