AIR | FUTURELAB+
A GENENTECH SCIENCE EDUCATION PROGRAM

NGSS Innovations and Design Principles: Summative Review, Unit 3, Laboratory Investigation

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 (CTE) Model Curriculum Standards for Biotechnology, meet at least 1 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 1 week to complete (9–10 weeks for the full unit). In total, the biotechnology curriculum has 72 lessons and eight labs that span 2 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.

As an organizational partner, the American Institutes for Research (AIR) provided external feedback about alignment of the curriculum to the three sets of standards to Futurelab+ curriculum developers during the formative period of the biotechnology curriculum. AIR is now providing external feedback and evidence regarding each unit of the final curriculum's alignment to each set of standards in three series of reports: CTE, UC science (D) subject requirement, and NGSS. The eight reports in the NGSS series provide feedback about aspects of NGSS in a sample of the curriculum (one lesson from each unit). Partners selected the Laboratory Investigation (Genetic Engineering for Protein Production) from Unit 3 (Nucleic Acids and Proteins: Disease Treatment Innovations) for this report. **This review was completed on materials received March 2, 2022, and has not been updated to reflect any revisions made to materials since then.**

Of note, because the primary design element of the curriculum was alignment to CTE, AIR used the NGSS Lesson Screener (not the Educators Evaluating the Quality of Instructional Products [EQuIP] Rubric) to identify aspects of the curriculum that incorporate NGSS. The EQuIP Rubric is typically used to determine whether a unit was designed for the NGSS by rating the evidence of NGSS alignment found in materials as *none*, *inadequate*, *adequate*, or *extensive*. **Because the curriculum was designed to align primarily to CTE standards, it was not expected that the curriculum would meet all NGSS criteria**. Nevertheless, in their current form, the materials from the Unit 3 laboratory investigation **meet three NGSS criteria** and **approach the remaining three NGSS criteria**. AIR created the *approaching* rating to indicate where a modification to materials would increase the rating to *adequate*. NGSS criteria, ratings, and recommendations are summarized in Exhibit 1.

Exhibit 1. NGSS Criteria, Ratings, and Recommendations

<table>
<tr><th colspan="2">Criterion</th><th>Rating</th></tr>
<tr><td rowspan="3">NGSS Shifts</td><td>A. Explaining Phenomena or Designing Solutions</td><td>Approaching</td></tr>
<tr><td>B. Three Dimensions</td><td>▪ DCI: Adequate
▪ SEP: Adequate
▪ CCC: Approaching
Overall rating: Approaching</td></tr>
<tr><td>C. Integrating the Three Dimensions for Instruction and Assessment</td><td>Approaching</td></tr>
<tr><td rowspan="3">Features of Quality Design</td><td>D. Relevance and Authenticity</td><td>Adequate</td></tr>
<tr><td>E. Student Ideas</td><td>Extensive</td></tr>
<tr><td>F. Building on Students' Prior Knowledge</td><td>Adequate</td></tr>
</table>

Note. DCI = disciplinary core ideas; SEP = science and engineering practices; CCC = cross-cutting concepts.

