FUTURELAB+
A GENENTECH SCIENCE EDUCATION PROGRAM

Subject Matter "D" Evidence: Unit 7, Plant to Pharmaceutical

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 7 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 7 meeting 1 year of the UC science (D) subject matter requirement as interdisciplinary coursework. **This review was completed on materials received May 3, 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 7, Plant to Pharmaceutical**, 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 7.

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 7, AIR staff reviewed the remaining Unit 7 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 7 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:

- **Define a design problem that can be solved through the development of an object, tool, process, or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.** In *Plant Medicine Product Development*, student teams identify how their proposed plant medicine would increase the quality of life of treated individuals as well as the benefits and potential or known side effects associated with their plant compound (Student 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 model to describe unobservable mechanisms.** In *Plant Medicine Product Development,* students create a detailed system model that includes both a prototype sketch and a two- or three-dimensional engineering prototype that specifically demonstrates the mechanism of action of their plant-based medicine (Student Section, p. 37).

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 *Drug Discovery Using Plant Extracts,* students perform a Kirby-Bauer disk diffusion test, which often is used in drug discovery labs to determine whether a plant extract or drug has antibacterial activity (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 *Drug Discovery Using Plant Extracts*, students analyze the results and data they collected to determine whether their plant has antibiotic properties (Student Section, p. 19).

Practice 5: Using mathematics and computational thinking

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

- **Use digital tools and/or mathematical concepts and arguments to test and compare proposed solutions to an engineering design problem.** As part of the Financial Analysis Scaling Team in *Plant Medicine Product Development*, students are required to determine the cost for purifying, shipping, and producing a specific volume or mass of medicine to determine whether product development is sustainable (Student Section, pp. 24–35).

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 *Plant Medicine Product Development*, student teams refine the prototype models that explain how a plant-derived medicine interacts with human cells to treat a disease or condition (Student Section, pp. 4–12).

Practice 7: Engaging in argument from evidence

Students engage in elements of *Practice 7, Engaging in argument from evidence* in Unit 8, including in the following instructional activity:

- **Construct and/or support an argument with evidence, data, and/or a model.** In *Drug Discovery Using Plant Extracts,* students first conduct a Kirby-Bauer test and then conduct additional research to make a claim, supported by multiple pieces of evidence, about whether their plant has antibacterial properties (Student Section, pp. 20–22).

Practice 8: Obtaining, evaluating, and communicating information

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

- **Compare, integrate, and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem.** In *Plant Medicine Product Development*, students identify a patient population and develop a full communication strategy for advertising and promoting their plant-based medicine (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 7, Lesson 7 NGSS Lesson Screener** report.

Criterion 3: All Phases of the Scientific Process

Throughout Unit 7, students complete learning activities to develop content knowledge and skills required for the unit's final project, which is to identify a plant-based medicine; develop a model that demonstrates how their compound interacts with cell structures to treat a specific human disease or condition; communicate to patients and stakeholders the costs, benefits, and risks associated with the development and production of the compound; and create a benefits-sharing agreement. Throughout the unit, students engage in the following activities:

- Use mapping tools to investigate relationships among human stakeholders, ecosystems, and plant-based medicine.
- Connect intellectual property to ethical collaboration practices and connect ecosystem health and human health to biodiversity.
- Create a class botanical collection and use evolutionary analysis to hypothesize relationships and medicinal properties.
- Investigate approaches to preventive healthcare.
- Explore how bioactive compounds are found in nature.
- Collaborate on project teams to model a plant-based medicine and create a plan to scale and manufacture the medicine.
- Communicate within and across project teams to evaluate and improve their products.
- Use models and marketing plans to provide evidence for why a drug should be produced by a biotech company.

Criterion 4: Employ Quantitative Reasoning and Methods Where Appropriate

Unit 7 has several opportunities for students to use quantitative reasoning, particularly during **Lesson 7**. During this lesson, students work to create and refine a financial analysis about the sustainability of their proposed plant-derived medicine (Student Section, pp. 24–35).

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

- Drug Discovery using Plant Extracts (5 days)
- Plant Specimens (3 days)
- Community Garden Design (2 days)

Unit 7 includes 10 days, or roughly 22% of unit time, of hands-on, teacher-supervised lab activities throughout 45 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 7 Flow Chart provides an overview for teachers about specific instructional activities and resulting student artifacts generated to demonstrate student learning, including case studies, time-lapse observations of an ecosystem, studies in intellectual property, discussions, protocols, Traditional Ecological Knowledge, profiles, and final presentations. Each lesson also includes several graphic organizers and worksheets for students.

Finally, in *Product Showcase* the overall summative assessment is to identify a plant-based medicine; develop a model that demonstrates how their compound interacts with cell structures to treat a particular human disease or condition; communicate to patients and stakeholders the costs, benefits, and risks associated with the development and production of the compound; and create a benefits-sharing agreement. Student must present their proposal to their peers, along with an accompanying product pitch and showcase (Student Section, pp. 1–13).

Criterion 7: Real-World Problems and Applications

Unit 7 of the Futurelab+ biotechnology curriculum excels at providing real-world problem and application connections for students.

As noted in several prior criteria, the Unit 7 activities have students identify a plant-based medicine; develop a model that demonstrates how their compound interacts with cell structures to treat a particular human disease or condition; communicate to patients and stakeholders the costs, benefits, and risks associated with the development and production of the compound; and create a benefit sharing agreement for stakeholders. Student peers will provide feedback during the *Product Showcase* (Student Section, 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 a variety of open-source programs and provides students with opportunities to manipulate and map data, run simulations, and use models and a marketing plan they create to explain how and provide evidence for why a plant-based drug should be produced by a biotech company.

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: *Plant to Pharmaceutical*

In *Plant to Pharmaceutical*, students develop a sales pitch for a drug derived from a plant with medicinal properties. They begin by using mapping tools to investigate relationships among human stakeholders, ecosystems, and plant-based medicine. Students connect intellectual property to ethical collaboration practices and connect ecosystem health and human health to biodiversity. The class creates a botanical collection and use evolutionary analysis to hypothesize relationships and medicinal properties. Students investigate approaches to preventive healthcare and then explore how bioactive compounds are found in nature. Finally, students form project teams and collaborate to model a plant-based medicine, create a plan to scale and manufacture the medicine, and develop a plan to communicate information to key stakeholders. The teams then use their models and marketing plans to provide evidence for why their drug should be produced by a biotech company.

Example Unit Assignment: *Product Showcase*

Students showcase their final products in an “external” communication format (e.g., video, brochure, slide deck) as a pitch to a target audience (e.g., regulators, doctors, patients) identified by the team. Each project team shares its molecular model showing how the compound acts to treat a condition, a complete manufacturing plan, and a sales pitch for the drug.

Lab Activity: *Drug Discovery Using Plant Extracts*

In this activity, students perform a Kirby-Bauer disk diffusion test, which often is used in drug discovery labs to determine if a particular plant extract or drug candidate has antibacterial activity. Students first collect a plant or plant product of interest and extract possible bioactive compounds from it. This plant extract is then soaked onto disks that are placed on LB agar plates spread with *E. coli* bacteria. Students then look for the presence or absence of bacterial growth around the disks and use these data to make a claim about whether the tested plant has antibiotic properties. Finally, students complete further independent research about the medicinal properties of their plant and consider whether it is viable for continued research for use as a potential pharmaceutical.

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