Institute

Inquiry Based Learning
Educational Consultants

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We hope the lesson plans add value incorporating inquiry into your classroom and they become part of your teaching arsenal.

We would appreciate feedback. We would also appreciate a $20 contribution which helps us maintain the website so we can continue distributing these lesson plans to other educators.

Mail your feedback and contribution to:
IBL Institute
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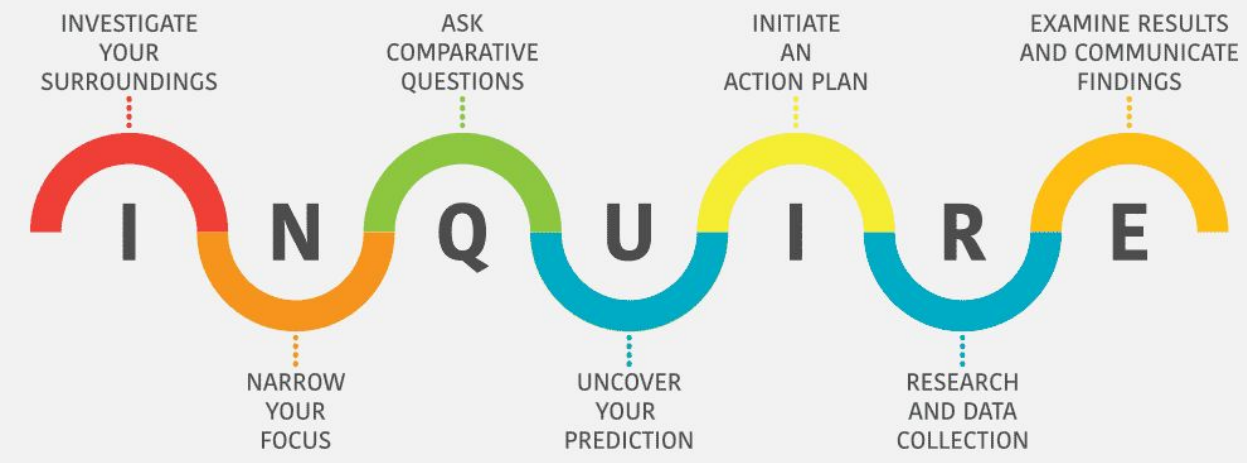
Exploring Bridge Formations

An inquiry-based lesson plan designed to promote critical thinking by integrating content with traditional and inquiry-based learning.



All Hands-On Learning is NOT Inquiry-Based Learning

Inquiry based learning is process-oriented and does not focus on a single correct answer, but rather emphasizes the process of gathering information and forming a conclusion. Traditional hands-on learning tends to be product-oriented and has students follow a pre-planned procedure to come to a single, specified answer.

Key Terms

Process Skills (PS)

Skills that students will engage in while thinking critically. These include observing, questioning, predicting, planning, investigating, interpreting, and communicating. These skills are found in each step of the inquiry process.

Investigating Surroundings

Observing the overall surroundings. What do I see? What is understood about the topic? What still needs to be understood?

Narrowing Focus

Observing student needs and interests, as well as academic content. Find the balance between natural curiosity and standards-based concepts. What area can be concentrated on to best promote growth and learning?

Questioning

Forming questions about what is not fully understood. Comparative questions can be investigated. They need to be able to lead into an action plan. What can be found out?

Uncover Prediction

Logically thinking to form a prediction about what could happen. What do I expect to happen based on my experiences and knowledge?

Initiate Plan

Figure out the action plan. Design an experiment which will answer the comparative question. What can I do to answer this question? How can I find this out?

Research and Collect Data

Investigating the elements of the experiment. Researching and collecting data that applies to the action plan.

Examine Results

Interpreting the data collected. What does this data mean? What else do I want to find out?

Communicating

Communicating the information that was found to someone else. The way the data is presented. What will the audience want to know? What will the audience be able to understand about this?

Table of Contents

Overview

This is an inquiry-based learning lesson in which students learn about different bridge formations. Students will be engaged in hands-on activities to build their own bridges to answer a comparative question regarding which bridge formations are able to support the most weight. They will analyze their findings and present to the class. The project will link IBL with traditional teaching by giving teachers options to best suit the class needs. More questions will emerge to continue scientific investigations and further the learning process.