- **Criterion A: Explaining Phenomena or Designing Solutions** *(Approaching)*. The laboratory investigation focuses on the techniques used to modify the DNA of an organism to create and isolate a protein product, and the investigation is introduced through phenomena stations; however, students do not revisit these phenomena to understand or explain them. To fully meet this criterion, students should revisit the phenomena they were introduced to and reflect on how what they have learned can be used to explain the initial phenomena.
- **Criterion B: Three Dimensions** *(Approaching)*. There is sufficient evidence that the current materials give students opportunities to build their understanding of science and engineering practices (SEPs) and disciplinary core ideas (DCIs). To fully meet this criterion, materials should allow students to develop their understanding of cross-cutting concepts (CCCs), such as patterns or structure and function. Materials note that students develop their understanding of the CCC Systems and System Models; however, this alignment is not readily identified and may not be the best fit.
- **Criterion C: Integrating the Three Dimensions for Instruction and Assessment** *(Approaching)*. There is sufficient evidence that materials give students opportunities to build their understanding of both SEPs and DCIs. To fully meet this criterion, materials should provide students an opportunity to demonstrate their understanding of CCCs, such as through prompting students to consider how altering the DNA structure shifts the function of the protein they are selecting for.
- **Criterion D: Relevance and Authenticity** *(Adequate)*. There is sufficient evidence that materials provide opportunities for students to engage with materials in a meaningful way and could be strengthened by incorporating culturally relevant teaching practices and providing students with a diverse representation of genders, ethnicities, and ages.
- **Criterion E: Student Ideas** *(Extensive)*. The reviewers found extensive evidence that the materials provide students with opportunities to share their own ideas and provide feedback about their peers' ideas, both essential science skills. Several opportunities for students to reflect on their own thinking and provide feedback to their peers are incorporated throughout the materials.
- **Criterion F: Building on Students' Prior Knowledge** *(Adequate)*. The reviewers found evidence that the materials build on students' prior learning in all three dimensions although do note that other CCCs may be more directly connected to this learning sequence. Alignment of materials to this criterion could be increased if the materials would provide explicit connections to students' prior learning concerning SEPs and CCCs.

AIR's review also included feedback regarding alignment of the laboratory investigation to three of the eight Futurelab+ guiding principles: equity, adaptability, and industry driven. The Unit 3 Laboratory Investigation met all three of these guiding principles:

- ***Equity***. Materials include diverse representation throughout activities and visual media and an opportunity to explore some benefits of bacterial transformation. Some additional scaffolding and instructional supports for reading materials may be necessary for students.
- ***Adaptability***. Materials appear to be adaptable and allow teachers to move between virtual, in-person, or hybrid settings, using different synchronous and asynchronous teaching methods.
- ***Industry driven***. Students are able to practice several techniques used by molecular biologists, lab technicians, and biomanufacturing technicians throughout the laboratory investigation.

Methodology

Released in 2013, the Next Generation Science Standards (NGSS) were developed by a consortium of states, teacher associations, and nonprofit organizations. The purposes of NGSS are to (1) combat ignorance of science, (2) create common teaching standards, and (3) develop greater interest in science among students so that more students choose to major in science in technology. The focus on the purposes requires changes in how science is taught and the materials used to teach science. These changes, or innovations, shift the focus of science instruction from an abstract recall of facts to students demonstrating proficiency by engaging in scientific practices.

Three dimensions are integrated into the NGSS and throughout NGSS-aligned materials: science and engineering practices (SEPs), cross-cutting concepts (CCCs), and disciplinary core ideas (DCIs).

Methods

The 2-year biotechnology curriculum consists of four core units each year. Each core unit has nine lessons and a lab. As is typical with NGSS-aligned lessons, a lesson consists of more than one class period of instruction 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 and covers 2 instructional years.

The American Institutes for Research (AIR) was asked to provide feedback and evidence of incorporation of some of the three-dimensional learning innovations common to the NGSS on a sample of the biotechnology curriculum. **Because the curriculum was designed to align primarily to CTE standards, it was not expected that the curriculum would meet all NGSS criteria**.

Additionally, there are significant similarities between the innovations measured by the NGSS Lesson Screener and the University of California (UC) science (D) subject requirement, as shown in Exhibit 2. For this reason, AIR selected to use the NGSS Lesson Screener for supporting evidence of three-dimensional learning.

Exhibit 2. Similarities Between UC Science Requirements and Measured Innovations

There are significant similarities 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 SEPs (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.

