GENES AND MICROBES:
Engaging Students and Teachers in NGSS-Aligned Curricula and Professional Development

Genetic Science Learning Center, University of Utah

PI and KEY CONTACTS

Louisa A. Stark, PhD, Principal Investigator
louisa.stark@utah.edu

Kevin Pompei, MEd, Co-PI/Program Manager/Instructional Designer
k.pompei@utah.edu

Dina Drits-Esser, PhD, Internal Evaluator
dina.drits@utah.edu

Kristin Bass, PhD, External Evaluator, Rockman et al
kristin@rockman.com

PROJECT GOALS

GOAL 1

Educate secondary-level students about (a) molecular genetics and how they shape human traits, and (b) cell biology through understanding human interactions with microbes, and their impact on human health.

Objective 1: Produce two curriculum units that each address the three dimensions of the NGSS.

Objective 2: Evaluate the efficacy for student learning of the two curriculum units using small-scale randomized controlled trials.

Objective 2.1: Develop valid student assessments for use in the randomized controlled trials and by teachers.

GOAL 2

Prepare teachers to use the two curriculum units through online professional development courses, and workshops at the state, regional and national levels.

Objective 1: Hold six online professional development courses for 180 middle and high school teachers at underserved schools across the US.

Objective 2: Present five or more dissemination workshops on the units at science teacher conferences.

High School Advisory Board
represented schools
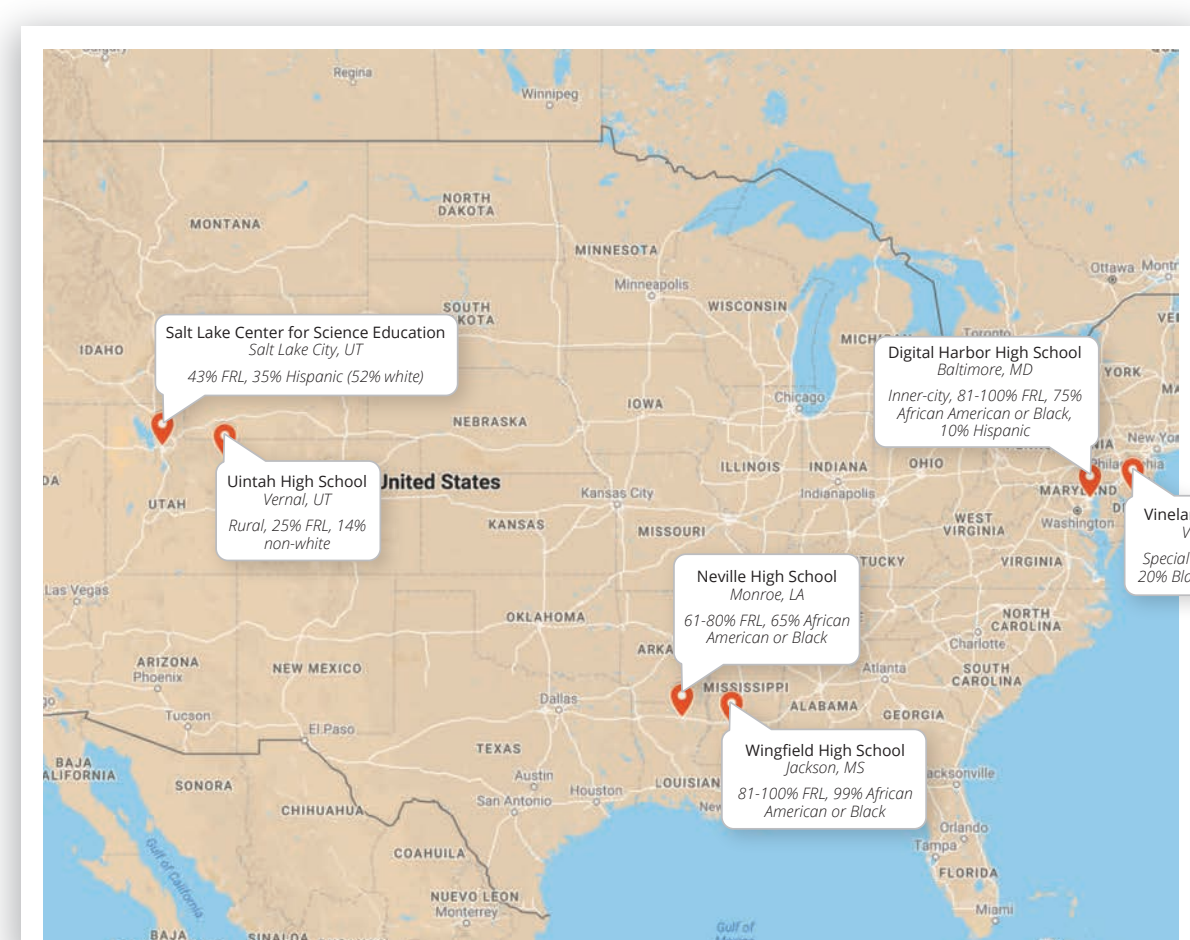
Middle School Advisory Board
represented schools

