# Introduction

# Formative Assessment Exemplar - BIO.3.5

**Introduction:**

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

Of note: All formative assessment clusters were revised based on feedback from educators after being utilized in the classroom. During the revision process, each cluster was specifically checked to make sure the phenomena was authentic to the DCI, supporting information was provided for the phenomena, the SEPs, CCCs, and DCIs were appropriate for the learning progressions, the cluster supported student sensemaking through the Gather, Reason, and Communicate instructional model, and the final communication prompt aligned with the cluster phenomena. As inconsistencies were found, revisions were made to support student sensemaking. If other inconsistencies exist that need to be addressed, please email the current Utah State Science Education Specialists with feedback.

**General Format:**

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

**Accommodation Considerations**:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

**References:**

Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

# Teacher Facing Info

**Teacher Facing Information**

**Standard:** BIO.3.5 Evaluate **design solutions** where biotechnology was used to identify and/or modify genes in order to solve (effect) a problem.

**Assessment Format:** Online Only (Requires students to have online access)

| **Phenomenon** | |
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| Treatment of cystic fibrosis with either Vector-Mediated Gene Therapy or CRISPR Gene Editing | Proficient Student Explanation of Phenomenon:<br><br>Students will identify the problems that exist from cystic fibrosis disease including the mutation in the gene causing cystic fibrosis, a defective protein in the cell membrane, an abnormal amount of mucus, and the observable symptoms like coughing and infection.<br><br>Students identify which problem would be best to solve in order to impact a solution for ALL the problems caused by cystic fibrosis. Students will use their knowledge of protein synthesis to identify fixing the gene mutation as being the root cause of cystic fibrosis.<br><br>Students then prioritize given criteria in solving the problems caused by cystic fibrosis. Students provide justification for how they prioritized the criteria using science knowledge.<br><br>Finally, students gather information about Vector-Mediated Gene Therapy and CRISPR Gene Editing and determine which solution is optimal based on prioritized criteria and the strengths and weaknesses of each solution. |

| **Cluster Task Statement** |
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| (Represents the ultimate way the phenomenon will be explained or the design problem will be addressed)<br><br>In the questions below you will evaluate two different design solutions in which biotechnology research is currently being used to modify genes to solve a human genetic disease problem. You will first define the problem, then prioritize criteria, and finally choose which of the two solutions you think is optimal based on your prioritized criteria and the strengths and weaknesses of each solution. |

| **Supporting Information** |
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| **Supporting Information 1 (Questions 1-5)**<br><br>Cystic fibrosis is an inherited disorder that impacts a single gene and affects the cells of the lungs, pancreas, and small intestines. These cells have a defective protein in the cell membrane which results in the production of abnormal amounts of mucus. This causes coughing, poor digestion, and an increased risk of infection. If untreated, individuals with Cystic fibrosis often develop fatal lung infections early in life. |

**Supporting Information 2 (Questions 6-7)**

**Vector-Mediated Gene Therapy**

HHMI 1 min video (click next below the cell, then click on Gene Therapy) *we're trying to find a direct link to this video

Gene therapy is the introduction, removal, or change in genetic material to treat a specific disease.A gene cannot be directly inserted into a cell, a carrier, also known as a vector, must be used. First, scientists must identify a vector capable of delivering the gene. Viruses have been found to be good vectors because they are able to get into cells and use the cell machinery. Scientists must also find a way to get the vector into the affected tissue. This can be difficult with tissues in the stomach and intestines (one of the areas affected by Cystic fibrosis) because the cells of these tissues break down and regenerate every five to seven days due to the wear and tear of digestive processes. Clinical trials of gene therapy have had little success in effectively repairing the gene. Scientists have not found a vector that successfully delivers the corrected gene and many patients have had adverse immune responses because of the use of a viral vector.

