# Science Education for Critical Thinking

**KAVLI INSTITUTE**
**of Nanoscience Delft**

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## Nederlands:

*Elke dag nemen we veel beslissingen. Het ligt in onze aard om informatie te verzamelen, te verwerken en te verspreiden. In dit proces zijn we niet zo rationeel als we zouden willen denken, eerder erg vatbaar voor verkeerde informatie. Zeker in de huidige tijd, waarin de hoeveelheid informatie overweldigend kan zijn, is het belangrijk om autonoom kritisch denken te ontwikkelen. Hierin is wetenschapsonderwijs een uitstekend platform om scholieren de juiste tools te bieden om feiten van meningen te scheiden, om te gaan met informatie-overflow en vooringenomenheid te minimaliseren.*

## English:

*Every day we make many decisions. It is in our nature to gather, process and disseminate information. In this process we are not as rational as we would like to think, rather very susceptible to misinformation. Especially in today's world, where the amount of information can be overwhelming, it is important to develop autonomous critical thinking. In this, science education is an excellent platform to provide students with the right tools to separate facts from opinions, deal with information overflow and minimize bias. Translated with www.DeepL.com/Translator (free version)*

# Before we start:

**Read the following statements:**

1. The responsibility of recycling is on the consumer rather than companies
2. Tik-Tok is damaging to youth
3. Covid vaccines should be mandatory
4. Porn sites are part of free internet and should not be restricted
5. Social media platforms (as Facebook) should be tightly regulated

**Relate each statement (by number) to your opinion- Agree/Disagree/Neutral**
*For example: 1- Strongly Disagree*

**Next, write down your feeling when reading each statement**
*For example: 1- Angry*

# What is critical thinking actually?

Creative thinking

- What types of thinking are we aware of?

- What is critical thinking?

- How do we process information?
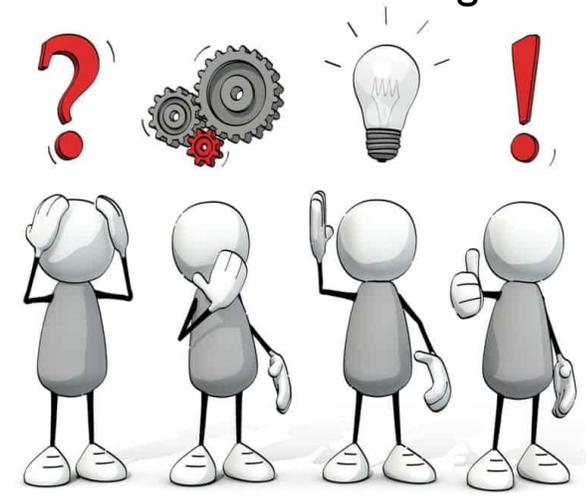
Daydream
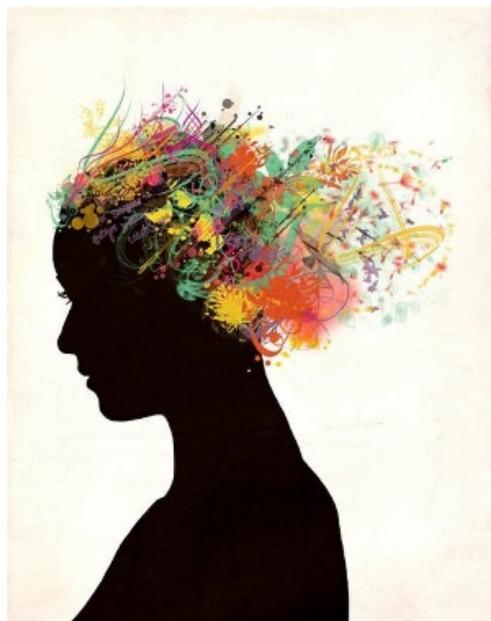
planning

Reflections

# Why is this workshop given by TU Delft?

Scientists routinely combine **creative thinking** (coming up with a hypothesis) and **critical thinking** (verifying this hypothesis)

*Rate of publication numbers increase
Vs.
Availability of resources to validate
these findings?*

**Many times Mis-information is not
intentional: researchers overstating their
findings or misrepresenting their data**

**Figure 1.** Number of world scientific publications: total and with constant journal set, 2000-2016



— All publications    - - - With constant number of journals

www.hceres.fr/OSTReport2019-Fig-1

Source: Computed by OST using WoS

Dynamics of scientific
production in the world,
in Europe and in France,
2000-2016
Science and Technology Observatory