Olympus Junior High, Holladay, UT (FRL 0-20%, 10% Hispanic, 75% white)
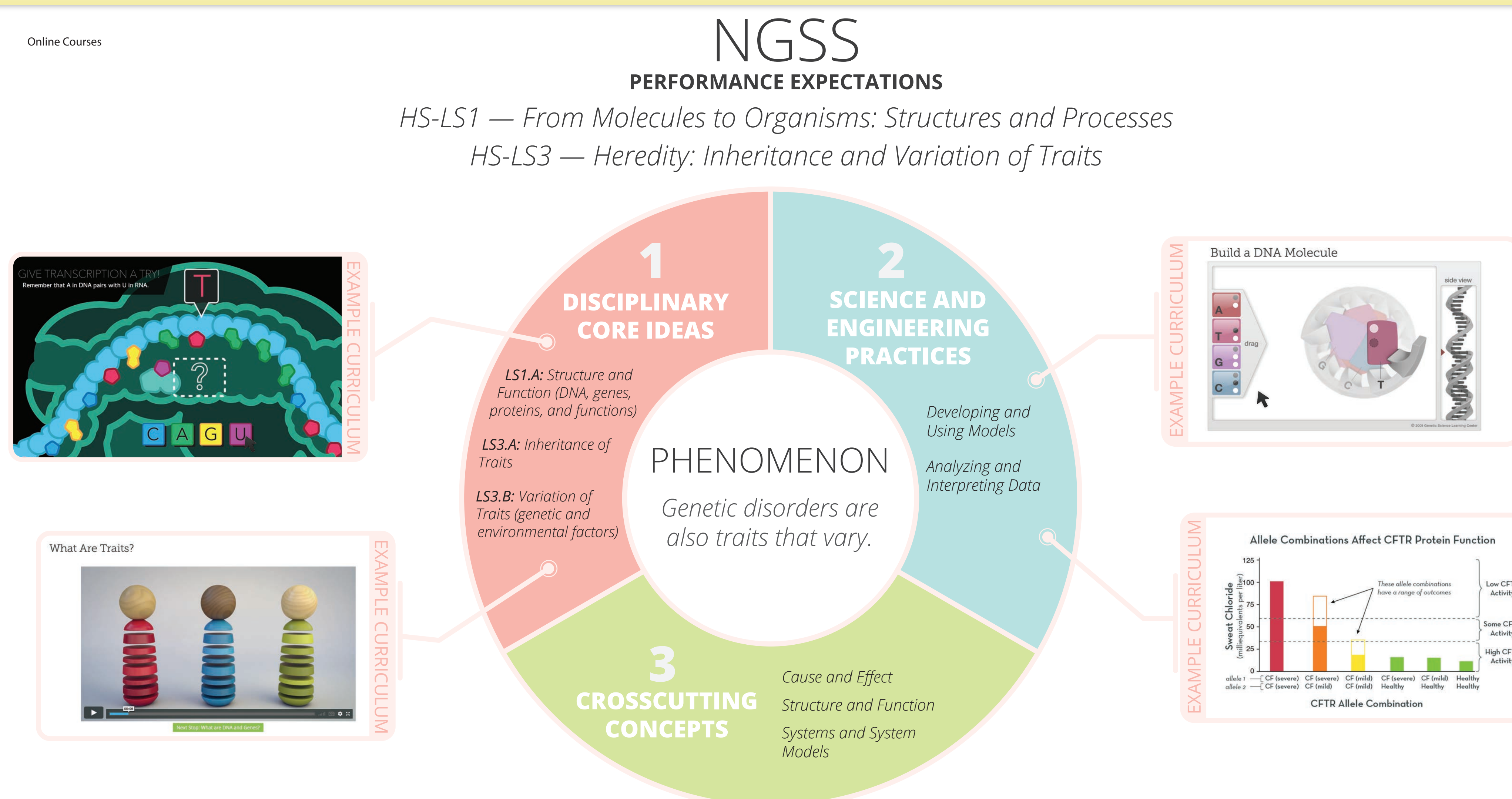Nibley Park, Salt Lake City, UT (FRL 41-60%, 35% Hispanic, 48% white)
Clayton Middle School, Salt Lake City, UT (FRL 21-40%, 16% Asian, 63% white)