Practical Application

This experiment allows students to understand bridge formations as well as the mechanics of how bridges support weight. Each student will have practice with the scientific process, including documenting and interpreting data.

Lesson Plan

Grade Level: 3rd- 5th

Class:

Teacher:

Time Required/Duration: 3- 45 minute class periods

Objectives

1. Incorporate the process of inquiry-based learning into a traditional direct instruction classroom setting.
2. Students will be able to use multiple means to find answers to their questions, including but not limited to participating in the inquiry experience, reading information from primary and secondary sources, watching videos, and talking with more knowledgeable individuals in their community.
3. Students will be able to identify different types of bridges.
4. Students will be able to build different types of bridges
5. Students will be able to present scientific data as well as journal their process.
6. Students will be able to collect data answering their comparative questions.
7. Students will be able to uncover additional questions and think critically about the data found.

Educational Standards

<u>Scientific Inquiry, Practices and Applications</u>

- Apply knowledge of science content to real-world challenges.
- Plan and conduct simple scientific investigations using appropriate safety techniques based on explorations, observations and questions.
- Employ simple equipment and tools to gather data and extend the senses.
- Use data and mathematical thinking to construct reasonable explanations.
- Communicate with others about investigations and data.
- The world is discovered through exploration.
- Exploration leads to observation. Observation leads to questions.

3.SS.HS.6
4.SS.HS.12
5.SS.HS.7

Materials

Needed:

1. Pennies
2. Rulers
3. Tape
4. Scissors
5. Paperclips

IBL Institute Provided at No Charge (Shipping and handling fees will apply):

1. Toothpicks
2. Pipe cleaners
3. Popsicle Sticks
4. Straws
5. Dried spaghetti
6. Mini marshmallows
7. Styrofoam cups

To order the IBL Institute provided supplies, please contact Jessica Begonia at 419-223-1362 with how many students and groups you will have in your classroom. Supplies will be scheduled for delivery two days before the experiment starts.

Vocabulary

Comparative Questions	Span
Prediction	Supports
Observe	Compression
Action Plan	Tension
Communicate Findings	Columns

Instructional Plan

Day 1

1. Lead students in a brief discussion about bridges. Why are bridges necessary? Where have they seen bridges before? What bridges are in their community?
2. Show pictures of various bridges to students and provide the background information (Appendix 3, page 18). **(Investigate surroundings)**
3. Explain to students that today they will be able to investigate how to build these various types of bridges. **(Investigate surroundings)**
4. Split the class into groups of 3 to 5 students.
5. In these groups, each student will be able to build the various bridges with toothpicks, pipe cleaners, marshmallows, and other materials to explore the differences between the designs. Each group should build at least 1 of each type of bridge.
6. Students should then observe these different bridge formations and create their own comparative question. If groups are struggling to create their comparative questions assist them in thinking about what variables to manipulate. Students may ask a comparative question such as: "What material will help support more weight _____ or _____? Or "Will a 18 inch _____ or an 18 inch _____ bridge support more weight? **(Ask Comparative Questions) (Narrow Focus)**
7. Have students discuss within their groups each of their predictions. **(Uncover Prediction)**
    a. Encourage them each to share their *own* predictions about the correlation.
8. Each group should create a plan about how they are going to proceed with investigating their comparative question. **(Initiate Action Plan)**

Day 2

1. Re-engage students in their comparative questions. Have each group share what they will be investigating today.
2. Have students work with their groups to build their bridges.
3. Once students have completed their bridges they will be able to test how much weight their bridge can hold. Groups can do this by themselves or you can have all students watch to see which bridge was the sturdiest.
    a. To measure this students can attach a styrofoam cup to the bottom of their bridge with uncoiled paper clips.
    b. Add pennies to the cup until the bridge can no longer withstand the weight.
    c. Record the amount of pennies each bridge was able to withstand. **(Research and Collect Data)**
4. Record findings in student investigation books.

Day 3

1. Students will re-engage in their comparative questions.
2. Within their groups, students will discuss which bridge was sturdier. **(Examine Results)**
3. Students will complete their post-assessment explaining the findings.
4. Students will prepare as a group what they found and present these findings to their peers. **(Communicate Findings)**
5. Have students complete Student Evaluation Sheet.

