Lesson 1: Scientific Consensus

Phenomena:

Scientists reach consensus through rigorous analysis of data.

Introduction:

In science, it's all about the data. The data tells the story, and conclusions are constrained by the careful scientific analysis of data. When scientists reach consensus about conclusions drawn from data, it is the result of years of exploration, analysis, and argument. Scientists are skeptical by nature. They don't simply accept initial results and conclusions. They challenge each other's methods and logic. They propose additional experiments and analyses. And, most importantly, they repeat experiments numerous times to make sure the data is consistent and analyses are thorough.

Scientists argue about methods and conclusions, but they don't debate. They do not stake out positions and argue that they are right. They argue about whether methods are adequate and appropriate. They argue about assumptions and conclusions. Ultimately, their arguments lead to clarity about what the data collected through experimentation shows. Consensus is agreement that the data is complete and the conclusions are incontrovertible.

This lesson is different from the four that follow it. The phenomena is not like most science lessons, and the learning objectives are more focused on skills than knowledge. This is a lesson about how science works, but while there are many lessons that teach the scientific method, this one teaches students how the science enterprise works, not individual scientists.

This lesson is also different in how it achieves its learning objectives. Through the process of interpreting real data and forming conclusions, students will construct their own understanding of what the data shows. This will inoculate them against misconceptions and misinformation. Even though the lesson will expose a misconception at the end, it is very important that the students are not told that the purpose of the lesson is to address the misconception. They must construct their own understanding of what the data tells them on their own first.

Be a Guide on the Side:

Your job as the teacher of this lesson is to guide students through the process of analyzing data and forming logical conclusions. We will provide you with the questions you can ask the students as they work in groups that will lead them to asking the right questions themselves. Remember, the goal is for the students to construct their own understanding, so it's important that they be guided to ask questions, not given answers.

Your students will examine different lines of evidence and form conclusions based on their analysis of data. Students will work in groups to analyze their data, and then prepare statements summarizing their conclusions and connecting them to their data. The students will then communicate their conclusions and their arguments supporting their conclusions with the class.

After group presentations, students will compare the conclusions drawn from different lines of evidence to form a class consensus. Once students can see that consensus is built by agreement about data and not debate about opposing sides, they will compare their consensus with that of the IPCC and other studies showing that 97% of climate scientists agree on the human impacts on climate change.

At this point, you will introduce the misconception that scientists disagree about the causes of climate change. This provides the opportunity to close the lesson and assess students' abilities to apply the lesson to new situations. In this last part of the lesson, students will then learn techniques used to cast doubt on climate change, and will practice spotting fallacies in misinformation examples. By comparing their process with that of real scientists, they will be able to recognize how misinformation can produce misconceptions, and they can practice identifying misconceptions using the FLICC method.

As a result of this lesson, students will learn that agreement on human-caused global warming increases with expertise, and that among the top experts—climate scientists—there's 97% agreement that humans are causing global warming. Students will be introduced to the five characteristics of science denial. Students will practice identifying denialist techniques in misleading arguments.

Lesson Outline:

Age Level	This lesson is designed for 9th grade. The lesson can easily be adapted for 5th grade and middle school applications, as well as for AP Bio, and Environmental Science applications. These adaptations will be provided in a separate supplementary document.
Time Needed	This lesson is designed to be taught in one 60-minute class period. The lesson can also be extended over multiple class periods by extending the amount of time spent on data analysis, classroom discussion, and/or the FLICC component. Descriptions of these extension opportunities will be provided in the supplementary document.
Vocabulary	**Data/Evidence (scientific):** information obtained from testing hypotheses through controlled experiments. Data may include statistical, descriptive, and other observational evidence. **Scientific consensus:** overwhelming agreement among experts in a field. **Anthropogenic global warming:** Global warming that is caused by human activity. **Science denial:** Rejection of scientific evidence. **FLICC:** The five characteristics of science denial (Fake experts, Logical fallacies, Impossible expectations, Cherry picking, Conspiracy theories).
CLEAN resources (CLEAN is the Climate Literacy and Energy	Tracking temperature (anomalies) - ● https://cleanet.org/resources/43157.html ● https://cleanet.org/resources/42837.html ● Google Earth https://cleanet.org/resources/43393.html ● Signs of Change (studying tree rings) - https://cleanet.org/resources/41807.html