**CRISPR Gene Editing**

HHMI 1 min video (click next below the cell, then click on CRISPR-Cas9) *we're trying to find a direct link to this video

CRISPR is a very new technology that has shown great success in editing the genes of plants, and some other organisms. In general it is a straightforward, targeted, and inexpensive approach to fixing even a single nucleotide within the DNA. However, so far it has only been used directly in humans in one situation. In March 2020, CRISPR-Cas9 was inserted directly into the eye of a person suffering from an inherited form of blindness. Other CRISPR studies in humans remove some cells from the body, edit them using CRISPR, and then put the edited cells back into the body.

All of these trials are ongoing with inconclusive results. Researchers are focused on finding the best ways to administer CRISPR to the body and ensuring that CRISPR never accidentally misses its target which could result in an unintended mutation in an otherwise healthy sequence of DNA.

**Cluster Questions**

Gather:
Cluster Question #___1___
Question Type: Multiple Select
Addresses:
__X__ DCI
__X__ SEP: Defining Problem
____ CCC
Answer:

- cystic fibrosis gene mutation
- defective protein in the cell membrane
- abnormal amounts of

Question 1:

According to the text above, select the problems caused by cystic fibrosis. Select all that apply:

- ☐ Abnormal amounts of mucus produced
- ☐ Cystic Fibrosis Gene mutation
- ☐ Cystic Fibrosis is spread to others by coughing
- ☐ Transcription and Translation machinery is damaged
- ☐ Defective protein in the cell membrane
- ☐ Other DNA in the cell is damaged
- ☐ Symptoms like coughing and infection

| | |
|---|---|
| mucus produced<br>• symptoms like coughing and infection | |
| Reason:<br>Cluster Question #___2___<br>Question Type: Short Answer<br>Addresses:<br>__X__ DCI<br>__X__ SEP Defining Problem<br>__X__ CCC Cause and Effect<br>Answer:<br>Fix the Cystic Fibrosis Gene mutation | Question 2:<br><br>If you could design a solution to any of the problems above, which one would have the greatest impact on solving ALL the problems caused by CF? |
| Communicate:<br>Cluster Question #___3___<br>Question Type:<br>Addresses:<br>__X__ DCI<br>__X__ SEP Defining Problem<br>__X__ CCC Cause and Effect<br>Answer:<br>Students would model DNA with a mutated gene, this gene produces an ineffective protein in the cell membrane, this results in too much mucus production, which causes the symptoms of coughing and infection.<br><br>In the model students should point out fixing the mutated gene would be most effective to solve all the problems caused by cystic fibrosis. A fixed gene results in the correct protein and normal mucus secretions. | Question 3:<br><br>How will fixing the one problem you identified above, have the greatest effect on fixing all the problems caused by cystic fibrosis?<br>Use Supporting Information 1 to develop a model that shows how the problems caused by cystic fibrosis are connected. Identify the specific problem you would solve in your model and provide an explanation for how that would fix the other problems in the model. |
| Gather:<br>Cluster Question #___4___ | Question 4: |

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| Question Type: Table Match<br>Addresses:<br>__X__ DCI ETS1.A<br>__X__ SEP: Defining Problem; Identify Criteria<br>____ CCC<br>Answer:<br>Students answers will vary | Rank order the criteria based on what you think is most important (4) to least important (1).<br><br>Criteria:<br>● Limited side effects from treatment<br>● Reduce the symptoms of mucus build up and infection risk<br>● Fixing or replacing the defective protein<br>● Access to treatment by all populations |
| Gather:<br>Cluster Question #___5___<br>Question Type: Short Answer<br>Addresses:<br>__X__ DCI ETS1.A<br>__X__ SEP: Defining Problem; Identify Criteria<br>____ CCC<br>Answer:<br>Students answers will vary | Question 5:<br><br>Explain your reasoning for the rank order of criteria you chose above? What scientific knowledge supports your reasoning? |
| Communicate:<br>Cluster Question #___6___<br>Question Type: Multiple Choice<br>Addresses:<br>__X__ DCI ETS1.C<br>__X__ SEP Determining Optimal Design Solutions<br>____ CCC<br>Answer:<br>Student answers will vary | Question 6:<br><br>Based on your list of prioritized criteria, and thinking about the strengths and weaknesses of each solution, which do you think is the optimal solution?<br>☐ Vector-Mediated Gene Therapy<br>☐ CRISPR Gene Editing |
| Communicate:<br>Cluster Question #__7____<br>Question Type: Short Answer<br>Addresses:<br>__X__ DCI ETS1.C<br>__X__ SEP Determining Optimal Design Solutions<br>____ CCC<br>Answer:<br>Student answers will vary. | Question 7:<br><br>In question 4 you prioritized criteria. Evaluate which solution, CRISPR or Vector, best meets the prioritized criteria and justify your conclusion using the evidence presented from the Supporting Information. |
| **Proficiency Scale** | |