Instructional Overview

1. The teacher will introduce the topic of bridges.
2. Students will each get a copy of the background science information.
3. Groups will work together to create models of different types of bridges.
4. Groups will come up with a comparative question regarding two bridges.
5. Each group will create two bridges to answer their comparative question.
6. Groups will test their bridges and record their data.
7. Students will write in their Investigation Books.
8. Students will complete the post assessment worksheet.
9. Groups will put together a presentation of their findings for their class.
10. The teacher will administer the student feedback form.

Post-Assessment

1. Have each student answer the questions on the worksheet.
    a. Discussion about the material during this time should be encouraged, the answers should also be in their own words and what they individually think.
2. Each group will prepare an explanation to the class about their findings. It should cover the data they collected during their investigation and any other relevant information.

Background Science- Teacher Information

Key Concepts:
There are three major types of bridges:

- Beam Bridges
- Arch Bridges
- and Suspension Bridges

The major difference among them is the distance they can cross between two bridge supports (columns, towers, walls, etc). This distance is called its **span.**

The amount of distance bridges can span depends on compression and tension.

Compression is the force that acts to compress or shorten what it is acting upon.

Tension is the force that acts to expand or lengthen what it is acting upon.

Imagine a spring: if you push the coils together you compress them; if you pull the coils apart you create tension.

Both of these forces are present in all bridges. The bridge has to be able to handle compression without buckling and tension without snapping. Bridges must either dissipate (spread the force over a greater area) or transfer (move force from an area of weakness to an area of strength). Arch bridges dissipate forces and suspension bridges transfer forces.

Beam Bridge: A horizontal structure that rests on two piers (one at each end). The weight is supported by the piers as the weight travels downward. Beam bridges can span 200 ft.

Arch Bridge: Arch-shaped with abutments at each end, which connect it to the ground. The weight is put into the abutments. Arch bridges can span 800-1,000 ft.

Suspension Bridge: Suspended from cables. The cables hang from towers that are attached to caissons, which are structures that go deep in the floor of a river or lake. Suspension bridges can span 7,000 ft.

Other types of bridges include cable-stayed, cantilevered, and truss bridges.

Bridges require a lot of planning. State Departments of Transportation (State DOT) are the government departments which handle all aspects of transportation within their states. This includes planning, building, and maintaining bridges. Before building a bridge, DOT will try to predict the impact of a bridge on the environment by doing a chemical analysis and taking all things into consideration, such as the flow of the channels of water.

To find your state's DOT website, visit https://www.fhwa.dot.gov/about/webstate.cfm . Once on the state DOT website, find information about bridges by using the search bar.

Source: Lewis, Joe. "Building Model Bridges Following the Engineering Process." *Yale-New Haven Teachers Institute* <http://www.yale.edu/ynhti.curriculum/units/2001/5/01.05.04.x.html>.

Journaling

Students will document their thoughts and questions each day for the duration of this lesson. Students will be writing in their investigation books, which they will add on to each day. Writing should be done each day, that way students can document what they have learned each day and add any new questions that come to their minds. If the students already regularly engage in a journaling activity, the teacher can choose to use that method instead of the investigation book. The goal of journaling is for students to reflect on their knowledge and how it has grown, as well as to think about and record the questions they have about this topic.

About Inquiry-Based Learning As It Applies To This Lesson Plan

This is a project that works best when students work in small groups (3-5). Inquiry is collaborative in nature. The process takes advantage of students' strengths to contribute to the project. Some are great communicators, some are problem-solvers, and some have well-developed technical skills. In the workplace, we also work in groups. We work as part of a team. The inquiry process develops skills necessary to solve complex problems in the world.

Investigate your surroundings and narrow your focus: Encourage each group to think about when they see bridges. Have them get familiar with the background science of the bridges. Encourage them to ask questions about why the bridges are built that way. Have them discuss: what bridges have they seen that look similar? What do they think the best way to build a bridge is with the given materials? This is a good time for students to write down questions. We suggest having them write individual questions on individual pieces of paper so the questions can later be sorted. It's not important to sort those now, but this can be revisited once the students are more in tune with the inquiry process.

