



OVERVIEW

[How Science Works](#) is a flexible tool that allows students to observe and map the often-nonlinear processes of scientific investigations. This Click & Learn can be used to analyze text or film-based resources, as well as student-driven inquiry projects. This document suggests a possible implementation strategy including reflection, sharing, and engaging with science media, to complement BioInteractive's [Scientists at Work](#) videos. An example of a product created by this Click & Learn for [The Effects of Fungicides on Bumble Bee Colonies](#) video is available from the "Downloads" box on the [How Science Works](#) resource page. This strategy can be easily adapted for any of BioInteractive's other films that include transcripts.

Additional information related to pedagogy and implementation can be found on [this resource's webpage](#), including suggested audience, estimated time, and curriculum connections.

KEY CONCEPTS

- Testing ideas is at the heart of the process of science, but many other activities and events, such as identifying a societal need, sharing ideas, and getting feedback from colleagues, also contribute to scientific progress.
- Science is a human endeavor that relies on individual researchers and the larger scientific community.
- Science both is shaped by and shapes the broader community in which it is embedded.
- Because the process of science is shaped by people and events, it often takes a more winding path than is typically portrayed in journal articles or most science media.

STUDENT LEARNING TARGETS

- Reflect on the process of science and how it can follow a winding path shaped by a unique combination of people and events.
- Analyze the chronology of a scientific investigation and identify the steps in the process that was used.
- Practice written and visual communication skills.

PRIOR KNOWLEDGE

Students will likely be familiar with concepts related to the nature and process of science, such as collecting and analyzing data. This activity builds on this knowledge to provide a fuller description of how science works.

MATERIALS

- access to the [How Science Works](#) Click & Learn
- transcripts for [Scientists at Work](#) videos (can be downloaded from the "Materials" box on video webpages)
- color-coded cards of the science activities and practices from the *How Science Works* flowchart, which are provided at the end of this document (optional; the cards can be provided as a list or projected to the class if preferred)
- whiteboards or sheets of paper
- colored pencils or highlighters (colors should match those of the activities cards: red/pink, green, blue, and purple)

PROCEDURE

1. Ask students to diagram their understanding of the process of science on a sheet of paper or whiteboard. They can work as individuals or in pairs.
2. Have students present their diagrams to another student (or group). They can then add elements to their work inspired by what they learned from their colleagues.

3. Provide students with the science activities cards, which they should use to revise or elaborate on their diagrams. Indicate that the colors refer to different domains of the scientific endeavor (red/pink for *Exploration & Discovery*, green for *Testing Ideas*, blue for *Benefits & Outcomes*, and purple for *Community Analysis & Feedback*).
 - *Alternative to cards:* Write or project the activities on a whiteboard and discuss where they may fit on student diagrams.
4. Show a Scientists at Work video from the BioInteractive website. Explain that the video is about scientists investigating a question. While the video is playing, students should listen for words that are similar to those on the activities cards.
 - *Alternative to cards:* Write or project the activities on a whiteboard. While watching the Scientists at Work video, students place a check mark next to activities heard or seen in the video.
5. Distribute a copy of the video transcript to each student or pair of students, along with colored pencils or highlighters that correspond to the domains in the *How Science Works* Click & Learn (again, red/pink for *Exploration & Discovery*, green for *Testing Ideas*, blue for *Benefits & Outcomes*, and purple for *Community Analysis & Feedback*).
6. Ask students to use the corresponding colors to underline activities from each domain in the video transcript. Students should find that all four domains are represented, although probably not equally. Students may identify or categorize activities differently from their peers.
7. Explain that, although science is typically taught as the scientific method/experimental design only, many more activities are involved in scientific discovery. These activities relate to how ideas for research come about, how they are evaluated by scientists, and how the results influence society. The steps feed into one another in an often-nonlinear fashion. Understanding the full richness of the scientific process is the goal of today's activity.
8. Introduce the *How Science Works* Click & Learn that the students will use to document the process of science.
 - a. Explain that the Click & Learn allows us to be "Monday morning quarterbacks." That is, we can use hindsight to analyze the activities that scientists used to investigate a topic.
 - b. After the introduction in the Click & Learn, students will see an interactive version of the *How Science Works* flowchart with text bubbles containing descriptions of activities that are part of the nature and process of science. Students can click on each bubble to create a sequence that matches the process of science in the video they are analyzing. As they build the sequence, each step is added to a list on the left side of the screen. In this list are text boxes where students can explain what happened during each of the scientists' activities. The list can be reordered by clicking and dragging on individual items. When their analysis is done, students can export their work as a PowerPoint.
 - c. The Click & Learn offers two versions of the *How Science Works* flowchart that can be used depending on the students' background. The "Detailed" framework is recommended for students in high school and college, while the "Basic" framework is recommended for students in middle school. Note that the "Basic" model has fewer components and more accessible language, but the "Detailed" model offers details that are more descriptive of the processes explored in BioInteractive videos.
 - d. Students can work through the Click & Learn individually, in groups, or with the whole class. In the last option, the teacher goes through the activity in front of the class, provides examples at each step, answers questions, and checks for understanding.
9. Have students use the Click & Learn to map the process of science depicted in the video.
 - a. Students may review the introduction at their own pace or skip it to start building their own customized flow chart.
 - b. Students should use their color-coded Scientists at Work transcript to decide which science activities, and in what sequence, to include in their map of the scientific process.
 - c. Using the transcript, students should write a detailed description of each activity in the pop-up panels in the list on the left side of the screen. Each panel provides space for typing text and adding attachments. (Click the down arrow in the top-right corner of the panel to expand it.)