Hunter Junior High, West Valley City, UT (FRL 41-60%, 35% Hispanic, 48% white)
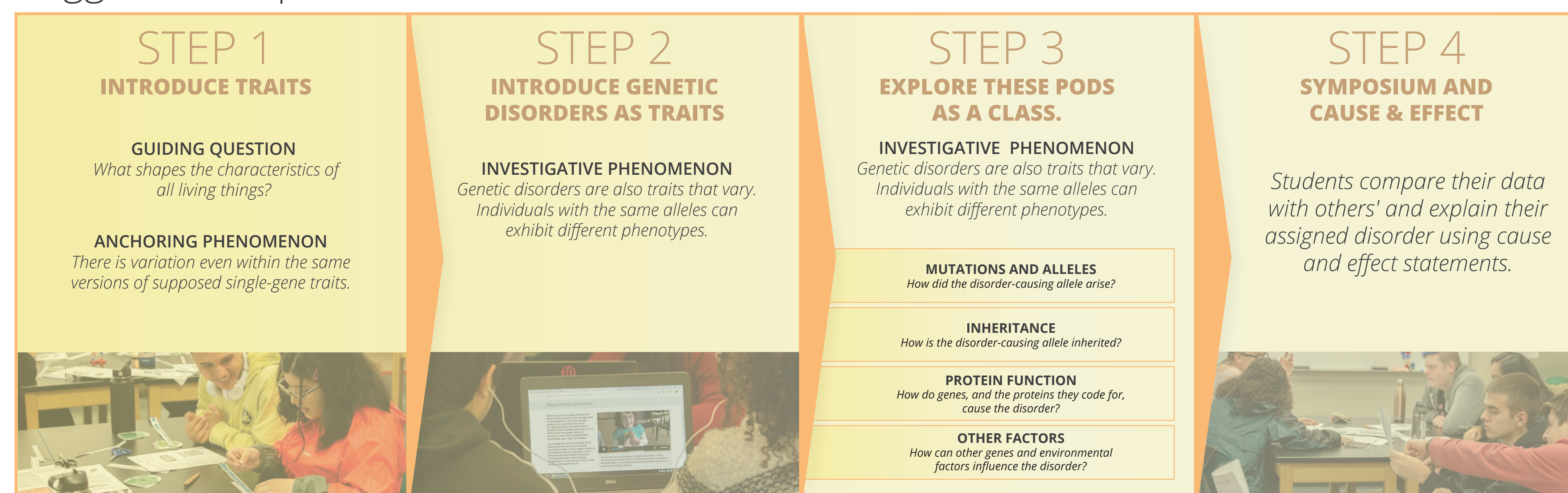Northwest Middle School, Salt Lake City, UT (FRL 81-100%, 69% Hispanic, 12% white)
Hillside Middle School, Salt Lake City, UT (FRL 41-60%, 40% Hispanic, 46% white)