Ask comparative questions: At the heart of inquiry is the comparative question. Comparative questions are ones that can be investigated. Some questions are very good questions, but they are very difficult to investigate. For example: Why are butterflies attracted to my flower garden? Good question, but difficult to investigate. However, we can take that question and change it to: Are butterflies attracted more to red flowers or white flowers? Do you see where we are going with this? You can now design an experiment to count how many butterflies visited each of the colors and compare the results. More questions will come of this process. Do the findings hold up for different kinds of butterflies? Another experiment can be designed. In the case of bridges, the comparative question, at least somewhat, is being provided by you. This makes the lesson plan a guided inquiry. An open inquiry is one in which the students pick the topic, create the questions, create the action plan, etc. some examples of comparative questions are: What material will help support more weight _____ or _____? Or "Will a 18 inch _____ or an 18 inch _____ bridge support more weight? Later, we will revisit the questions the students asked above and have them separate those questions that can be investigated and those that cannot. Often, questions that would be difficult to investigate can be made investigable by turning them into comparative questions.

Uncover your prediction: We are not talking about group-think here. What do you individually think? Each group will be collecting data from their bridges. Will the data show that one bridge was built better than another? Each student will have a prediction and they should record that prediction. A prediction is not the same thing as a hypothesis. A hypothesis might be: All swans are white. A prediction would be: I think the next swan I see will be white. A prediction is based upon the individual's experiences, observations, opinions, knowledge, and instincts.

Initiate an action plan: The experiment has been provided. The action plan was designed to help students answer the comparative question. Students will build the bridges and logically find an answer to the comparative question. It's not one of those "do the experiment and I will let you know the right answer." There is no right answer. Ask the students to record their data on the data sheet provided. To make future lesson plans or repeats of this one more inquiry-based, simply ask them to make a data sheet and record their findings. Perhaps have half the groups use the data sheet provided and then let the other half come up with their own. Part of inquiry requires you to give up some control to allow your students to figure it out.

Examine results and communicate findings: Each group will present their findings to the class. Typically, each group would prepare a graph, data table, chart, pictures or whatever they want to communicate their findings to the class. A poster or section of white board is helpful. The group goes to the front and each member usually participates. As a group, they share the data found with the class. They share their individual predictions. They share their analysis of the measurements and how they came to their conclusion. How do they answer the comparative question? What did they learn from the experience? Classmates then have an opportunity to ask questions to the presenting group.

Student/Teacher Roles for Each Step:

Investigate your surroundings:	The students are doing this
Narrow your focus:	The students are doing this
Ask comparative question:	The teacher and students are doing this
Uncover your prediction:	Each student is doing this
Initiate an action plan:	The teacher and the students are doing this
Research and data collection:	The students are doing this*
Examine results and communicate findings:	The students are doing this

*You may use the data sheet provided or the student may create their own

Group Procedures

Day 1:

1. In your group, work on trying to build each of the three major types of bridges we are looking at.
    - ❏ Arch Bridge
    - ❏ Beam Bridge
    - ❏ Suspension Bridge

2. If you struggle, keep trying, ask someone in your group, or read the background science for help.
3. After your bridges are built, think about what comparative question you could create.
4. Synergize with your group to create a comparative question.
5. Write your own prediction.
6. Create an action plan as a group.

Day 2

1. Synergize to create your bridges. Make sure they are as sturdy as possible.
2. Test how much weight your bridges can hold!
    a. Attach a cup to your bridge using bent paper clips.
    b. Add pennies to the cup until it can't hold any more.
    c. Count how many pennies the bridge was able to support.
3. Record your findings.

Day 3

1. Discuss which bridge was sturdier. How do you know this?
2. Work on writing your findings neatly on your post-assessment.
3. As a group discuss what information is important to share.
4. Decide what you will say to the class.
5. Practice what each person will say during the presentation.
6. Present your findings to the class.

Extensions

To extend this lesson, students can explore different bridges in your city, county, or state.