Awareness Network – a collection of digital resources for teaching about climate change)	Charting Temperature Changes (paleoclimate history) - ● Greenland Ice Sheet Project - https://cleanet.org/resources/43452.html ● Sediment cores - https://cleanet.org/resources/43162.html ● Ice cores - https://cleanet.org/resources/42848.html ● From Isotopes to Temperature (from coral records) - https://cleanet.org/resources/42748.html ● Climate Modelling 101 - https://cleanet.org/resources/46256.html ● NASA Global Time Machine - https://climate.nasa.gov/interactives/climate-time-machine
Disciplinary Core Ideas	● HS-ESS2.D1: The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. ● HS-ESS2.D3: Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate. ● HS-ESS2.D4: Current models predict that, although future regional climate changes will be complex and varied, average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.
Performance Expectations	● HS-ESS2-4: Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. ● HS-ESS3-5: Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.
Educator Prep	● Activity sheet (Pattern 1: Upper vs lower atmosphere) ● Activity sheet (Pattern 2: Annual cycle) ● Activity sheet (Pattern 3: Daily cycle) ● Graph: Agreement vs expertise ● FLICC: Five characteristics of science denial ● Misinformation: Global Warming Petition Project Background material ● Consensus on consensus paper (Cook et al. 2016) ● Denial101x video: Five characteristics of science denial ● Video: Peter Doran interview
5E	● Engage/Explore – team analysis of data – 25 minutes ● Explain – team presentations and class discussion – 20 minutes ● Extend/Evaluate – 15 minutes
Fact	Based on independent lines of evidence, a scientific consensus has formed

	that humans are causing global warming.
Myth	31,000 dissenting scientists prove there's no scientific consensus agreement on human-caused global warming.
Fallacy	**Fake experts:** people who convey the impression of expertise but with no relevant expertise are often used to cast doubt on expert consensus.

Engage

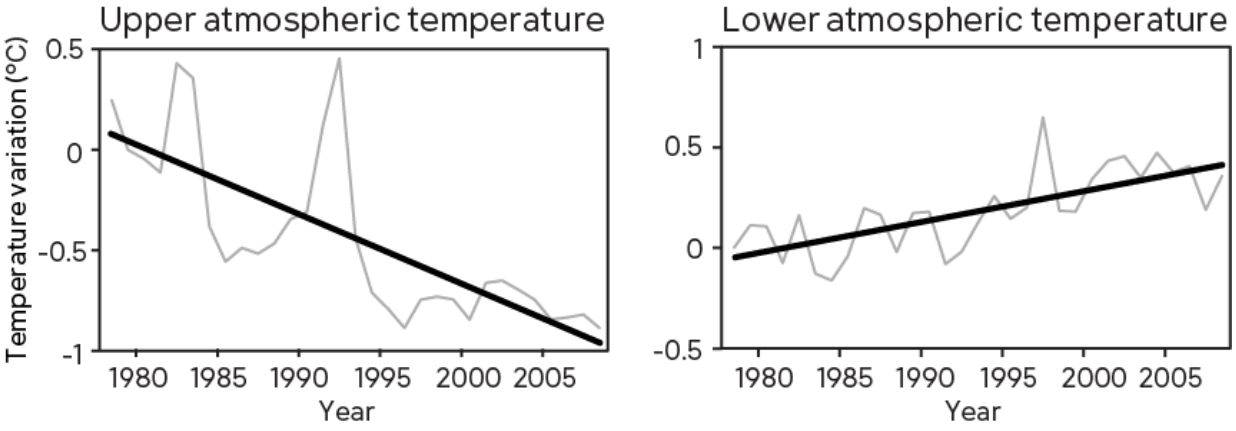
In this lesson, exploration of data is the engagement activity. Students should be formed into teams and told that they are going to analyze data to look for trends that they can report to the class.

