**Title:**Investigating Climate Change Evidence

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**Abstract:***This activity uses the jigsaw method to encourage students, in groups, to become experts on different types of evidence as a means of understanding climate change. Each group focuses on a topic, highlights at least one data set within that topic, and researches the data collection process along with the potential consequences of the evidence. Students are asked to critique the evidence they investigate, using a prepared checklist, and to share the results of their research with their classmates. Finally, students evaluate the evidence behind a skeptic’s claim, and discuss the knowns and unknowns about climate change.*

 **Learning objectives:***Students will know what evidence exists for a changing climate, based on current data.*

*Students will become comfortable investigating data and critiquing available websites using their own criteria or a prepared checklist.*

*Students will know how to critique at least two common claims made by climate change skeptics, using scientific evidence.*

**Timeframe:***1 hour background on carbon cycle - optional*

*2 one- hour classroom discussions*

**List of materials:***Computers with internet availability(for use outside of class)*

*Student handouts*

**Procedure and general instructions (for instructor). REQUIRED.**
*1. Prior knowledge: Depending on student familiarity with the topic, review the general science of the carbon cycle. I spend a full class period on this, using traditional lecture, a demonstration to prove that carbon gas has mass, and a series of box model diagrams that illustrate the carbon cycle.*

*2. Day 1: Students are placed into expert groups and provided with the attached handout (see Investigating Climate Change Evidence handout). I give them time to meet in groups briefly during the first class session, and then allow one week for them to research their topic. Each group is expected to come to class with copies of printed graphs (or graphs on their laptops) to share with their classmates.*

*3. Assignment, Part 1: Students spend time outside of class researching their topic, and determining whether or not they “trust” their data set(s) using the “Is it credible” handout. This checklist reflects student generated ideas about how to decide if a scientific source is credible that was created earlier in the semester for another topic. Depending on your students, you can generate this list with them as a class activity or provide them with the handout.*

*4. Day 2 (after one week): Students spend the first 10-15 minutes in their expert groups, and I walk around to each group, checking for understanding of the key concepts and questions. Students are expected to come to class with their group’s data summaries and graphs, ready to share with others. I make sure that each member of the group has the ability to share his/her group’s graphs, either by showing the graphs from their laptops or by presenting the graphs from a printed powerpoint slide.*

*5. Day 2: Students now split into their jigsaw groups. The easiest way to do this is to ask each group to count off by the number of students in the group, so that you have one representative from each expert group in the jigsaw groups. My classes are limited to 25 students, so I have three groups of eight students, with one expert group bringing two representatives. Once students are in their jigsaw groups, they are asked to share their topic, their data set, and any questions or concerns that they have. I expect each “expert” to share their evidence for aprox. 5 minutes, and allow for other students in the group to ask clarifying questions. Usually, students vary in how long they are able to discuss their data sources – novice students tend to finish very quickly while more experience science students have no trouble talking about their data for 5 minutes. If a group is struggling, I spend more time with them, making sure that the student “expert” explains the graph in question, how the data were collected, etc. Students are encouraged to take notes of each others’ work, since this will be useful in the second part of the assignment.*

*6. Assignment, Part 2: Now that students have some familiarity with the evidence of climate change, they are asked to investigate and evaluate a climate “skeptics” website. They have to evaluate the science on the site, picking one specific claim and research the evidence behind it. For example, there is a claim that polar bear populations are actually increasing, and therefore the idea that polar bears are threatened is false. However, once students dig a bit deeper, they find out that only two of the 19 populations are not declining, and many of the populations do not have sufficient data to determine a trend (see* [*http://pbsg.npolar.no/en/status/status-table.html*](http://pbsg.npolar.no/en/status/status-table.html) *for more details on this topic). This encourages them to think a bit deeper about the scientific evidence behind a claim – it is not enough to simply read an article in the popular media. Students need to feel confident looking for additional evidence and critiquing the claims made on websites and in published articles. Students also read the article in the New Scientist, “What We Do, and What We Don’t Know About Climate Change” to help them think about the range of evidence that is available.*

*7. Day 3: Students collaborate with a partner to share their climate skeptics investigations, and discuss the scientific claim that they tried to understand in more depth. As a class, we review several of the claims and discuss what science currently knows about this topic. Some common claims that I discuss with students include:*

*- The sun is the main cause of global warming.*

*- Global temperatures aren’t really increasing – we have monitoring stations in too many urban areas, which skews the global dataset.*

*- Carbon dioxide can’t possibly be a problem, because humans breathe it out. Does that mean you want us to stop breathing?*

*I allow students to think about how they might discuss these claims with a skeptic, and which pieces of evidence they would use to explain their reasoning. I ask students to begin a list of “known” and “unknown” pieces of evidence, and to rank the evidence that we have learned as a class.*

**Procedure and general instructions (for students).**

***Investigating Climate Change Evidence Assignment***

***Part 1:*** *I have assigned each of you to become an expert in one of the following topics.  Prepare these data as directed to share with your classmates; you’ll be working in small groups and so you’ll learn about each of these topics when we meet on \_\_\_\_\_\_\_\_\_\_\_\_.  Make sure that each member of your group has a copy of your data assessment, along with copies of your graphs (either a hard copy or on a laptop). You will submit your written explanation of these data to me* ***as a group (one summary of your data per group)****. When thinking about whether you “trust” these data, you should refer to the “Is it credible” handout from earlier in the class.*