Hcéres
targeting quality
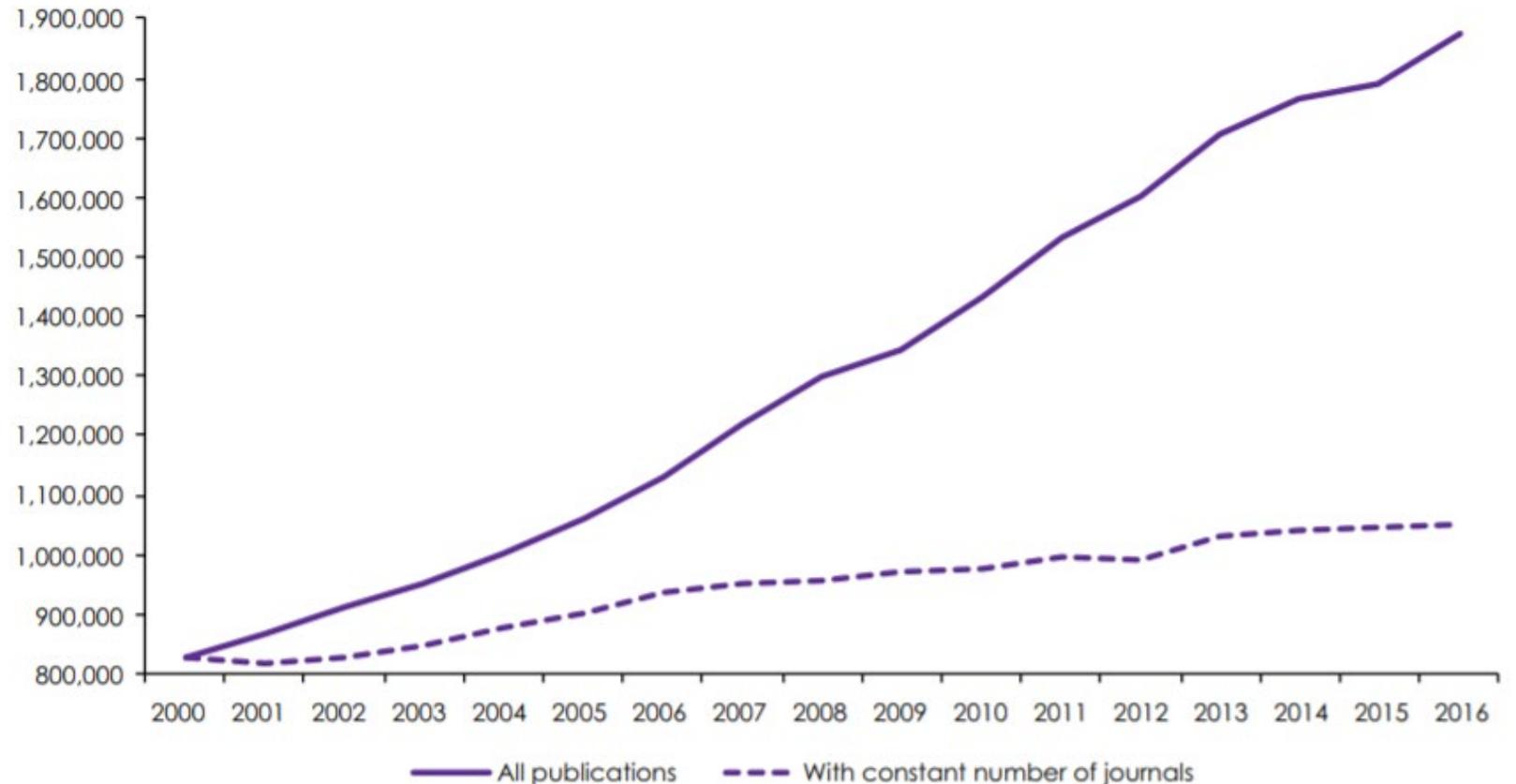
# Diving into the meaning of critical thinking: lets talk about Climate Change
## (formally known as Global Warming)



*(Photo: Getty Images)*

# Impacts of global warming -consensus among scientific community

- Loss of biodiversity

- Melting Ice and Rising sea level

- Extreme weather events: Heat waves, Fires, Floods- decreasing water quality

- Heavy costs on health, society and economy

As always, developing areas, women and children, are at higher risk

*Sir David Attenborough*

# Climate change denial – Not a problem of science

Numerous studies have found overwhelming scientific consensus on human-caused global warming both in the scientific community (*Anderegg et al., 2010; Carlton et al., 2015; Doran & Zimmerman, 2009*) and in the scientific literature (*Cook et al., 2013; Oreskes, 2004*).

Only small minority of climate scientists reject the consensus position –
climate denial has a vanishingly small presence in the scientific literature

The small number of published studies that reject mainstream climate science have been shown to possess fatal errors: inappropriate statistical methods, false dichotomies, and conclusions based on misconceived physics

Contrarians have a higher presence in media coverage of climate change relative to expert scientists (Petersen, Vincent, & Westerling, 2019)

*The next section, including figures is taken from:*

*Cook, J. (2020). Deconstructing Climate Science Denial. In Holmes, D. & Richardson, L. M.*
*(Eds.) Edward Elgar Research Handbook in Communicating Climate Change. Cheltenham: Edward Elgar.*

*Benestad et al. (2016)*

*Abraham et al. (2014)*

# Climate change denial- a problem of communication

> We must reject the **perennial prophets of doom** and their predictions of the apocalypse

> I don't believe it.

**I don't think it's a hoax**, I think there's probably a difference. But I don't know that it's manmade.

It's freezing in New York — **where the hell is global warming?**

> The United States will join **one trillion trees** initiative

The weather has been so cold for so long that the **global warming HOAXSTERS** were forced to change the name to climate change to keep $ flow!

## Donald J. Trump

The concept of global warming was **created by and for the Chinese** in order to make U.S. manufacturing non-competitive.

> The environment is very important to me. Someone wrote a book that **I'm an environmentalist**

The badly flawed Paris Climate Agreement protects the polluters, hurts Americans, and **cost a fortune**. NOT ON MY WATCH!

> I want the cleanest water on the planet. **I want the cleanest air anywhere** — crystal-clean water

**BBC**

*Self-illusion:*

# Looking into some justifications for climate change denial:

GEORGE MASON UNIVERSITY
CENTER for CLIMATE CHANGE COMMUNICATION

*Not real*     *Its not us!*     *Its actually not bad*     *Its inevitable*     *Climate science is Unreliable*

## Taxonomy of Climate Misinformation Claims

**Super-claims**

1. Global warming is not happening
2. Human GHGs are not causing global warming
3. Climate impacts are not bad
4. Climate solutions won't work
5. Climate movement/science is unreliable

**Sub-claims**

1.1. Ice isn't melting
1.2. Heading into ice age
1.3. Weather is cold
1.4. Hiatus in warming
1.5. Oceans are cooling
1.6. Sea level rise is exaggerated
1.7. Extremes aren't increasing
1.8. Changed the name

2.1. It's natural cycles
2.2. Non-GHG forcings
2.3. No evidence for GHE
2.4. $CO_2$ not rising
2.5. Emissions not raising $CO_2$ levels

3.1. Sensitivity is low
3.2. No species impact
3.3. Not a pollutant
3.4. Only a few degrees
3.5. No link to conflict
3.6. No health impacts

4.1. Policies are harmful
4.2. Policies are ineffective
4.3. Too hard
4.4. Clean energy won't work
4.5. We need energy

5.1. Science is unreliable
5.2. Movement is unreliable
5.3. Climate is conspiracy

**Sub-sub-claims**

1.1.1. Antarctica isn't melting
1.1.2. Greenland isn't melting
1.1.3. Arctic isn't melting
1.1.4. Glaciers aren't vanishing

2.1.1. It's the sun
2.1.2. It's geological
2.1.3. It's the ocean
2.1.4. Past climate change
2.1.5. Tiny $CO_2$ emissions

2.3.1. $CO_2$ is trace gas
2.3.2. GHE is saturated
2.3.3. $CO_2$ lags climate
2.3.4. Water vapor
2.3.5. Tropospheric hot spot
2.3.6. $CO_2$ high in past