Explore

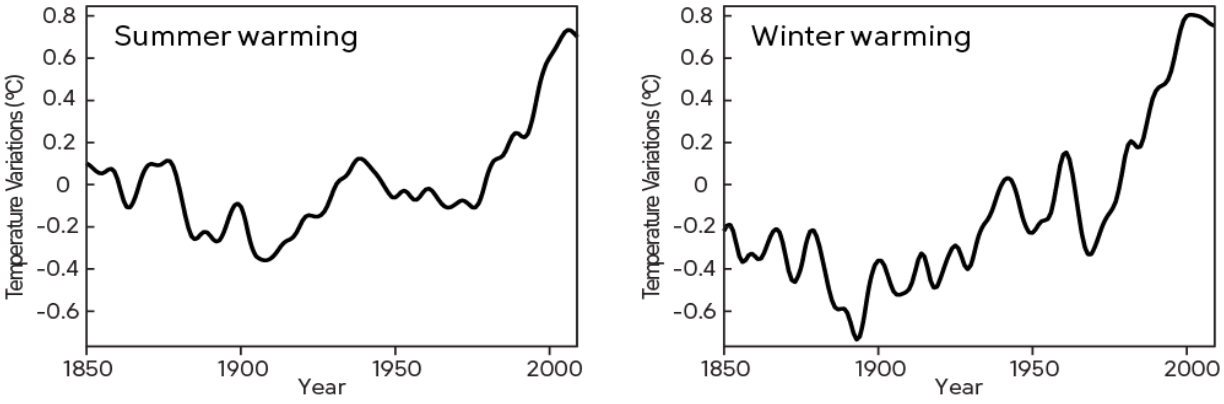
This part of the lesson should take **30-45 minutes**. You should allocate **20-25 minutes** for the first part of the lesson where students are working with their data, and another **15-20 minutes** for student presentations*.

Form your students into three to six groups. Assign each group to one of the sets of data below. If you have more than three groups, assign more than one group to each data set. Form groups as learning teams, not friend groups. Groups should be no smaller than 4 students and no larger than 6.

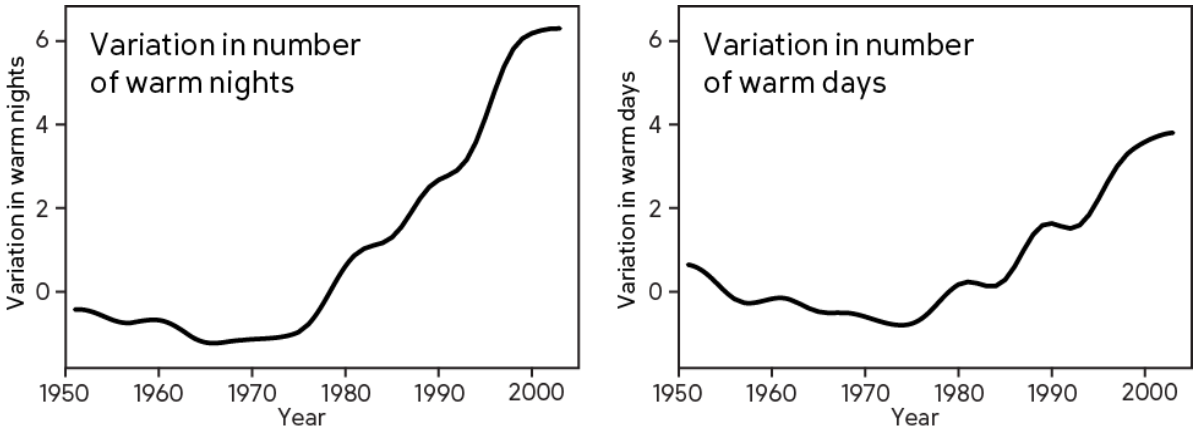
Pattern 1: Upper vs lower atmosphere



Pattern 2: Annual cycle



Pattern 3: Daily cycle



Tell the students that they must find at least one trend or pattern in their data. They must form various hypotheses about causes for the trend, and they must discuss their hypotheses as a group. Finally, they must come to an agreement on the hypothesis they think explains the data best. Students should spend 5-10 minutes studying the data and looking for trends. They should spend 10-15 minutes discussing hypotheses. They must also discuss how to present their hypothesis to the class and be prepared to defend their conclusions.

You may provide your students with access to various online tools to help them in their analysis. These tools will be provided in the Explain section. These tools can help the students identify what is driving the pattern they observe in their data.

Each group then presents to the class their conclusion, explaining why the climate driver should result in the observed data. The purpose of this activity is for students to *independently* come to the conclusion from diverse lines of evidence that observed climate patterns are consistent with

human causation and rule out other natural causes–thus experiencing for themselves the process of forming a scientific consensus.

*Have students share their group conclusions with the class. This portion of the lesson should take **15-20 minutes**.

Guidelines for students

What are your major conclusions? List three conclusions you can draw from this data. Identify any trends you see and suggest causes for the trends. Your conclusions should be specific and supported by the evidence you see. Do not speculate about what you cannot infer directly from the data.

1.
2.
3.

Now, describe how your conclusions are supported by the data. How strong are the trends seen in your data? How do your conclusions correspond to trends seen in your data? Do you see a strong connection between the trends observed and the causes suggested by your conclusions?