**Proficient Student Explanation:**

Students will identify the problems that exist from cystic fibrosis disease including the mutation in the gene causing cystic fibrosis, a defective protein in the cell membrane, an abnormal amount of mucus, and the observable symptoms like coughing and infection.

Students identify which problem would be best to solve in order to impact a solution for ALL the problems caused by cystic fibrosis. Students will use their knowledge of protein synthesis to identify fixing the gene mutation as being the root cause of cystic fibrosis.

Students would model DNA with a mutated gene, this gene produces an ineffective protein in the cell membrane, this results in too much mucus production, which causes the symptoms of coughing and infection.

In the model students should point out fixing the mutated gene would be most effective to solve all the problems caused by cystic fibrosis. A fixed gene results in the correct protein and normal mucus secretions

Students then prioritize given criteria in solving the problems caused by cystic fibrosis. Students provide justification for how they prioritized the criteria using science knowledge.

Finally, students gather information about Vector-Mediated Gene Therapy and CRISPR Gene Editing and determine which solution is optimal based on prioritized criteria and the strengths and weaknesses of each solution.

| Level 1 - Emerging | Level 2 - Partially Proficient | Level 3 - Proficient | Level 4 - Extending |
|---|---|---|---|
| **SEP:** Does not meet the minimum standard to receive a 2. | **SEP:** Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints | **SEP:** 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 tradeoff considerations. | **SEP:** Extends beyond proficient in any way. |
| **CCC:** Does not meet the minimum standard to receive a 2. | **CCC:** Cause and effect relationships may be used to predict phenomena in natural or designed systems. | **CCC:** Systems can be designed to cause a desired effect. | **CCC:** Extends beyond proficient in any way. |

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| **DCI:**<br>Does not meet the minimum standard to receive a 2. | **DCI:**<br>Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affects the traits of the individual. Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits<br><br>In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other.<br><br>In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are | **DCI:**<br>DNA molecules contain four different kinds of building blocks, called nucleotides, linked together in a sequential chain.<br><br>The sequence of nucleotides spells out the information in a gene. DNA controls the expression of proteins by being transcribed into a “messenger” RNA, which is translated in turn by the cellular machinery into a protein. In effect, proteins build an organism’s identifiable traits.<br><br>In sexual reproduction, chromosomes can sometimes swap sections during the process of meiosis (cell division), thereby creating new genetic combinations and thus more genetic variation. Although DNA replication is tightly regulated and remarkably accurate, errors do occur and result in mutations, which are also a source of genetic variation. Environmental factors can also cause mutations in genes, and viable mutations are inherited.<br><br>Environmental factors also affect expression | **DCI:**<br>Extends beyond proficient in any way. |

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| | beneficial, others harmful, and some neutral to the organism. | of traits, and hence affect the probability of occurrences of traits in a population. Thus the variation and distribution of traits observed depends on both genetic and environmental factors. | |

**(Student Facing Format on following page)**

# Student Assessment

Name: _____ Date: _____

**Stimulus**

**Reading 1: Cystic Fibrosis**
**(Questions 1-5)**

Cystic fibrosis is an inherited disorder that impacts a single gene and affects the cells of the lungs, pancreas and small intestines. These cells have a defective protein in the cell membrane which results in the production of abnormal amounts of mucus. This causes coughing, poor digestion, and an increased risk of infection. If untreated, individuals with Cystic fibrosis often develop fatal lung infections early in life.