3.2.1. Species can adapt
3.2.2. Polar bears ok
3.2.3. Oceans are ok

3.3.1. $CO_2$ is plant food

4.1.1. Policy increases costs
4.1.2. Policy weakens security
4.1.3. Policy harms environment
4.1.4. Rich future generations
4.1.5. Limits freedom

4.2.1. Green jobs don't work
4.2.2. Markets more efficient
4.2.3. Policy impact is negligible
4.2.4. One country is negligible
4.2.5. Better to adapt
4.2.6. China's emissions
4.2.7. Techno fix

4.3.1. Policy too difficult
4.3.2. Low public support

4.4.1. Clean energy unreliable
4.4.2. CCS is unproven

4.5.1. FF is plentiful
4.5.2. FF are cheap
4.5.3. Nuclear is good

5.1.1. No consensus
5.1.2. Proxies are unreliable
5.1.3. Temp is unreliable
5.1.4. Models are unreliable

5.2.1. Climate is religion
5.2.2. Media is alarmist
5.2.3. Politicians are biased
5.2.4. Environmentalists are alarmist
5.2.5. Scientists are biased

5.3.1. Policy is conspiracy
5.3.2. Science is conspiracy

# Doubts regarding scientific conduct or integrity

The concept of Uncertainty is grasped differently in the general public than within scientific community:

Uncertainty for Scientist means that each measurement lays within a certain range of values.

Uncertainty as can be grasped by general public means we don't know if it will actually happen

The implications are - Attacks on the integrity of science conduct, or even the integrity of climate scientists themselves:

- **climate science** is corrupt (Jacques & Knox, 2016)
- **climate scientists** being deeply corrupt, hysterical, and working in the interest of the powerful (Roper, Ganesh & Zorn (2016)
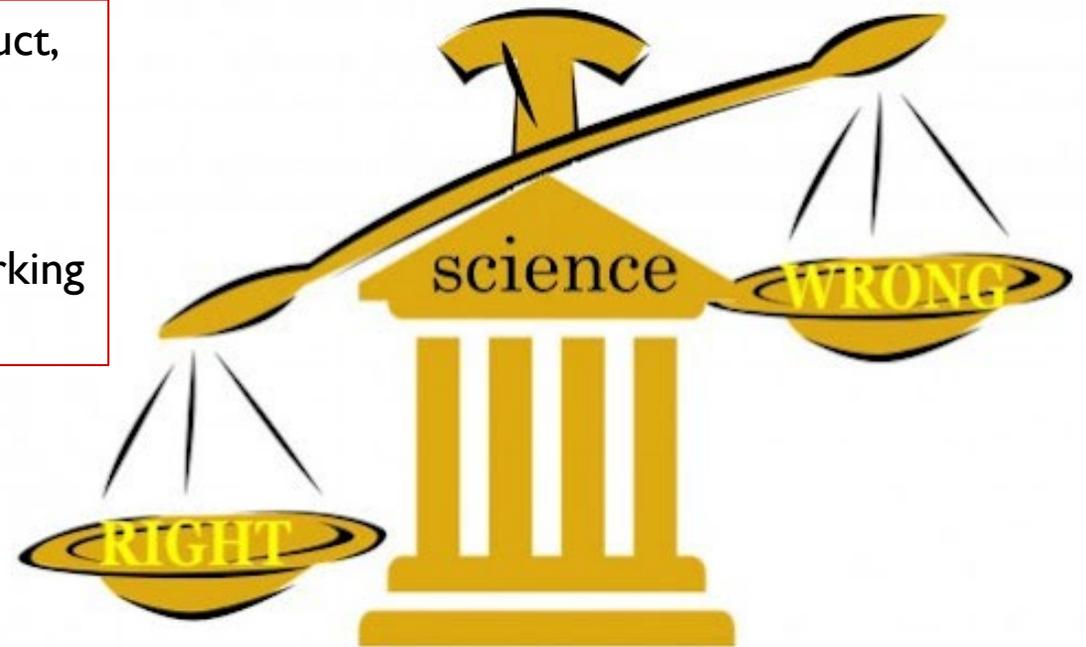
# Case study- climate change discussion from a critical thinking point of view

Rhetorical methodologies- FLICC (Diethelm &McKee 2009; Hoofnagle 2007; Hansson 2017):