How confident are you in your conclusions? Rate your confidence using this scale:

1. Very confident. The data clearly supports my conclusions.
2. Somewhat confident. The data supports my conclusions, but I think the data may not tell the whole story.
3. Not confident. The data is weak and does not show clear trends.
4. Not confident. The data is incomplete, misleading, and/or is from an unreliable source.

Explain

As the teacher, you should know the following explanations for each pattern. As the students are studying their data, you should move through the groups and listen for key ideas to emerge. Be prepared to ask the students questions that will lead them to consider the elements of these explanations.

Pattern 1 accompanying explanation: Different climate drivers result in different patterns in our climate system. For example, two of the most common drivers of climate change are solar activity and greenhouse gases, but both result in different climate patterns. When solar activity increases, it has a warming effect across all of the atmosphere. This means that the upper atmosphere and the lower atmosphere should both show a warming trend if the sun is the main cause of global warming. In contrast, greenhouse gases like carbon dioxide are heat-trapping gases that trap heat in the lower atmosphere. Greenhouse gases trap and re-emit infrared heat in all directions. In the upper atmosphere, much closer to space, any extra heat emitted by greenhouse gases that goes in an upwards direction can escape to space. The extra greenhouse gases make the upper atmosphere better at losing heat. This means that if

greenhouse warming is the main cause of global warming, we should expect to see the upper atmosphere cool at the same time that the lower atmosphere warms.

Pattern 2 accompanying explanation: Different climate drivers result in different patterns in our climate system. For example, two of the most common drivers of climate change are solar activity and greenhouse gases, but both result in different climate patterns. When solar activity increases, it warms the Earth. The warming should be stronger during the summer when more sunlight is hitting the Earth's surface. That means if the sun was the main cause of global warming, we would expect to see summers warming faster than winters. In contrast, warming from greenhouse gases should show a different pattern. During winter, the Earth's surface cools by radiating heat out to space. Greenhouse gases trap some of this heat, slowing the winter cooling. An increased greenhouse effect means less winter cooling. If greenhouse gases are causing warming, we expect to see winters warming faster than summers.

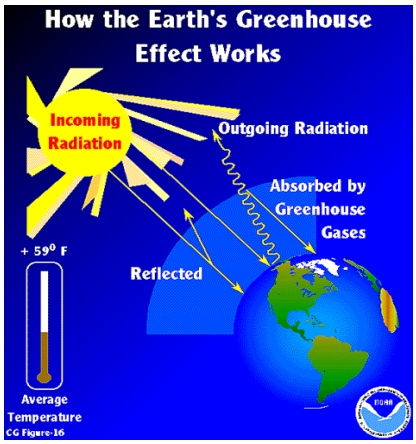
Pattern 3 accompanying explanation: Different climate drivers result in different patterns in our climate system. For example, two of the most common drivers of climate change are solar activity and greenhouse gases, but both result in different climate patterns. When solar activity increases, it warms the Earth. The warming should be stronger during the day when sunlight is hitting the Earth's surface. That means that if the sun was the main cause of global warming, we would expect to see days warming faster than nights. In contrast, warming from greenhouse gases should show a different pattern. At night, the Earth's surface cools by radiating heat out to space. Greenhouse gases trap some of this heat, slowing the night cooling. An increased greenhouse effect means less nighttime cooling. If greenhouse gases are causing warming, we expect to see nights warming faster than days.

Possible questions to ask your students:

- How can the sun impact Earth's average global temperature?
- How can Greenhouse Gases impact Earth's average global temperature?
- Why is the troposphere warmer than the stratosphere?
- Are the troposphere and stratosphere composed of the same gases? Are there the same amounts of each gas in each layer?
- Why does each layer cool at night?
- Why are summer days and nights warmer than winter days and nights? Do you think the stratosphere has seasonal variations too?
- What happens where the troposphere and stratosphere meet? Why are the layers so distinct?