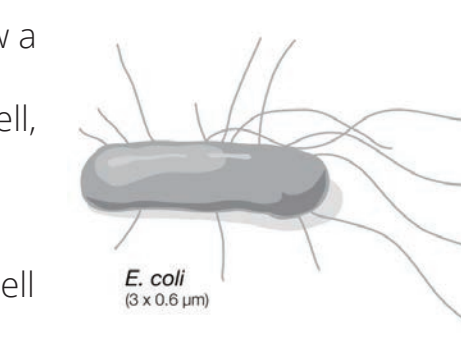## HIGH SCHOOL UNIT: EXPLORING GENETICS THROUGH GENETIC DISORDERS

Online Courses

NGSS
PERFORMANCE EXPECTATIONS
HS-LS1 — From Molecules to Organisms: Structures and Processes
HS-LS3 — Heredity: Inheritance and Variation of Traits

1 DISCIPLINARY CORE IDEAS
LS1.A: Structure and Function (DNA, genes, proteins, and functions)
LS3.A: Inheritance of Traits
LS3.B: Variation of Traits (genetic and environmental factors)

2 SCIENCE AND ENGINEERING PRACTICES
Developing and Using Models
Analyzing and Interpreting Data

3 CROSSCUTTING CONCEPTS
Cause and Effect
Structure and Function
Systems and System Models

PHENOMENON
Genetic disorders are also traits that vary.

EXAMPLE CURRICULUM — Build a DNA Molecule

EXAMPLE CURRICULUM — Allele Combinations Affect CFTR Protein Function

Suggested Sequence

STEP 1
INTRODUCE TRAITS

GUIDING QUESTION
What shapes the characteristics of all living things?

ANCHORING PHENOMENON
There is variation even within the same versions of supposed single-gene traits.

STEP 2
INTRODUCE GENETIC DISORDERS AS TRAITS

INVESTIGATIVE PHENOMENON
Genetic disorders are also traits that vary. Individuals with the same alleles can exhibit different phenotypes.

STEP 3
EXPLORE THESE PODS AS A CLASS.

INVESTIGATIVE PHENOMENON
Genetic disorders are also traits that vary. Individuals with the same alleles can exhibit different phenotypes.

MUTATIONS AND ALLELES
How did the disorder-causing allele arise?

INHERITANCE
How is the disorder-causing allele inherited?

PROTEIN FUNCTION
How do genes, and the proteins they code for, cause the disorder?

OTHER FACTORS
How can other genes and environmental factors influence the disorder?

STEP 4
SYMPOSIUM AND CAUSE & EFFECT

Students compare their data with others' and explain their assigned disorder using cause and effect statements.

MIDDLE SCHOOL UNIT: CELL BIOLOGY

Human interactions with microbes and pathogens as a gateway to learning cell biology.

DISCIPLINARY CORE IDEAS: Structure and Function
SCIENCE PRACTICES: Developing & using models; Engaging in argument from evidence
CROSSCUTTING CONCEPTS: Scale; Structure and Function

ACTIVITIES BY NGSS PERFORMANCE EXPECTATION

MS-LS1.1
Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.

The Virtual Microscope
Students explore a variety of specimens, like animals, plants, fungi, protists, bacteria, viruses. Specimen details can be viewed at the organismal, tissue, cell, cell component, and molecular levels. Students learn how various cell types are organized into tissues and understand the relative sizes of various organisms and cell types.

Living vs. Nonliving
Students sort various specimens, depicted on cards, into living and non-living categories. This activity includes several tricky examples (e.g., seed, chicken egg, feather, wood) and encourages students to come up with additional categories (e.g., from something living, formerly living).

MS-LS1.2
Develop and use a model to describe the function of a cell as a whole and the ways parts of cells contribute to the function.

Mystery Cell Model
Students receive an envelope filled with cell parts and descriptions, which they assemble into a model of a differentiated cell. They then determine what type of cell their model depicts, what type of tissue it resides within, and other types of cells it interacts with. Initial models will depict an airway epithelial cell, a plant parenchyma cell, and a motor neuron.

MS-LS1.3
Use argument supported by evidence for how the body is a system of interacting subsystems composed of groups of cells.

How do Pathogens Make us Sick?
Students model an infection of a differentiated cell. They use the model to understand how a bacterial or viral pathogen disrupts the function of the cell, and they explain how this in turn disrupts a tissue, organ, and/or body system. Models will include approximately 5 cell type and pathogen pairs.