1. **F**ake experts
2. **L**ogical fallacies
3. **I**mpossible expectations
4. **C**herry picking
5. **C**onspiracy theories
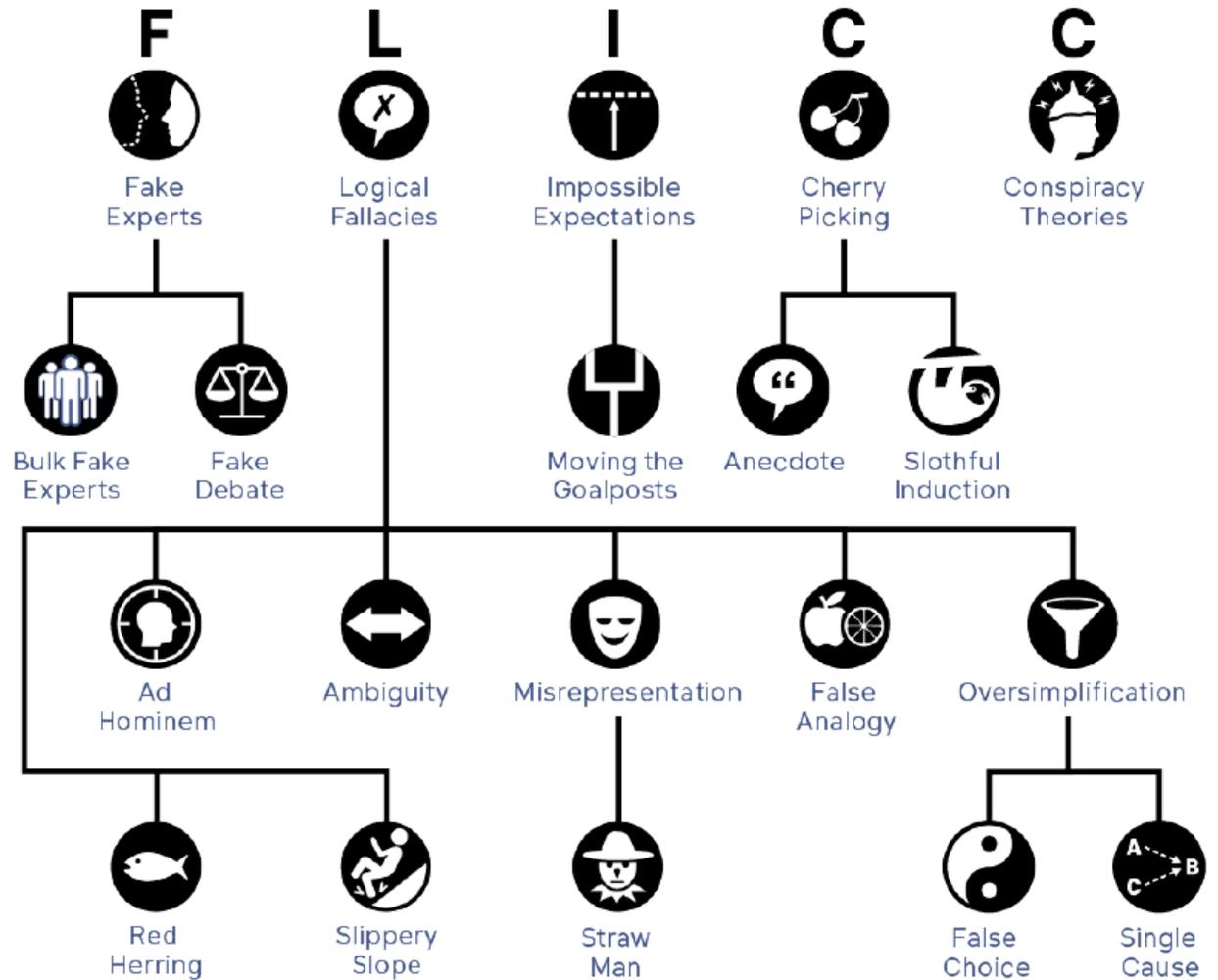
# **F**ake experts- casting doubt

Fake experts are spokespeople that convey the impression of expertise on a topic while possessing little to no relevant expertise. You can recognize their title: "**private researchers**" that were not approved by the community, as for example published in peer-reviewed journals
 (Hannson, 2017)



2008

Art Robinson

*Biochemist in education*
*Formally faculty member at University of California*
*Head of a privately financed laboratory*

[M*A*S*H](#)    [Charles Darwin](#)    [*Star Wars*](#)    [Spice Girls](#)

# **L**ogical fallacies

*Logical fallacies occur in arguments where the premises or starting assumptions do not logically lead to the conclusion*

**\*Using a person:**
(name) is well known authority, therefore (name's) statements are true (not if not related to the area of specialty)

**\*Circular argument:**
StarWars is the greatest movie ever, since it is one of the most financially successful films of all times…
(financial success does not relate to artistic quality)

**\*Emotional stress:**
It has to be true! It is so painful to think otherwise..

**\*Power by numbers:**
Millions cannot be wrong… (well..)

# **L**ogical fallacies- in Climate discussion:

**Ambiguity-**
Climate science (or all science fields for that matter) is **complex** and is hard to grasp all the causes and relations

Giving evidences that are **not logically relevant** to the conclusion presented-
CO2 is only 0.04% of the atmosphere. So it cant affect that much…
(well, in fact, similar to many other substances, small amounts can have strong effects)

**Oversimplification-**
CO2 is plant food- therefore more CO2 means better growth for plants.
Wrong! Plants indeed use CO2 for energy, but they also rely on **delicate balance** in water supply and narrow temperature range.

**Single cause- ignoring multiple factors**:
Climate has changed before humans, so this one is really not about us.
Wrong again! If something was the cause once- it does not mean it is always the case.
Always be aware of **co-dependence** and **positive feedback**.

# Impossible expectations

Demanding higher levels of evidence after receiving requested evidence.

*Sea level was proven to increase.*
*Then came the demand to **prove the rate of rise-** is it accelerating?*

**Question:**

Do you believe science should provide absolute proof?

Do you think high level of expectations can be biased (gender/race)?

Can you find examples for unrealistic expectations from your experience? Personal/professinal?
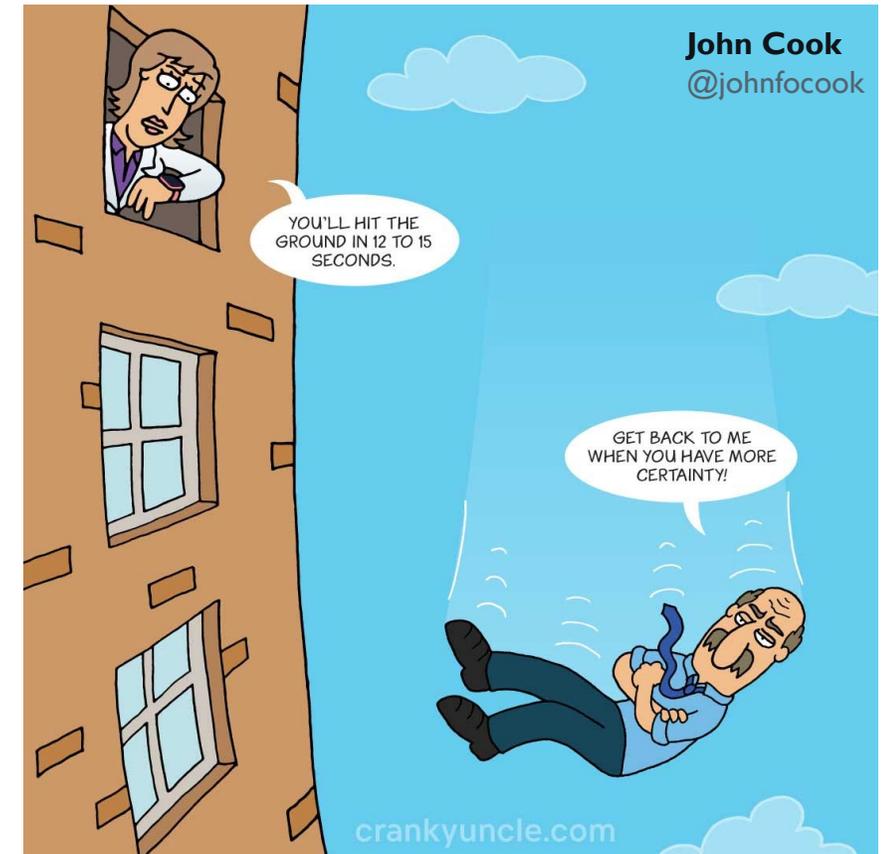
# Cherry picking

Cherry picking involves **selectively** focusing on data that leads to a conclusion different from the conclusion that arise looking at **all available data** (Cook, Ellerton, & Kinkead, 2018).