- d. Students can save their work to a local computer or Google Drive via the menu (icon with three horizontal bars) in the top-right corner of the Click & Learn. The files can be reopened from this same menu for additional revision.
 - e. Students should use the menu to export their completed analysis as a PowerPoint, which can then be projected or printed.
10. Have students evaluate and reflect on their learning.
- a. By comparing the models from different PowerPoints, students can discuss why they might not have exactly the same results.
 - b. Have students write reflections on the importance of the different domains and their interconnectedness. Appropriate prompts may vary depending on the video selected, but suggested prompts include:
 - Which science activities seemed most helpful in pushing the investigation forward?
 - Which activities surprised you?
 - Describe the importance of testing to the process of science. How is this reflected in the *How Science Works* diagram?
 - Can you imagine a scientific investigation that doesn't involve testing ideas?
 - Will investigations always start in the *Exploration & Discovery* domain? Why or why not?
 - What is the importance of community in scientific research?
 - Did the video include any examples of how scientific research influences society or how scientific research is influenced by societal needs and culture? If so, describe them.

OPTIONAL EXTENSIONS

Students can use the *How Science Works* Click & Learn to think about the variation in how the scientific process proceeds. The Click & Learn can help students document a story about a scientific discovery, explain why researchers came to pursue their question(s) of interest, and what happened as a result of their findings. These crucial steps are often omitted from stories of science but are captured in the *How Science Works* framework.

Many learning activities, some of which are suggested below, could be supported by this Click & Learn using procedures similar to the one described above.

- Students designing and conducting their own research project can use the Click & Learn to document their process of discovery or reflect upon their process at the end of their study. They can use the resulting PowerPoint to present their work to the class.
- Students can dissect a scientific discovery described in a newspaper article, a chapter in a popular science book, or a popular science article (e.g., from *Scientific American*).
- Students can analyze or review a scientific case study taught in class (for example, those obtained from the [National Center for Case Study Teaching in Science](#) collection or the ["Science in Action" stories](#) from the *Understanding Science* website).
- Students writing their own scientific case study can use the Click & Learn to guide their thinking. Students would begin by researching a scientific discovery and logging their findings in the Click & Learn. They could then write their case study by using the Click & Learn to select the steps used during the investigation.
- College students can analyze the contents of a scientific paper, observing that most of the steps in the paper are probably from the *Testing Ideas* domain. The class can discuss why this is the case, and what is gained or lost by omitting steps from the other domains.

CREDITS

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Cards for “Detailed” framework:

Curiosity	Develop hypothesis	Develop technology
Practical problem	Expected results/observations	Inform policy
Exploring the literature	Actual results/observations	Address societal issues
Making observations	Supports hypothesis	Build knowledge
Personal motivation	Opposes hypothesis	Satisfy curiosity
Finding inspiration	Inspire revised/new hypothesis	Solve everyday problems
Sharing data and ideas	Inspire revised assumptions	
New technology	Gathering data	Discussion with colleagues
Asking questions	Interpreting data	Publication
New observation or idea	Replication	Theory building
Serendipity	Feedback and peer review	Coming up with new questions/ideas

Cards for “Basic” framework:

Curiosity	Coming up with an explanation	Learn more
Practical problem	Gathering data	Answer questions
Making observations	Interpreting observations	Satisfy curiosity
Sharing data and ideas	Revising what I thought after more observations	Solve everyday problems
Reading about scientific discoveries	Repeating the investigation	Coming up with new questions/ideas
Asking questions	Feedback and peer review	Listening to classmates
New observation or idea	Pure chance	Discussion with classmates