1. Identify the different types of bridges explored.
    a. Students can think of the bridges they see in their communities in their everyday lives, and/or can research bridges in the area on computers. While they do this, encourage them to think about how their life would be different if these bridges were not there, and the importance of having safe bridges.
    b. Using the background science (page 18) or online research, students should identify which type of bridge they found. They can use pictures to compare the bridges.
2. Build a model of the bridge from your area and complete the extension worksheet (Appendix 5, page 29).
    a. Use what was learned about bridges from the lesson to make the model in the best way. Think about what did not work out before and try to make changes that would make the best model possible.
    b. Think about how this model is different from the previous models. How is it different? Why?
3. Have a class discussion about the impact that bridges have on the area.
    a. Have students think about a bridge in the area, or one they have seen often.
    b. Have students share with a partner how life would have been for people before that bridge was built. What changed?
    c. Now, have them share how they think life for the animals and plants was before the bridge was built. What changed?
    d. Students can research the impact of bridges on the environment and record their findings.
4. Search online for your state's department of transportation bridge plan checklist (there may be several different checklists, look for a list that has m
    a. Provide this checklist to the students, reading through some of them (this is typically a long list, if possible, go through the list beforehand and select several of the items that will be relevant to the class and their understanding).
    b. Have the students choose a couple of the items to investigate.
    c. Have students think through why that item would be important to make sure the bridge has. Students will make a list of these reasons, comparing the different contents of the list and discussing why they are similar and how they are different.

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Word Wall: Bridges

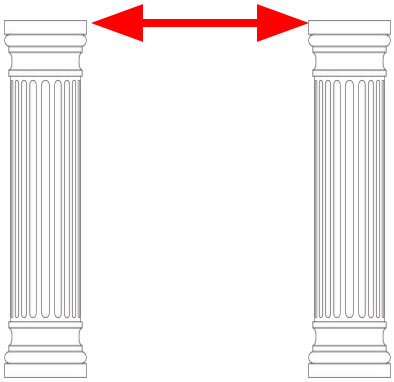
Comparative Questions- questions we can investigate

Prediction- what you think before you investigate

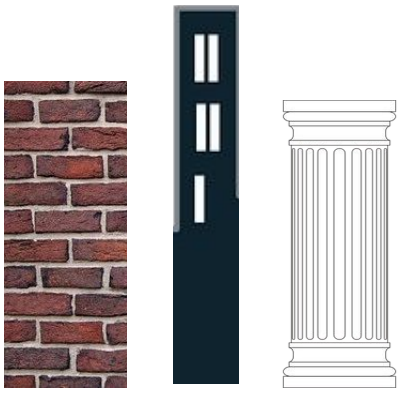
Observe- to watch carefully and notice important details

Action Plan- the steps you will take during your investigation

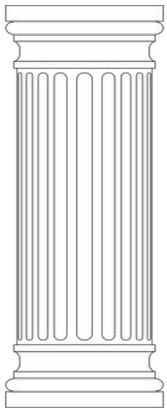
Communicate Findings- explaining what you found to your peers



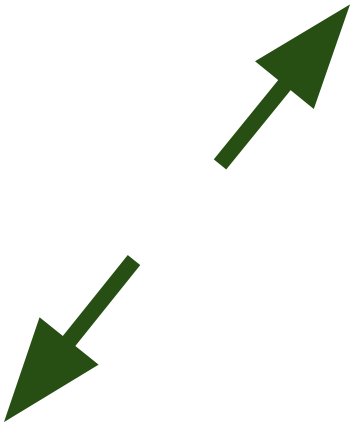
Span- the distance between two bridge supports



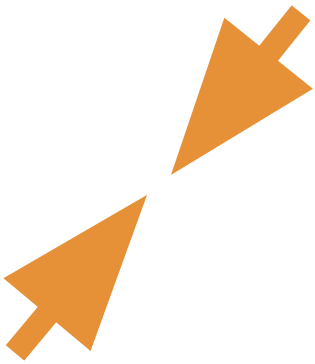
Supports- holds the bridge up, such as walls, columns, and towers



Columns- an upright pillar that often holds up a bridge

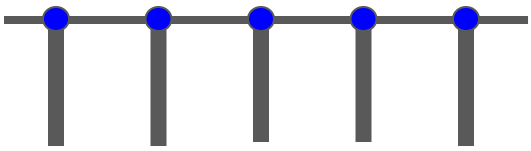


Tension- force that expands or lengthens what it is acting upon

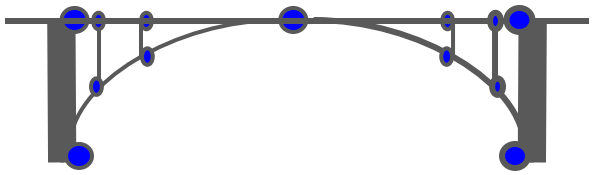


Compression-force that compresses or shortens what it is acting upon

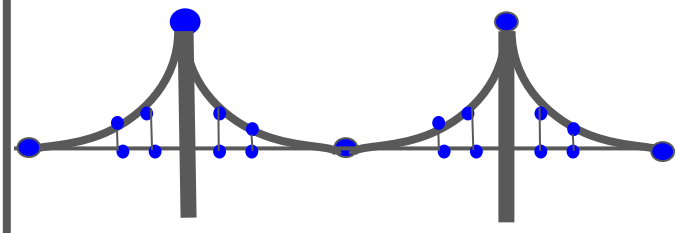
Background Science



Beam bridges are the simplest type of bridge. This often means they are used for short distances. Beam bridges are often supported by columns.