*Hansen et al., PNAS September 26, 2006*
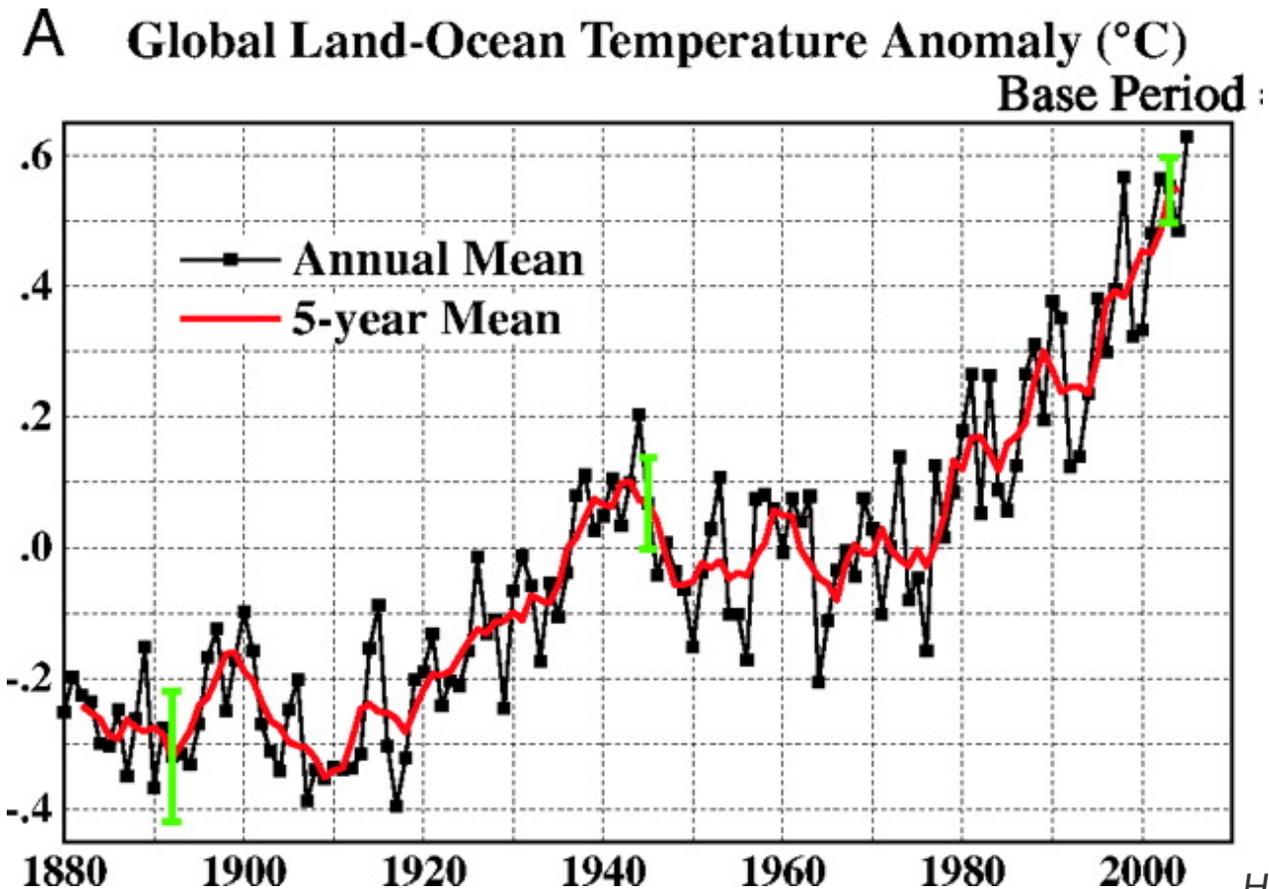
# **C**herry picking

**Anecdote** relies on **isolated examples** rather than scientific evidence in order to draw misleading conclusions

*The fact that its snowing doesn't mean it is not getting warmer- despite the snowball solid proof, 2014 was actually measured to be extremely hot.*



**Slothful induction ignores relevant evidence** when coming to a conclusion

The sun is causing global warming

*But actually…*

Over the last few decades, global temperatures have increased while <u>solar activity decreased</u>

Some glaciers are actually growing!
what are you talking about melting then?

*But actually…*

Well, glaciers can grow because of <u>other factors</u>, not related to warming, as local precipitation
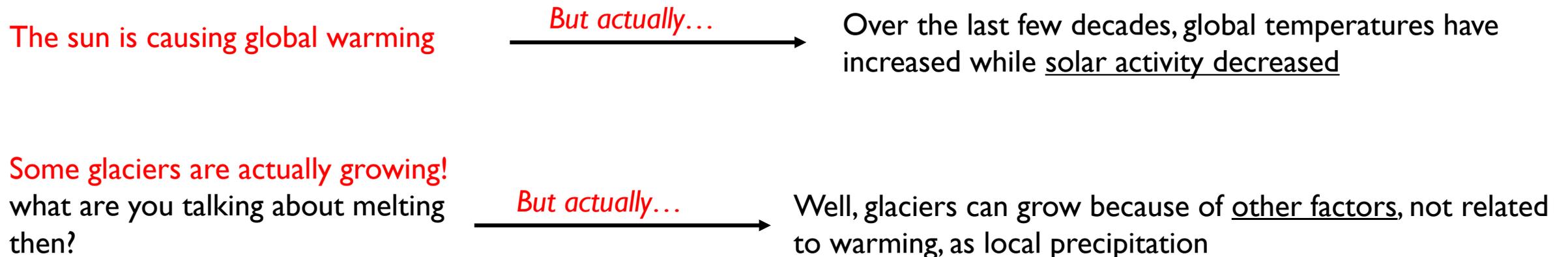
# Conspiracy