NGSS Lesson Screener

The NGSS Lesson Screener, developed by Achieve in collaboration with the National Science Teaching Association, is a framework for collecting evidence on (1) whether a lesson being developed or revised is on the right track for incorporating NGSS innovations, (2) if a lesson warrants further review using the EQuIP Rubric, and (3) to what extent a group of reviewers have a common understanding of the NGSS or of designing lessons for the NGSS. Because these materials were designed primarily to align to CTE standards, with aspects of NGSS and three-dimensional learning incorporated, using the Lesson Screener was more appropriate than using the EQuIP Rubric.

The NGSS Lesson Screener includes six criteria (labeled A–F). The first three Lesson Screener criteria (A–C) consider evidence of three NGSS shifts: (A) Explaining Phenomena or Designing Solutions, (B) Three Dimensions (of learning), and (C) Integrating the Three Dimensions for Instruction and Assessment. The last three NGSS criteria (D–F) consider features of quality design: (D) Relevance and Authenticity, (E) Student Ideas, and (F) Building on Students' Prior Knowledge.

Each screener criterion lists several indicators that help determine the extent to which a lesson incorporates an innovation. In other words, these indicators, or descriptions, denote whether the lesson materials meet a criterion. **A rating of *adequate* or higher means that the lesson meets the criterion**.

Possible criterion ratings on the NGSS Lesson Screener include the following:

- None (no evidence to meet the criterion)
- Inadequate (limited evidence to meet the criterion or direct evidence that the materials are not aligned)
- Adequate (enough evidence to meet the criterion)
- Extensive (more than enough evidence to meet the criterion)

For this curriculum review, AIR added an *approaching* rating to the NGSS criterion ratings. This new rating, created by AIR, indicates where a slight modification to materials would increase the rating to *adequate*.

Sampling

To complete the series of NGSS Lesson Screener reviews, AIR sampled one lesson in each of the eight core units for a total of eight NGSS alignment and evidence reviews. **AIR randomly selected four of the lessons; the other four lessons were re-reviews of materials AIR reviewed during the formative review process**. AIR re-reviewed the Laboratory Investigation (Genetic Engineering for Protein Production) from Unit 3 (Nucleic Acids and Proteins: Disease Treatment Innovations) for this report.

Two AIR staff independently and then collaboratively reviewed the Unit 3 Laboratory Investigation to provide impartial evidence of where in the lesson and to what extent NGSS innovations are incorporated. After each AIR reviewer independently completed the review and provided a rationale for the ratings on each indicator, the team met to arrive at a final rating for each criterion (see Exhibit 3).

Exhibit 3. Lesson Review Process

Following the Lesson Screener standard review protocol, the AIR review team

- individually reviewed the lesson to record criterion-based evidence,
- individually made suggestions for improvement,
- collaboratively discussed findings to make a final rating determination, and
- summarized findings into a report.

Feedback and Evidence: Unit 3 Laboratory Investigation

AIR found evidence that the Unit 3 Laboratory Investigation materials meet three of the six NGSS criteria identified by the Lesson Screener and are approaching the remaining three criteria. All six criteria and evidence supporting AIR's ratings are discussed in detail in this section (see summary in Exhibit 1).

NGSS Ratings and Evidence

Rating for Criterion A: Explaining Phenomena or Designing Solutions: ***Approaching***

The reviewers found that the laboratory investigation focuses on the techniques used to modify the DNA of an organism to create and isolate a protein product. The investigation is introduced through phenomena stations; however, students do not revisit these phenomena to understand or explain them, which suggests the phenomena stations serve as instructional "hooks" rather than as intentional experiences that students investigate to develop a strong understanding of over time. **Alignment to this criterion can be increased by intentionally having students revisit the phenomena explored in the opening activity to further explain or describe how the laboratory activities that they are doing apply to those phenomena.**