E. coli bacterium

PROGRESS

- Results of teacher needs survey:
  - Middle school teachers tend to address Performance Expectations (PEs) directly. We will develop activities that align closely with the PEs.
  - Teachers want their students to understand living things at the organismal, tissue, cell, cell component, and molecule levels.
  - Teachers want their students to understand single-celled and multicellular plants and animals, as well as bacteria and viruses.
  - Teachers want their students to understand how a cell's organelles interact and how these components relate to a differentiated cell's specialized function.
  - Students are highly interested in bacteria and viruses, especially ones that infect people.
- Alpha testing 2 activities with up to 6 teachers and their classrooms (May 2019)
- Completed curriculum materials will be pilot tested in classrooms during the 2019/2020 school year, then revised for use in an RCT.

DISSEMINATION

ONLINE COURSES
- Priority acceptance: teachers of underrepresented students and those of low socio-economic levels
- Will include science/content knowledge updates, guided review of the units and small-group collaboration around implementation.

IN-PERSON WORKSHOPS
National Association of Biology Teachers (NABT)
National Science Teachers Association (NSTA)
State-level science teacher conferences

RESEARCH & EVALUATION

RESEARCH QUESTIONS

EFFICACY OF MATERIALS

HIGH SCHOOL UNIT:
- During a unit that explores basics genetics concepts, do students who engage in a concurrent investigation of a disease-causing allele improve in their understanding of genetics compared with students who do not engage in the investigation?
- Does two-week retention of knowledge vary according to instructional condition?

MIDDLE SCHOOL UNIT:
- Do students exposed to the GSLC units (i.e., the treatment condition) improve their understanding of the focal topics more than students who are taught the same content using conventional methods (i.e., the control condition)?
- Does two-week retention of knowledge vary according to instructional condition?

COST EFFECTIVENESS
HOW DO THE TREATMENT AND CONTROL CONDITIONS VARY IN:
- Cost of the instructional materials (middle school unit only)
- Time it takes to prepare materials for the lessons

ASSESSMENT ITEM DEVELOPMENT

- Collect evidence for the validity of the pre and post student knowledge tests
  - Content evidence of validity—experts review items for accuracy and alignment with curriculum learning objectives
  - Construct evidence of validity
    - "Think-aloud" cognitive interviews with students
    - Pilot test with at least 94 students that have not studied the module

MIXED-METHODS RESEARCH DESIGN

QUANTITATIVE STUDY
- RCT comparisons of unit with the concurrent allele investigation vs. without the investigation - high school unit
- RCT comparisons of GSLC unit vs. conventional materials (business-as-usual) – middle school unit
  - Testing in schools with predominantly underrepresented students
- Power analysis: 100 students/condition will reveal a minimum detectable effect size of 0.31 (considered small)
  - Assume that power = 80 and that pretest covariates will explain at least 40% of the variance in the outcome
- Student assessments: Pretest, posttest, 2-week posttest

QUALITATIVE STUDY
Classroom observations
- Daily classroom observations by researchers and curriculum developers
  - 3 teachers (alpha test)
  - 2 teachers (pilot)
  - 2-4 teachers (RCT)
Teacher measures
- End-of-unit surveys to learn about which components of the unit were engaging, challenging, and/or in need of improvement (pilot)
- Daily teacher logs to measure fidelity of implementation and areas in need of improvement (RCT)
- End-of-unit surveys to measure experience with unit (RCT)
Student measures
- End-of-unit surveys to learn about which components of the unit were engaging, challenging, and/or in need of improvement (pilot and RCT)

PROGRESS

HIGH SCHOOL UNIT CURRICULUM AND ASSESSMENT TESTING IS UNDERWAY
- Alpha test (May 2018)
  - 3 teachers, 5 classrooms
- Curriculum pilot testing (April 2019)
  - 2 teachers in 2 schools. 4 classrooms total
  - 114 students in grades 9-11
    - East High School (Free and Reduced lunch = 60%, 60% non-white)
    - Salt Lake Center for Science Education (Free and Reduced lunch = 44%, 48% non-white)
- Assessment item pilot test (April 2019)
  - 27 multiple choice items, 3 open ended items
  - Same classrooms as curriculum pilot test