Supporting secondary students' understanding of Earth's climate system and global climate change using Easy Global Climate Modeling (EzGCM)

Authors

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Introduction

- The Next Generation Science Standards (NGSS) emphasize that secondary science students should demonstrate the understanding of the basic science of Global Climate Change (GCC), comprehend how climate data is collected and analyzed, and learn to apply this knowledge in decision- and policy-making.
- Scientific modeling is emphasized as a core component of science classrooms by the NGSS.
- Modeling supports students' conceptualization and epistemological understanding of complex phenomena such as GCC.

About the CliMES Project

- CliMES is a five-year NSF-funded project in the United States, which involved the collaboration between two R1 universities and a single Mid-western school district.
- We developed, refined, and studied a three-week climate EzGCM-based curriculum for secondary classrooms.
- The module was implemented in three high schools by four 9th grade level teachers in geoscience courses.

About EzGCM

- EzGCM is a web-based climate modeling suite designed for non-scientists that uses authentic NASA global climate data.
- It allows students engage in authentic methods of research, including: i) running simulations; ii) processing model output into meaningful scientific data sets; iii) creating useful scientific visualizations; and iv) analyzing student-generated data to improve comprehension of key climate concepts.

- Results from the study show steady improvements in students' conceptual understanding of Earth's climate system and global climate change across the three years.
- Student learning gains as measured by the pre-/post-module concept inventory, while not statistically-significant in Years 1 and 2, increased substantially by Year 3.

Year	Pre-Test	Post-Test	T-test
1	*M*=14.76, *SD*=4.54	*M*=14.97, *SD*=4.91	$t(93) = 0.60$, $p = 0.55$
2	*M*=13.58, *SD*=4.97	*M*=14.51, *SD*=4.66	$t(52) = -2.00$, $p = 0.051$
3	*M*=14.22, *SD*=4.54	*M*=15.13, *SD*=15.49	$t(268) = -4.36$, $p < 0.01$

- EzGCM afforded students unique opportunities to engage with climatic variables to better understand trends, relationships between climate variables, and formulate claims based on evidence about various factors related to climate change.

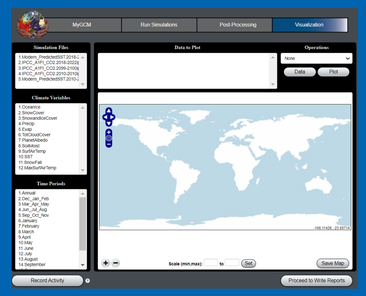

Figure 1. EzGCM processes
"[With EzGCM] you can go on and look at climate models and make predictions, with different variables about… weather and climate patterns" (Student Year 2).

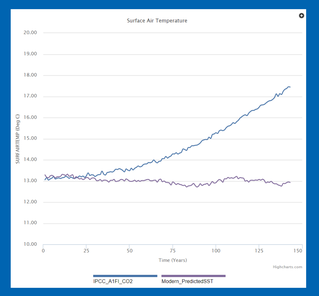

Figure 2. Modern predicted and IPCC simulations
"It [the graph] showed that the temperature is increasing above the predicted temperature... over time... at a linear rate... possibly exponential [rate]" (Student Year 3).

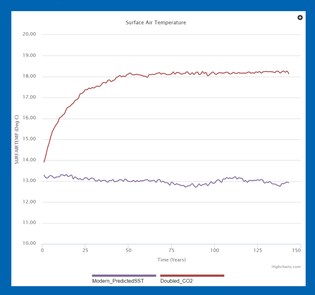

Figure 3. Doubled CO_2 simulation
"If you do the doubled-CO_2 simulation for the control simulation, you will see the surface air temperature will increase a lot more in the doubled CO_2". (Student Year 1).

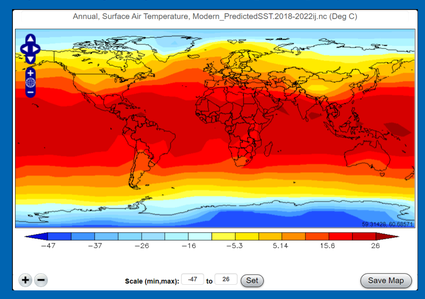

Figure 4. Temperature map visualization
"[The map] is the yearly surface air temperature, there it is [possible to see that] the surface air temperature is greater in some spots than others" (Student Year 1).

Research Questions

- **RQ 1:** To what extent has the EzGCM-based curriculum supported student learning outcomes about Earth's climate and GCC over time?
- **RQ 2:** In what ways do model features enhance students' model-based reasoning about Earth's climate system and GCC?

Theoretical framework

- Evidence Based Reasoning Framework helps assess students' reasoning about the phenomenon under investigation - "global increase in the average surface temperatures".
  - Learning processes should afford opportunities to students for assessing evidence, deducting logic and considering the validity of a claim based on the evidence provided.
- Fundamental concepts underlying Earth's climate system and GCC:
  - Temporal changes in surface air temperature and CO_2, spatial changes in surface air temperature, exponential growth, relationship between variables, and temperature anomalies.

Methods

- Data was collected in the classrooms of two teachers (Year 1) and all four teachers (Year 2&3).
- Instruments:
  - Pre-post concept inventory: Y1-*n*=94; Y2-*n*=53; Y3-*n*=269. Total *n*=416.
  - Student interviews: Y1-*n*=21; Y2-*n*=54; Y3-*n*=37. Total *n*=112.
- Data analyses: Mixed methods
  - Descriptive statistics, t-tests of the students' pre- and post- tests.
  - Students' interviews based on protocol grounded in the EBR framework and fundamental concepts but focusing on students' use of EzGCM.

Resources

- EzGCM: www.ezgcm.org
- Poster references: https://bit.ly/RefCliMES
- CliMES studies: https://bit.ly/StudiesCliMES

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