*Questions for all groups to answer in their assessment:*

1. *Summarize the graphs you are looking at in one paragraph. Explain the trend in the graph. If there are tricky vocabulary words – like “anomaly”, for example – make sure you know what they mean!*
2. *How were these data collected? Explain the process. For example, are the data you are looking at annual means? How often were data collected (daily, weekly, monthly)? Were all data collected from the same location? Are there replicates?*
3. *Who collected these data? How was the data collection funded?*
4. *Do you trust these data – why or why not?*
5. *What are some of the potential consequences for ecosystems of the evidence you reviewed?*

1.  New York Climate Record: Temperature -
    Go to: <http://www.ncdc.noaa.gov/cag/> and select 2 different locations in New York. The options should read:

Parameter: Average Temperature

Time Scale: 12-month

Month: July

Start year: 1895

End Year: 2014

State/Region: New York

Climate Division/City: YOUR CHOICE

Right click on the graphs, copy and save them into a powerpoint presentation or word document to show the class. Then, look at the graph on the Sun’s Energy : <http://www.climate.gov/news-features/understanding-climate/climate-change-incoming-sunlight> . You can’t copy and save this graph because it is an interactive graphic- but you can get a screen shot to display to your classmates. How does this graph relate to the temperature changes you saw earlier? Does the sun’s energy explain the temperature changes?

2.  Global Temperature Data -

Go to the Berkeley Earth Surface Temperature study website: <http://berkeleyearth.org/index.php> . Click on “Findings”, and you will see a link for “draft papers available here”. Look at the “Berkeley Earth Analysis of Full Data Set”. Copy and paste the two graphs on this page into a word processing document (or powerpoint). Hint: Click on Data Set to get some background about the data used in the project. This page also has a neat video showing the land temperature anomaly. Note: pay attention to who funded this – some snooping about the Koch Charitable Foundation would be useful for you.

3.  Ocean Heat Content –

 Go to <http://www.climate.gov/news-features/understanding-climate/2013-state-climate-ocean-heat-content> and look at the graph showing average global ocean heat content. You can’t copy and save this graph because it is an interactive graphic- but you can get a screen shot to display to your classmates. Then, go to <http://www.climate.gov/news-features/understanding-climate/climate-change-global-temperature> and view the global temperature anomaly record. You can’t copy and save this graph because it is an interactive graphic- but you can get a screen shot to display to your classmates. Do these data support the ocean graph? Why or why not?

4.  Global Sea Level Changes –

First, go to <http://tidesandcurrents.noaa.gov/sltrends/sltrends.shtml> and summarize where sea levels are increasing, and where they are not increasing. Then, click on 3 different states on the left and investigate the historical trends in more depth.  Right click on the graphs, copy and save them into a powerpoint presentation or word document to show the class.  Summarize your findings, explaining what they mean to the class.  Why are sea levels increasing in some places, but not in others? Focus specifically on what is happening along the Alaska coastline – there are some helpful hints in the FAQ part of the website. Checking out this website might also help for that question: <http://seagrant.uaf.edu/map/climate/docs/sea-level.php> .

5.  Sea Ice Changes –

Go to: <https://nsidc.org/data/seaice_index/> and look at the graph and the image.  View both the Arctic monthly data and the Antarctic monthly data (use the tabs up top to go between the locations).  Right click on the Monthly Sea Ice Extent Anomaly Graphs, copy and save them into a powerpoint presentation or word document to show the class.  Find out why there is a difference in the trends between the Arctic and the Antarctic – and make sure you understand the word anomaly! There is a short explanation at: <http://nsidc.org/icelights/arctic-sea-ice/> or <http://nsidc.org/arcticseaicenews/faq.html>. When do scientists expect the Arctic to be ice-free in the summer? What implications will this have for people and the larger ecosystem?

6.  Ocean Acidification –
    Go to [http://pmel.noaa.gov/co2/story/Ocean+Acidification](http://pmel.noaa.gov/co2/story/Ocean%2BAcidification) and use this page to learn about ocean acidification. Click on the graph (Hawaii Carbon Dioxide Time Series) on the right hand side of the page, and copy and paste the image. Then, go to [http://pmel.noaa.gov/co2/story/OA+Educational+Tools](http://pmel.noaa.gov/co2/story/OA%2BEducational%2BTools) and view the short video on Ocean Acidification. Explain the change over time that you observe. How is this visualization different from the graph you looked at first?

7.  Glaciers –
Go to <http://nsidc.org/glims/glaciermelt/> and view the two graphs towards the bottom of the article (Measurements of Glacier Change and Contributions to Sea Level).  Copy and paste the images, and be ready to explain them to your classmates.  How are these two graphs related? Then, go <http://nsidc.org/data/virtual_globes/> and open the “Glaciers and Climate Change” file in Google Earth. Choose two of the glaciers and look at the photo comparisons to share with your classmates (right click on the photos to copy images).  Explain how things have changed over time, and what might have caused these changes.