Rating for Criterion B: Three Dimensions: ***Approaching***

The reviewers found that, although materials do not fully meet this criterion by providing opportunities to build understanding of grade-appropriate elements in **all three dimensions**, materials *approach* this criteria. Specifically, there is sufficient evidence that materials give students opportunities to build their understanding in both SEPs and DCIs. Materials do note that students work to develop their understanding of Systems and System Models; however, reviewers did not find evidence of that specific CCC in materials. Although reviewers found examples of where CCCs could be incorporated or referenced, particularly for structure and function, teachers who are new to NGSS would need additional guidance about where and how to incorporate this dimension. **More explicit connections for CCCs, such as structure and function, would help strengthen the materials in this area.**

The following bulleted evidence supports the *approaching* rating for this criterion because the lesson materials include examples of opportunities and support for students explicitly developing their understanding of elements of both SEPs and DCIs:

SEPs, including:

- **Developing and Using Models**: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system (Student Guide, Part 4: Making a Model, p. 34).

DCIs, including:

- **LS1.A: Structure and Function**: All cells contain genetic information in the form of DNA molecules (Teacher Section, p. 7).

Rating for Criterion C: Integrating the Three Dimensions for Instruction and Assessment: ***Approaching***

The reviewers found that materials *approach* (but do not fully meet) this criterion by providing opportunities to build understanding of grade-appropriate elements in **all three dimensions**. Specifically, there is sufficient evidence that materials give students opportunities to build their understanding of both SEPs and DCIs. **Aligning materials to this criterion could be increased if the materials would provide students with explicit opportunities to demonstrate their understanding of various CCCs, such as patterns. As with Criterion B, reviewers found examples of where CCCs**

could be incorporated or referenced throughout the lesson; however, teachers who are new to NGSS would need additional guidance about where and how to incorporate this dimension.

The following bulleted evidence supports the *approaching* rating for this criterion because the lesson materials include examples of opportunities and support for students to explicitly demonstrate their understanding of elements of both SEPs and DCIs:

SEPs, including:

- **Developing and Using Models**: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system (Student Guide, Part 4: Making a Model, p. 34).

DCIs, including:

- **LS1.A: Structure and Function**: All cells contain genetic information in the form of DNA molecules (Student Section, p. 7).

Rating for Criterion D: Relevance and Authenticity: *Adequate*

The reviewers found evidence that the materials engage students and teachers in authentic and meaningful scenarios that reflect the real world. The materials provide some opportunities for students to engage with materials in a meaningful way and could be strengthened by providing students with a diverse representation of gender, ethnicities, and age groups, as well as by incorporating culturally relevant teaching practices. The following bulleted evidence supports the *adequate* rating for this criterion:

- **Day 1 Small-Group Activity**: Students complete a gallery walk and investigate phenomena stations to record observations and questions about the phenomenon at the station (Teacher Section, p. 6).
- **Day 1 Whole Group**: Students brainstorm how bioengineers use the natural relationship between bacteria and plasmids to create the products they viewed at the phenomena stations.

Rating for Criterion E: Student Ideas: *Extensive*

The reviewers found extensive evidence that the materials provide students with opportunities to share their own ideas, as well as provide feedback about their peers' ideas. Several opportunities exist for students to reflect on their own thinking, including taking a self-survey, identifying ideas from their own research that students feel are most important, and using an *interesting but irrelevant* protocol to provide feedback to their peers.

The following bulleted evidence supports the *extensive* rating for this criterion:

- **Day 3 Small-Group Activity**: Students synthesize what they learned by drawing a scientific model that explains what happens inside the transformed bacteria to cause them to produce a new protein (Teacher Section, p. 11).
- **Day 3 Small-Group Activity**: Students exchange models and provide feedback about different aspects of each other's models (Teacher Section, p. 11).

Rating for Criterion F: Building on Students' Prior Knowledge: *Adequate*

The reviewers found evidence that the materials build on students' prior learning in all three dimensions, although other CCCs may be more directly connected to this learning sequence than the ones identified in the materials. Alignment of materials to this criterion could be increased if the materials would provide explicit connections to students' prior learning concerning SEPs and CCCs. The following bulleted evidence supports the *adequate* rating for this criterion:

- **Day 1 and Day 4 Teacher Note**: Teachers are provided additional information about prerequisite knowledge and skills students need to successfully complete the laboratory investigation.