Best match- choosing the climate driver

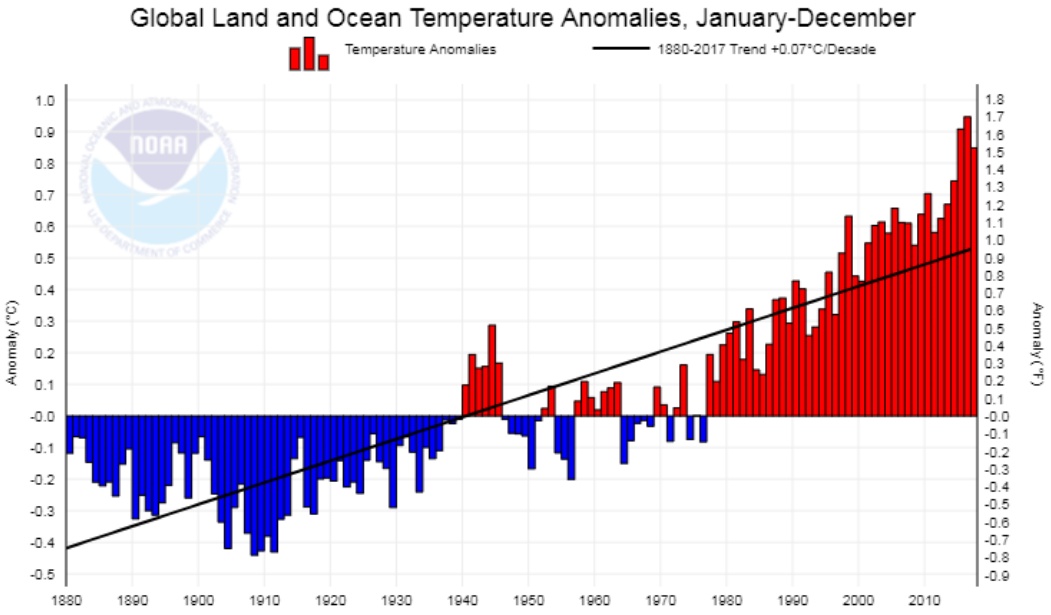
Solar Activity and Greenhouse Gases are considered **climate drivers**. This means that changes in these phenomena can have an impact on climate. You may choose to give the students this diagram *(source: NOAA)*.



https://www.esrl.noaa.gov/gmd/outreach/lesson_plans/images/CG_Figure_16.gif

You may also choose to provide the following graph, but you should wait until they have begun their discussion and asked questions about the roles of solar activity and the greenhouse effect. Do not provide these graphs at the beginning of their discussion, but have them ready to provide once the students have identified possible climate drivers.

The graph below represents the average temperature anomaly for the global average temperature with respect to the 20th century global average temperature.
Climate at a Glance. Retrieved March 07, 2018, from



https://www.ncdc.noaa.gov/cag/global/time

Ask the students to explain what this graph means in terms of global temperatures, and what forces they think could be causing this trend.

Extend

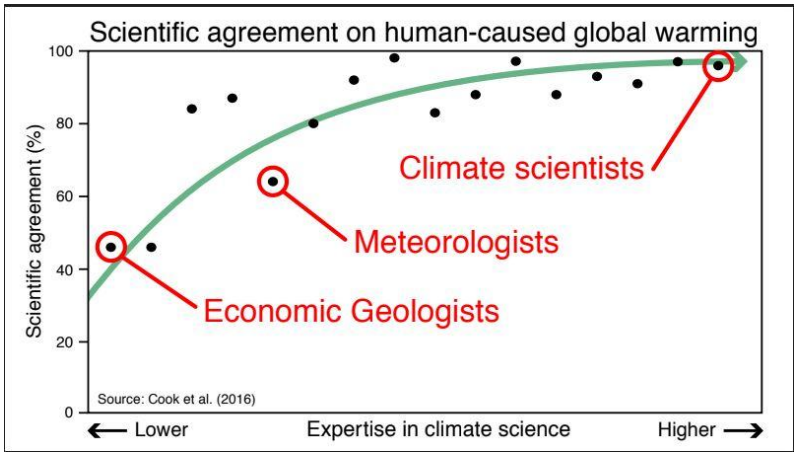
After the students have reported their conclusions, explain how evidence for human-caused global warming is based on many lines of evidence. This should be a brief summary that pulls

together what the students have reported and what you overheard during their discussions. The purpose of this summary is to transition the students into the FLICC activity that will extend their learning and also serve as the evaluation/assessment activity.

This should take no more than **5 minutes**.

Introduce the 97% consensus. Based on Cook et al. (2016), explain how multiple studies find overwhelming consensus among climate experts. To lead into the topic of misinformation, explain the finding that scientific agreement grows with expertise in climate science.

Scientific consensus forms when independent lines of evidence converge on a consistent conclusion.