**Reading 2: Types of Biotechnology**
**(Questions 6-7)**

**Vector-Mediated Gene Therapy**
HHMI 1 min video (click **next** below the cell, then click on **Gene Therapy**)

Gene therapy is the introduction, removal, or change in genetic material to treat specific diseases. A gene cannot be directly inserted into a cell, a carrier (also known as a vector) must be used. First, scientists must identify a vector capable of delivering the gene. Viruses are good vectors because they can get into cells and use the cell machinery. Scientists must also find a way to get the vector into the affected tissue. This can be difficult with tissues in the stomach and intestines (one of the areas affected by Cystic fibrosis) because the cells of these tissues break down and regenerate every five to seven days due to the wear and tear of digestive processes. Clinical trials of gene therapy have had little success in effectively repairing the gene. Scientists have not found a vector that successfully delivers the corrected gene and many patients have had adverse immune responses because of the use of a viral vector.

**CRISPR Gene Editing**
HHMI 1 min video (click **next** below the cell, then click on **CRISPR-Cas9**)

CRISPR is a very new technology that has shown great success in editing the genes of plants and some other organisms. In general, it is a straightforward, targeted, and inexpensive approach to fixing even a single nucleotide within the DNA. However, so far it has only been used directly in humans in one situation. In March 2020, CRISPR-Cas9 was inserted directly into the eye of a person suffering from an inherited form of blindness. Other CRISPR studies in humans remove some cells from the body, edit them using CRISPR, and then put the edited cells back into the body.
All of these trials are ongoing with inconclusive results. Researchers are focused on finding the best ways to administer CRISPR to the body and ensuring that CRISPR never accidentally misses its target which could result in an unintended mutation in an otherwise healthy sequence of DNA.

**Your Task**

In the questions below you will evaluate two different design solutions in which biotechnology research is currently being used to modify genes to solve a human genetic disease problem. You will first define the problem, then prioritize criteria, and finally choose which of the two solutions you think is optimal based on your prioritized criteria and the strengths and weaknesses of each solution.

**Question 1**

According to the information found in **Reading 1: Cystic Fibrosis**, select the problems caused by cystic fibrosis. Select all that apply:

- ☐ Abnormal amounts of mucus produced
- ☐ Cystic Fibrosis Gene mutation
- ☐ Cystic Fibrosis is spread to others by coughing
- ☐ Transcription and Translation machinery is damaged
- ☐ Defective protein in the cell membrane
- ☐ Other DNA in the cell is damaged
- ☐ Symptoms like coughing and infection

**Question 2**

If you could design a solution to any of the problems listed above in question 1, which one would have the greatest impact on solving ALL the problems caused by CF?

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**Question 3**

How will fixing the one problem you identified above, have the greatest effect on fixing all the problems caused by cystic fibrosis?

Use **Reading 1: Cystic Fibrosis** to develop a model that shows how the problems caused by cystic fibrosis are connected. Identify the specific problem you would solve in your model and provide an explanation for how that would fix the other problems in the model.

**Question 4**

Rank order the criteria for solving the problem of cystic fibrosis based on what you think is most important (4) to least important (1).

Criteria:

- ☐ Limited side effects from treatment
- ☐ Reduce the symptoms of mucus build up and infection risk
- ☐ Fixing or replacing the defective protein
- ☐ Access to treatment by all populations

**Question 5**

Explain your reasoning for the rank order of criteria you chose in Question 4 above. What scientific knowledge supports your reasoning?

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**Question 6**

Based on the information found in **Reading 2: Types of Biotechnology**, your list of prioritized criteria, and thinking about the strengths and weaknesses of each solution, which do you think is the optimal solution? Check the solution you think is optimal.

- ☐ Vector-Mediated Gene Therapy
- ☐ CRISPR Gene Editing

**Question 7**

In question 4 you prioritized criteria. Evaluate the solutions presented in **Reading 2: Types of Biotechnology.** Identify the solution that best meets the prioritized criteria and justify your conclusion using the evidence presented in Reading 2.

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