Futurelab+ Design Principles

Although several Futurelab+ design principles (Exhibit 4) overlap with the Lesson Screener criteria, especially concerning Principle 1 (Equity) and Principle 6 (Education Standards Aligned), AIR was asked to look for evidence of the design principles independent of NGSS. AIR cannot provide feedback about all principles because several principles relate more to how materials were designed; however, within this section, AIR provides feedback regarding the principles of Equity, Adaptability, and Industry Driven.

Feedback about the principle of Education Standards Aligned can be surmised from the CTE alignment matrix and summary evidence reports provided for each unit.

Feedback about the principle of California Focus can be surmised from the California Subject Matter D report prepared for each unit. No formal evaluation tool was created or used to provide this feedback.

Exhibit 4. Futurelab+ Principles

1. Equity | **Prioritize** meeting the needs of the most **underserved students** using socially responsible language.
2. Adaptability | Empower and equip teachers and students to **seamlessly move between virtual and in-person learning** environments.
3. Industry Driven | Reflect **in-demand biotech skills** and **career-laddering opportunities.**
4. Teacher Voice | Informed by **teacher input** and must be **teacher-demand driven.**
5. Teaching Breadth and Inclusivity | Build to engage a **broad set of teachers.**
6. Education Standards Aligned | Demonstrate **relevance** and **validity** with educators.
7. Open Source | Opt for **open frameworks** over proprietary approaches.
8. California Focus | Prioritize **California state standards and educational contexts** as a foundation for future scaling efforts nationwide.

Equity

Materials include diverse representation throughout activities, and visual media provide an opportunity to explore some benefits of bacterial transformation. Some additional scaffolding and instructional supports for reading materials may be necessary for students who struggle with reading technical information in texts.

Adaptability

The Unit 3 Laboratory Investigation may be difficult to support in a hybrid or virtual environment because the investigation requires several specific laboratory materials to conduct. Guidance is given to teachers on ways to conduct the investigation virtually.

Industry Driven

Students are able to practice several techniques used by molecular biologists, lab technicians, and biomanufacturing technicians throughout the laboratory investigation.

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*. Retrieved October 11, 2021, from https://www.scusd.edu/sites/main/files/file-attachments/protocols_0.pdf?1445031253.

Appendix A. Lesson Screener Criteria

	Criterion	Description
NGSS Shifts	**A. Explaining Phenomena or Designing Solutions**	The lesson focuses on supporting students to make sense of a phenomenon or design solutions to a problem.
	B. Three Dimensions	The lesson helps students develop and use multiple grade-appropriate elements of the SEPs, DCIs, and CCCs, which are deliberately selected to aid student sensemaking of phenomena or designing of solutions.
	C. Integrating the Three Dimensions for Instruction and Assessment	The lesson requires student performances that integrate elements of the SEPs, CCCs, and DCIs to make sense of phenomena or design solutions to problems, and the lesson elicits student artifacts that show direct, observable evidence of three-dimensional learning.
Features of Quality Design	**D. Relevance and Authenticity**	The lesson motivates student sensemaking or problem solving by taking advantage of student questions and prior experiences in the context of the students' homes, neighborhoods, and communities, as appropriate.
	E. Student Ideas	The lesson provides opportunities for students to express, clarify, justify, interpret, and represent their ideas (i.e., making thinking visible) and to respond to peer and teacher feedback.
	F. Building on Students' Prior Knowledge	The lesson identifies and builds on students' prior learning in all three dimensions in a way that is explicit to both the teacher and the students.

Note. DCI = disciplinary core ideas; SEP = science and engineering practices; CCC = cross-cutting concepts.

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