# And finally- our phycology:

**Our brain has a limit to its capacity for new information**
**Psychological biases** is the tendency to selectively use information, tends to increase under pressure



*https://mbird.com/*
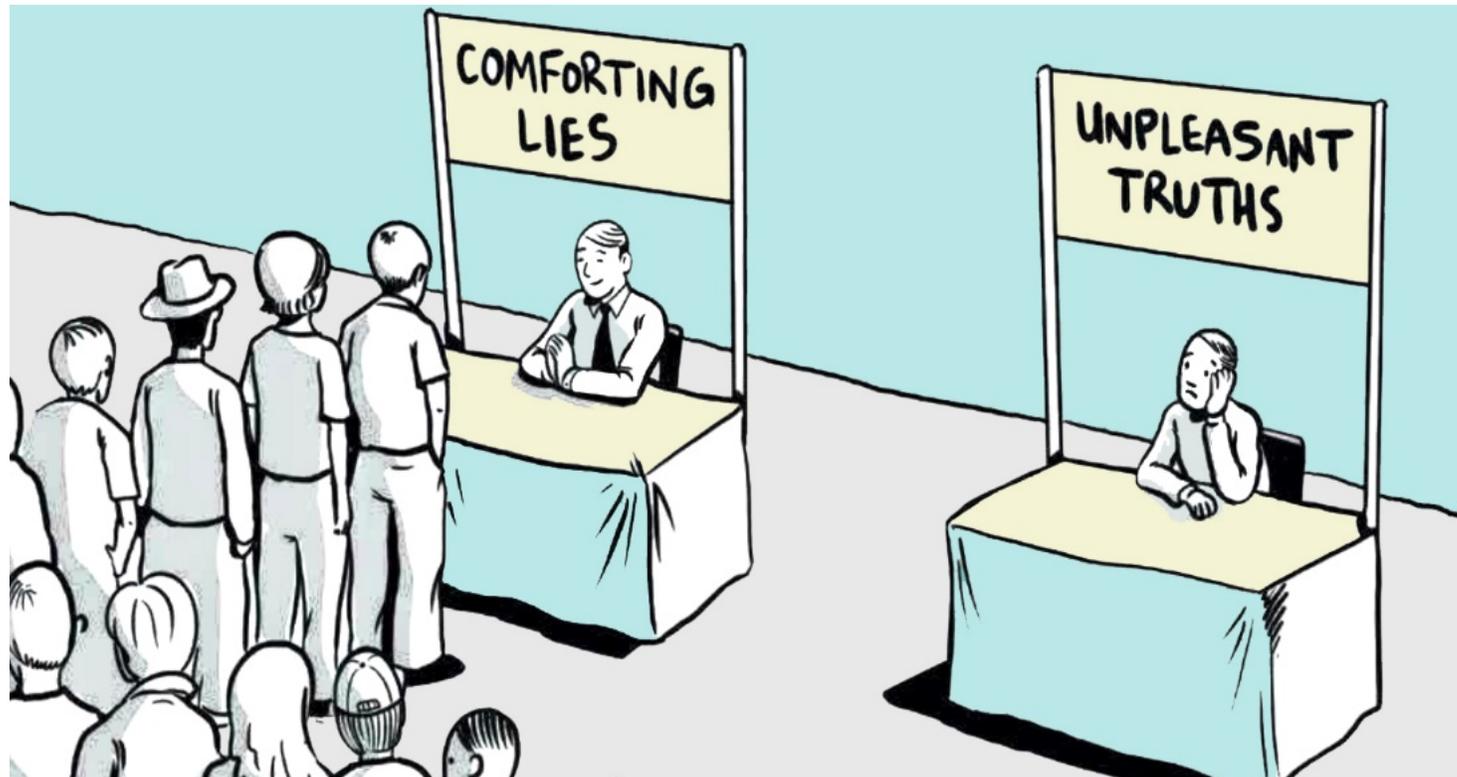
# And finally- our phycology:

**Confirmation bias:**
People tend to attribute greater weight to information that confirms prior beliefs relative to disconfirming evidence. Our psychological tendency is to focus on opponents' weaker arguments

**Jumping to conclusions-** making a decisions before receiving full information

**Over confidence-** when we feel we are knowledgeable over this topic, we might disregard the logical process, forget certain facts.

**Avoiding responsibility-** ignoring all impactors, and tending to cast blame on others- prone to stereotypes

**Question: Can you think of examples from your personal experience?**

# From Climate Change to Gender Bias

In the 1850s, Eunice Foote, an amateur scientist and activist for women's rights, made a remarkable discovery about greenhouse gases that could have helped form the foundation of modern climate science.



On the Heat in the Sun's Rays.

ART. XXXI.—*Circumstances affecting the Heat of the Sun's Rays;*
by EUNICE FOOTE.

(Read before the American Association, August 23d, 1856.)

MY investigations have had for their object to determine the different circumstances that affect the thermal action of the rays of light that proceed from the sun.
Several results have been obtained.

MRS. HENDERSON

In her 1856 paper about the experiment, "Circumstances Affecting the Heat of the Sun's Rays," she wrote that a cylinder with moist air became warmer than one with dry air. A cylinder filled with carbon dioxide warmed even more, and, once removed from the light, "it was many times as long in cooling."

