INTRODUCTION

From the outset let's be clear that we are at an **AMAZING** --and I believe a very **HOPEFUL** --time to reflect on educational research in climate change education. In particular, in my lightning, and may I add, "**THUNDER" talk** ("Thunder" added to place increased attention on the need for educational research in CC), I will address how such research may assist you in your teaching (and for those of you who are journalists, reporting) of this topic. Have I intrigued you? If so, I recommend you hold tightly on to your seats, and **LET'S BEGIN!**

But let's be clear—there truly is a dramatic contrast between how the topic is viewed (and taught) in the rest of the world and in the US. That is, it is a "best of times, worst of times" contrast, just as Charles Dickens presented in the mid 1800s in his classic book a TALE of Two Cities." In most of the rest of the world, climate change education is part and parcel of their science education; in contrast, in our country, we are playing catch up, and in some places, facing obstacles.

The dynamic body of educational literature worldwide on climate change education leads me to focus on three areas that would support you in your quest to effectively teach and report on climate change:

- **The Climate Change Topic and the US context**

- **What Students Know About Climate Change (Accurate Or NOT)**

- **Science Classroom Practices To Effectively Teach Climate Change**

I. The Climate Change Topic and the US Teaching Context

CC is Complex

We all recognize that CC, consisting of multiple scientific, social, and political systems, presents some unique challenges and opportunities for us science educators to meaningfully assist our learners to apply science to everyday actions. Our current version of accelerated and human caused CC, is a phenomenon that is complex in nature and worldwide in its scope. Because of it's negative impacts on life as we know it, it calls on us to take actions to improve the present situation. Specifically, actions are needed personally, locally, and globally to mitigate and adapt as we can to existing and forecast impacts of it.

Environmental education research has long promoted the notion that the primary reason someone may not take actions to improve the environment is that the person is ill informed or ignorant. However, more contemporary research in this area has found that (predictably!) a more complex set of factors apply than originally thought. While knowledge is *necessary* for individuals and societies to take action to protect the environment, such knowledge may be *insufficient to prompt* such action. Other factors, such as beliefs and attitudes apply. Learners ask, "How can my actions (or my society's) make a meaningful difference?" "Is it my (or my society's) responsibility to take action in this matter?"

Our US Context

Here is a notable finding from research for you to consider: In the US, a seminal study in 2016 in the journal Science "Climate confusion among US teachers of science" by Plutzer and his colleagues reported survey findings from a relatively large sample of teachers of science (MS and HS combined), N=1500. Only **7 out of 10 science** teachers taught it, and, on average, for **less than one hour PER YEAR**. Many teachers do not know that 97% of climate scientists are in agreement regarding the

science of climate change. Internationally, the teaching community shows no such significant confusion.

While the topic is admittedly complex and therefore challenging conceptually as well as politically, the good news is that the latest version of science standards for K-12 in our country (the Next Generation Science Standards, NGSS) include climate change as a coherent topic to be taught over many years, with a focus on middle and secondary school science. MD and the District of Columbia have adopted the NGSS, thus the standards offer teachers in those areas support for climate change education. Other states that draw from the NGSS in developing their own science standards also benefit.

So, to summarize, comparing CC education in the USA with most of the rest of the world (with a few exceptions including New Zealand), it is one of two cities --or situations (ours, a bit unresolved; the remainder of the world's resolved or not facing significant obstacles). And comparing within the USA context only, it is one of two cities --or situations, one in which teachers are beginning to teach it with a coherent and scientifically informed curriculum and one in which it is not being taught or if so, ineffectively.

2. What Students Inaccurately "Know" and Do NOT about Climate Change

Here are the main research findings up-to-date about what students do not know and do know accurately about climate change:

Inaccurate (alternative conceptions):

1.Many learners confuse weather and climate,

2. Some conflate the greenhouse effect and ozone depletion

3. Some think recycling will significantly mitigate CC., and

4. (a finding from my research team) About 20% of learners think projections made by scientists are uncertain because they believe they are only opinions.

Accurate:

1. Recognize that fossil fuels are increasing the amount of $CO_{2;}$

2. Are generally aware that the atmosphere functions to hold heat energy to warm the Earth.

3. Attribute recent increase in global temperatures to human-generated emissions

4. In my research team's study of student thinking about climate change, students had the most accurate ideas to communicate regarding climate change consequences.

3. Ideas About Science Classroom Practices To Effectively Teach Climate Change

First, a cautionary note: Educational research has suggested that much care in particular is required to address the cc topic. Avoid evoking learners' fearful emotions that have been observed immobilize them. Instead, promote an emotional connection within cc education that will prompt learners to want to do something about it. Therefore, "doom and gloom" has no place in a "futures perspective" and "solution based" climate change education in which learners reflect on what type of environmental future they want to have and what actions need to be taken individually and socially for that to be achieved.

I will now address three topics applicable to the classroom: Context, Teachers' motivation, and classroom practices.

Context. Given the complexity of the science of change change, how much of what is known about it is necessary to educate a learner about it to prepare them to become reasonably scientifically literate AND to prompt action? Emerging education research (including by my research team) suggest that knowledge about the role of human activities in causing observable impacts of climate change is a necessary minimum. Impacts include extreme weather, sea level rise, enhanced urban heat island effect, and human health. In addition, knowledge is needed on what mitigation actions are recommended and what ways exist, to the extent they our

efforts fail to mitigate CC, to adapt. Degrees of uncertainty exist on these important matters that we should engage learners in reasoned debate in our classrooms and beyond—not, however, on if CC exists, since that is established science.

Teachers' Motivation. For those teachers who do teach CC in the USA what motivates them to do so? A recent 2017 exploratory study of middle school science teachers identified these motivations:

• A "can do" attitude based on a belief that CC was a powerful topic to teach science authentically and in a multidisciplinary manner;

• A deepness of knowledge (about science) from learning experiences (including Professional Development from informal science education entities such as the National Museum of Natural History);

• An openness to share a personal value for environmental stewardship.

Classroom practices. Main take-a-ways from the bulk of research findings on climate change education are:

1. Present it from a scientific perspective in which there is a consensus for its occurrence and causes .

2. Focus on learners engaging with scientific data (learner collected and data from established and vetted databases) in a reasoned and logical way to make sense of the data and to understand the interpretations of such data made by scientists

3. Focus on identifying local and global consequences of CC.

The benefits of teaching CC in this way include:

1. Increased student motivation;

2. Development of analytical and rationale thinking ; and,

3. Improvement in the ability to construct arguments from evidence.

And to give you a heads up, a new area is being investigated for preparing teachers of science to teach climate change, led by my research team at UMD, to approach the teaching of climate change through a computational mindset with a systems thinking focus. As they say, **stay tuned!**

At this point, If anyone is now thinking, “Hey, I wanted a more direct answer to what, when and how I should teach climate change in my practice,”

my response is, FAIR POINT! Today you are in a community of fellow motivated educators and climate change experts in which you can learn about many of the scientific and pedagogical findings in climate change and its education. Take what you think is now ready for “prime time” and TEST it in your own classroom practice. Determine firsthand what works, and does not in your teaching situation. As it always has been in our profession when it comes down to it, **teachers are the key**.

In conclusion, I salute your interest and commitment to rise up to the challenge of informing and educating everyone about the science of climate change. ALL of the diverse organisms on this planet will benefit.

Thank you.