***Part 2:****Investigate a “Climate Skeptics” website. Choose your own or use one of the ones below (search for terms like global warming farce, hoax, fake, etc).*

1. *Climate Change 101:* [*http://www.climatechange101.ca/*](http://www.climatechange101.ca/)
2. *CO2 Science:* [*http://www.co2science.org/*](http://www.co2science.org/)

*Choose one skeptic’s claim, and determine whether the evidence behind it is accurate by researching other sources that discuss the same claim. Explain the evidence on the site you chose – realizing that there may not be graphs, but just claims. Think about the science methods that were used– how were these data collected? Are they the same data as is used in other studies, but just analyzed differently? Investigate who has done the science on your site and who has funded them, and think about whether this might have influenced the message the site is trying to convey.*

***Then,*** *read “What we do- and don’t – know about climate change” from the New Scientist (*[*http://www.newscientist.com/special/climate-knowns-unknowns*](http://www.newscientist.com/special/climate-knowns-unknowns)*). You should* ***compare the claims*** *from the Climate Skeptics’ website to the claims made in the New Scientist article. You may also want to use data that was shared by your classmates in Part 1 to help you.*

*To turn in: Write a 1-2 page summary, answering the following:*

1. *Summarize one of the claims made on the climate skeptic website.*
2. *Explain the evidence used to back up the position.*
3. *Is the argument valid? Why or why not? Compare the claim from the climate skeptics’ website with those made by the New Scientist, and give examples of where the evidence used on the website or in the article are more convincing for you. You may also use other outside resources (such as evidence from the class jigsaw activity) to help you.*
4. *Who funded the organizations and website? Do you trust what is written here, based on the organization and the funding? Why or why not?*
5. *Imagine you have to speak to someone from the website and critique the scientific arguments behind their position. Explain what you would say to this person to convince them that their science is incorrect or incomplete, using the New Scientist article AND other sources.*
6. *What else would you like to know in order to feel more confident about this topic?*

**OPTIONAL SECTIONS
A few suggested pre-assessment questions:**

1. Rate your level of agreement with the statement below by circling one of the choices that follow.

*“Climate change is happening and humans are having an effect on the earth’s climate.”*

**Circle One:** Strongly disagree Somewhat disagree

Somewhat agree Strongly agree

What do you consider to be the most important facts or evidence that support your answer?

1. Someone says to you*: “Plants take in oxygen and give off carbon dioxide.”*

**Circle one:** I agree I disagree I partly agree

Explain why you agree, disagree, or partly agree.

1. You plant a tree in a meadow and return 30 years later. Your tree has grown from a seed into a

 500-pound maple tree. Where did **most** of the **mass** of the tree come from?

 a. oxygen

 b. carbon

 c. water

 d. nutrients in the soil

 **Is it credible? Handout (optional)**

**Is it credible?**

There are differences between **evidence** and **claims**. Scientific claims will, and should, change over time as new evidence arises and different theories are debated. Scientists routinely debate and justify **claims using evidence.** Evidence is data – data can be quantitative or qualitative. You use evidence to support your claim – so you need to check into the evidence behind a claim, but you also need to think about the validity of the claim for other reasons.

**1. Here are some guidelines that could help you judge the credibility/validity of a claim in a science article.**

□ Is the claim supported by evidence? If so, see if you can evaluate the evidence using the checklist below.

□ Is this a peer-reviewed journal article, or something else?

□ Can you identify the author? Who is the author? Is the author reputable? What evidence do you have about the author? Who does the author work for (government, university, private, industry)?

□ Where is the article published? Is it a conservative, liberal, or objective source?

□ Are there other data or works cited?

□ Did multiple sources come to the same conclusion, or is this the first work stating this claim?

□ Did someone fund this work who might have a bias (ie was the work paid for by a company, organization, or interest group?)

**2. Thinking about the evidence that the claim refers to…**

□ What is the sample size?

□ Was there replication? (note: replication may not be possible in all investigations)

□ What kind of investigation was this – is it a model, an experiment, an observation, or a comparative study? *There are benefits and drawbacks to each kind of investigation.*

□ Does this study use, or reference, more than one kind of investigation? For example, does it use

 both deep sea cores and surface cores? A model and an experiment?

□ How was this study conducted? How were data collected? What can you find out about the data collection process, and does this raise any concerns for you in terms of validity or replication?

□ Are there other studies that have found similar results?

□ How long has this study been going on? Is it a one-time study, or something that is taking place continuously?

□ Does the article suggest things that we may not know, or may need to research further?

**3. Is this article credible?**

How did you decide/come to an opinion about this article? (List other guidelines that you used)

**4. When deciding on an issue, you should:**

* Read at least 5 separate studies, in peer-reviewed journals
* Look for a synthesis article either in a peer-reviewed journal or endorsed by a government or activist group
* Think about the precautionary principle – if there is the possibility of harm, we should protect the public and wait for evidence before using a product/making a decision
* Read articles in the popular press to get a sense of the major players, major issues
* Read the company’s website in question