# From Climate Change to Gender Bias
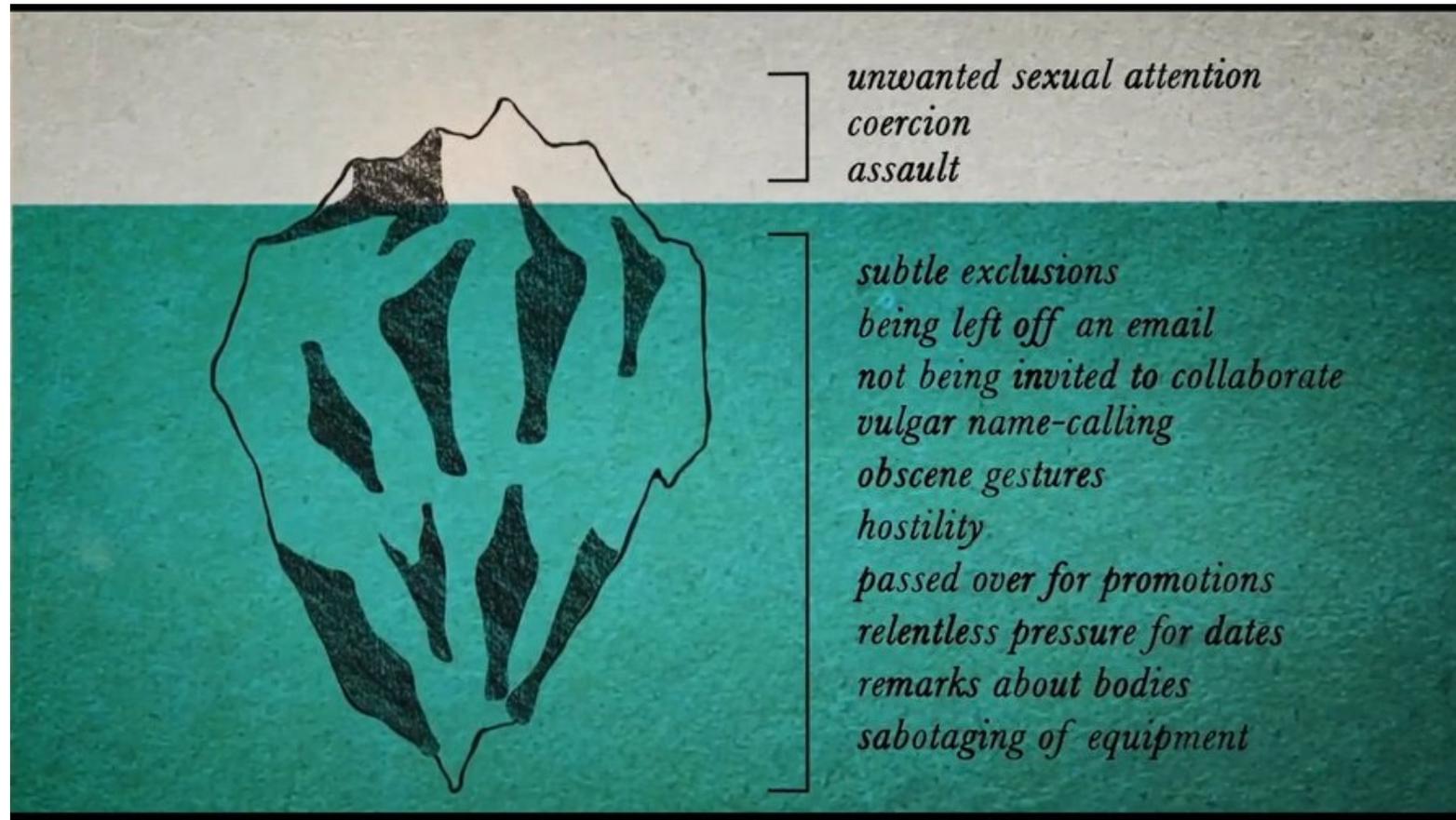


Picture a scientist

Implicit bias test:

CLICK

https://implicit.harvard.edu/implicit/takeatest.html

# Project Implicit

## Preliminary Information

On the next page you'll be asked to select an Implicit Association Test (IAT) from a list of possible topics . We will also ask you (optionally) to report your attitudes or beliefs about these topics and provide some information about yourself.

We ask these questions because the IAT can be more valuable if you also describe your own self-understanding of the attitude or stereotype that the IAT measures. We would also like to compare differences between people and groups.

**Data Privacy:** Data exchanged with this site are protected by SSL encryption. Project Implicit uses the same secure hypertext transfer protocol (HTTPS) that banks use to securely transfer credit card information. This provides strong security for data transfer to and from our website. IP addresses are routinely recorded, but are completely confidential. We make the anonymous data collected on the Project Implicit Demonstration website publicly available. You can find more information on our Data Privacy page.

**Important disclaimer**: In reporting to you results of any IAT test that you take, we will mention possible interpretations that have a basis in research done (at the University of Washington, University of Virginia, Harvard University, and Yale University) with these tests. However, these Universities, as well as the individual researchers who have contributed to this site, make no claim for the validity of these suggested interpretations. If you are unprepared to encounter interpretations that you might find objectionable, please do not proceed further. You may prefer to examine general information about the IAT before deciding whether or not to proceed.

If you have questions about the study, please contact Project Implicit at questions@projectimplicit.net. To obtain more information about the study, ask questions about the research procedures, express concerns about your participation, or report illness, injury or other problems, please contact:

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Website for Research Participants: https://research.virginia.edu/research-participants

**I am aware of the possibility of encountering interpretations of my IAT test performance with which I may not agree. Knowing this, I wish to proceed**  ←

*Step 1: click on "I wish to proceed"*

**Step 2: choose "Gender-Career IAT"**

**Step 3: Continue**

**Age** ('Young - Old' IAT). This IAT requires the ability to distinguish old from young faces. This test often indicates that Americans have automatic preference for young over old.

**Religion** ('Religions' IAT). This IAT requires some familiarity with religious terms from various world religions.

**Sexuality** ('Gay - Straight' IAT). This IAT requires the ability to distinguish words and symbols representing gay and straight people. It often reveals an automatic preference for straight relative to gay people.

**Gender - Career.** This IAT often reveals a relative link between family and females and between career and males.

**Transgender** ('Transgender People - Cisgender People' IAT). This IAT requires the ability to distinguish photos of transgender celebrity faces from photos of cisgender celebrity faces.

**Arab-Muslim** ('Arab Muslim - Other People' IAT). This IAT requires the ability to distinguish names that are likely to belong to Arab-Muslims versus people of other nationalities or religions.

**Disability** ('Disabled - Abled' IAT). This IAT requires the ability to recognize symbols representing abled and disabled individuals.

**Presidents** ('Presidential Popularity' IAT). This IAT requires the ability to recognize photos of Joseph Biden and one or more previous presidents.