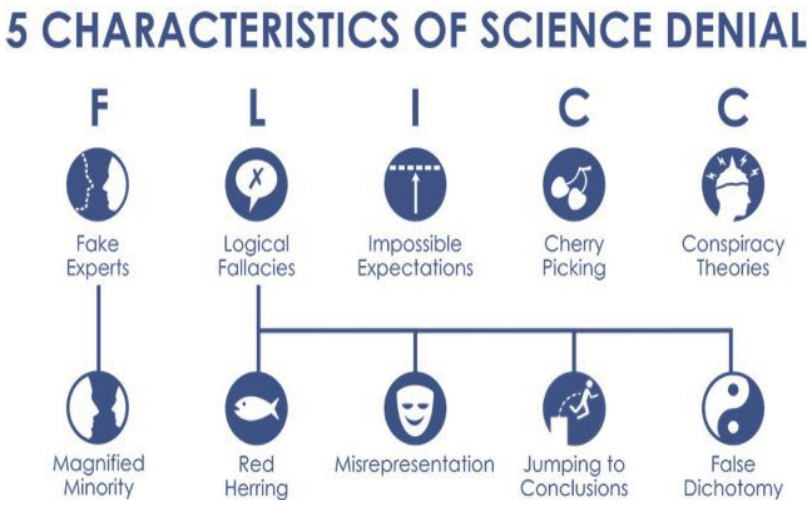
Note that understanding that highest agreement is found among the relevant experts is key to detecting the fake expert strategy later in the lesson.

Evaluate – FLICC

Introduction to FLICC

This portion of the lesson should take **10 minutes**.

Introduce the five techniques of science denial: fake experts, logical fallacies, impossible expectations, cherry picking and conspiracy theories (summarized with the acronym FLICC). Explain that you will shortly give an example of misinformation and see if the students can detect the technique used. Then explain each technique (possibly give non-climate examples).



Fallacy:	Example	The Problem
Fake expert	"Evolution is too complicated to be explained by natural selection" -Michael Behe, a biochemist	While Michael Behe is a scientist, he is not an evolutionary biologist, so his claims should not be taken as expertise.
Red herring	Timmy, upon being caught cheating during a test by his teacher, exclaimed: "I know I've made a mistake, but please, think of my parents! They'll be so disappointed."	Timmy is using an unrelated piece of information to distract his teacher from the issue at hand.
Misrepresentation ("strawman")	"How could anyone think we're descended from monkeys? Evolution is so stupid!"	Misconstruing the theory of evolution such that discrediting it seems to be a logical assumption.
Jumping to conclusions	"I've met two nice people on my vacation so far, so everyone I meet on my vacation will be nice!"	Generalizing information based on just a few occurrences.
False Dichotomy	"You're either with me or against me"	Creates only two, opposite choices when in reality the person could feel neutral or intermediate.
Impossible Expectations	"Seat belts are dumb. People still die in car crashes!"	The goal of seat belts is not to stop ALL car crashes, but to REDUCE injury when they do occur.

Cherry-picking	A politician lists all the cities where his policies decreased crime, but doesn't mention those where they increased crime.	The politician is omitting information to make his ideas and policies seem more efficient than they actually are.
Conspiracy theories	"That crop circle was made by aliens, but the government is lying to us and covering it up!"	Claiming that your assertion cannot be verified because the evidence is being hidden.

Spot the fallacy exercise

Introduce the students to a screenshot of the Global Warming Petition Project as misinformation. Clarify that the chief argument of the Petition Project is that there is *no scientific consensus* on human-caused global warming. Split the students into groups and assign them the task of resolving the conflict between the 97% consensus and the Petition Project. Can students spot the technique of denial used in the Petition Project?

Read the following statement - What does this make you think about?

> *31,000 dissenting scientists prove there's no scientific consensus agreement on human-caused global warming.*

Many parts of the statement attempt to sound important. In the chart below, reflect on what *sounds* important about the descriptor in the first column.

Write your thoughts in the second column (we will complete the third column later).

	Why does it sound important?	PROBLEMS
The number of people?		
The type of people being described?		
The claim about global warming?		

Show the source of the statement, http://www.petitionproject.org/index.php, and lead a class discussion.

Students are likely to present a range of different answers and sometimes multiple answers will have a degree of validity due to the informal nature of logical fallacies. Nevertheless, the best fit in this case is the technique of fake experts. Point out that anyone with a science degree could join the petition, and 99.9% of the signatories were not climate experts.

What are some of the problems associated with this website, their methods and findings?

Go back to the chart on the previous page and fill in the **problems** column. Explain the problems for each portion of the statement.

After examining the website, how does it employ the FAKE EXPERTS strategy to try to steer people's opinions?

Reflection questions:

How effective can a **fake expert** be if people do not study the material?

How can you identify when **fake experts** are being used by media sources?