Arch bridges have been used for centuries. They originally were made with rocks and stones. The arch helps support the weight as it passes over the bridge.



Suspension bridges are used to span large distances. The deck (or road) is suspended by cables. This means that the columns must be very strong.

Investigation Book

Investigator: _____

KWL Chart
Bridges

K Things I Know	• • •
W Things I Wonder	• • •
L Things I Learned	• • •

Things I Want to Investigate

The factors I am investigating are:

My comparative question is:

I think that :

Bridge #1

Type of Bridge: _____ **Length:** _____

Materials Used: _____

Amount of Weight Held: _____

Bridge #2

Type of Bridge: _____ **Length:** _____

Materials Used: _____

Amount of Weight Held: _____

What made you excited about today's lesson?

What is one thing you learned about today?

My findings:

What I am taking away from this inquiry:

Vocabulary

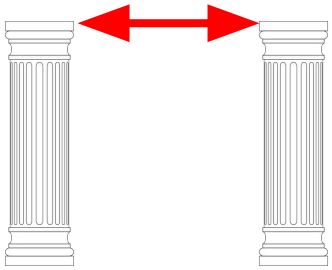
Comparative Questions- questions we can investigate

Prediction- what you think before you investigate

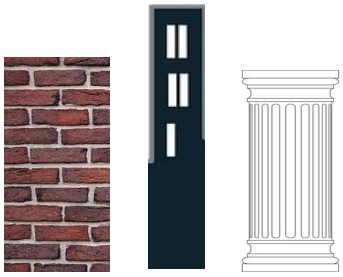
Observe- to watch carefully and notice important details

Action Plan- the steps you will take during your investigation

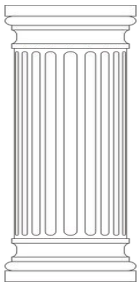
Communicate Findings- explaining what you found to your peers



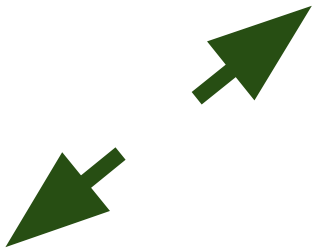
Span- the distance between two bridge supports



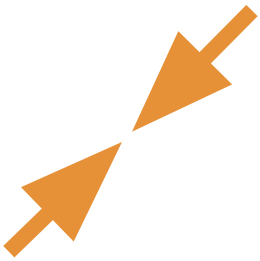
Supports- holds the bridge up, such as walls, columns, and towers



Columns- an upright pillar that often holds up a bridge



Tension- force that expands or lengthens what it is acting upon



Compression- force that compresses or shortens what it is acting upon

Name: _____

What was your comparative question?

_____

_____

State important information about your bridges.

Bridge #1

_____

_____

Bridge #2

_____

_____

What were your results?

_____

_____

Thinking about bridges, what would you like to investigate further?

_____

_____

Extension Worksheet

Name: _____

What bridge are you modeling after?

_____

What type of bridge is it?

_____

_____

How is it different from the bridges you already built?

_____

_____

Draw a picture of your bridge after making it.

Appendix 7 - Student Feedback

1. Did your bridges turn out how you had expected? Why or why not?

2. What did you learn from this?

3. What additional questions come to mind after having done the experiment?

4. Was it fun and/or interesting?

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Appendix 8 - Teacher Feedback

1. What evidence suggests students grasped the major themes of the experiment?

2. Do you anticipate other guided or open inquiry projects arising from this project? What questions did the students ask that suggest understanding and interest in the subject?

3. To what extent did this project fit into your curriculum and teaching agenda?

4. Would you consider doing this again?

5. What would improve this experience?

Please return completed surveys to
jessica.begonia@alloway.com