**Weapons** ('Weapons - Harmless Objects' IAT). This IAT requires the ability to recognize White and Black faces, and images of weapons or harmless objects.

**Asian American** ('Asian - European American' IAT). This IAT requires the ability to recognize White and Asian American faces, and images of places that are either American or Foreign in origin.

| Age IAT |
| Religion IAT |
| Sexuality IAT |
| Gender-Career IAT |
| Transgender IAT |
| Arab-Muslim IAT |
| Disability IAT |
| Presidents IAT |
| Weapons IAT |
| Asian IAT |

## Welcome

You have selected the Gender-Science Task. In this study you will complete an Implicit Association Test (IAT) in which you will be asked to sort words into groups as fast as you can. In addition to the IAT, there are some questions about your beliefs, attitudes, and opinions, and some standard demographic questions. This study should take about 10 minutes to complete. At the end, you will receive your IAT result along with information about what it means.

We thank you for being here!

Continue

· Project Implicit ·

# Implicit Association Test

Next, you will use the 'E' and 'I' computer keys to categorize items into groups as fast as you can. These are the four groups and the items that belong to each:

| Category | Items |
|---|---|
| Male | Man, Son, Father, Boy, Uncle, Grandpa, Husband, Male |
| Female | Mother, Wife, Aunt, Woman, Girl, Female, Grandma, Daughter |
| Science | Astronomy, Math, Chemistry, Physics, Biology, Geology, Engineering |
| Liberal Arts | History, Arts, Humanities, English, Philosophy, Music, Literature |

There are seven parts. The instructions change for each part. Pay attention!

Continue

**1**

Press "E" for
Science

Press "I" for
Liberal Arts

Part 1 of 7

Put a left finger on the **E** key for items that belong to the category Science.
Put a right finger on the **I** key for items that belong to the category Liberal Arts.
Items will appear one at a time.

If you make a mistake, a red **X** will appear. Press the other key to continue.
Go as fast as you can while being accurate.

Press the **space bar** when you are ready to start.

**2**

Press "E" for
Science

Press "I" for
Liberal Arts

Philosophy

If you make a mistake, a red **X** will appear. Press the other key to continue.

# Our phycology- Tools for awareness:

**How to minimize our psychological bias?**

**Be aware!** Mindfulness.
Examine your emotional response. What is your motivation? Do you feel social pressure? Do you feel intimidated?

**Consider the opposite-**
Imagine the data you encounter leads to the **opposite conclusion**

**Discuss with others-** Don't be afraid to **challenge** your beliefs.

**Take time to process-** Don't rush into conclusions

**Embrace the uncomfortable.**
(Rebecca Baugh, MSc at TUD )

# Critical means:

* Have some **scepticism** (positive),
* Refer to the **general context** of knowledge in the field
* Look for the background and the orientation of the information **source.**

* Ask questions: Is the **data** sufficient to drive the statements given?
   Was the **methodology** fitting to the questions, and was it shown to be **reproducible**?
   Are there **other** approaches/alternative solutions?

* Be critical about **your own view**:

Before reading- what was my initial response to the title and the summary (before getting the full information). Curiosity? Resentment?

After reading- did we refer to the thought process or just to the data presented? Or both? Do we agree/disagree? Why? Do we have sufficient background in the field?

**Statement #1**

# Last year was hotter than the previous year. That means the globe is warming.

## True      or      False

**Statement #1**

# Last year was hotter than the previous year. That means the globe is warming.

# True    or    False

**Statement #4**

A scientific idea that is tested over and over must be wrong or bad, because it keeps being tested.

True        or        False

**Statement #4**

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Interdisciplinary Teaching about Earth
for a Sustainable Future

# A scientific idea that is tested over and over must be wrong or bad, because it keeps being tested.

## True    or    **False**

**Statement #7**

There is no way to reasonably determine whether any observed climate change is because of human activity.

True      or      False

**Statement #7**

InTeGrate
Interdisciplinary Teaching about Earth
for a Sustainable Future

There is no way to reasonably determine whether any observed climate change is because of human activity.

True        or        **False**

**Statement #11**

# Climate models for the future cannot be right because we cannot even predict the temperature 10 days from now.

## True        or        False

**Statement #11**

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for a Sustainable Future

# Climate models for the future cannot be right because we cannot even predict the temperature 10 days from now.

## True      or      **False**

**Statement #12**

# Scientists do not "believe" that atmospheric CO₂ is increasing, rather, they "accept" that atmospheric CO₂ in increasing.

## True        or        False

**Statement #12**

# Scientists do not "believe" that atmospheric $CO_2$ is increasing, rather, they "accept" that atmospheric $CO_2$ in increasing.

**True**      or      **False**

# Part B- after Coffee break- active discussion groups

1. Lets go back to the statements from the beginning:

1. The responsibility of recycling is on the consumer rather than companies
2. Tik-Tok is damaging to youth
3. Covid vaccines should be mandatory
4. Porn sites are part of free internet and should not be restricted
5. Social media platforms (as Facebook) should be tightly regulated

2. Pick one that raised high emotional response
    Can you pinpoint why you are emotionally involved?
    How knowledgeable are you in this field (1-10)?

2. Now imagine you hear this statement from one of your students. How would you respond?

3. You have 15 min to collect information on-line on this topic. You have free choice of resources

4. You have 10 minutes to write down your main arguments (shortly):     True/False + justifications + specify resources.

5.  Last 30 min: discussion. One presents while the others play a role of "teachers"-
reflecting on the manner of conversion according to the rules given.
*(for example, the statement is logically incorrect/selectively ignores other evidence..)*



https://laurakmcb.wordpress.com/

# Summary

*Critical digestion of information requires high level of awareness to our **own bias** and limited capacity

*To make a critical digestion of information given, you need to place it within **general context**- don't accept only information/opinion that confirms your prior believes. Challenge yourself

***Ask questions** according to the classifications specified here- are the tools used to verify the agenda given suitable to provide the information? Are we given a broad perspective, also referring to opposing opinions?
Is the logical process correct, or rather jumping into conclusions based on little information?
What is the orientation of the source?

*Be aware to social pressure. Phrase your arguments in a manner that allows the opposing side to **listen** and respond

*Use every opportunity to practice. **Talk to people with different approaches**. Listen and ask questions that point to the thought process