Technology-enabled Inquiry Climate Change Learning: Examining Group Work with Realistic Scientific Tools

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Problem statement

Lots done to teach climate change through inquiry

(Lueddecke, Pinter, & McManus, 2001; McCright, 2012; Gautier & Rebich, 2005)

Lots done to develop technology to aid this teaching

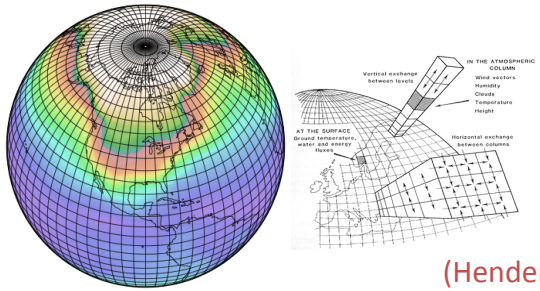
(Butler & Macgregor, 2003; Gautier & Soloman, 2005; Wu & Lee, 2015; Sterman et al., 2014)

It's important to do research in class

(NAGT, 2015; NRC 1996, 2000; NGSS, 2013)

Central research question

Does learning built around a key tool of climate scientists, a global climate model (GCM), impart clear climate change understandings?



(Henderson-Sellers, 1985)

- Conservation of momentum

$$\frac{\partial \vec{V}}{\partial t} = -(\vec{V}\cdot\nabla)\vec{V} - \frac{1}{\rho}\nabla p - \vec{g} - 2\vec{\Omega}\times\vec{V} + \nabla\cdot(k_m\nabla\vec{V}) - \vec{F}_d$$

- Conservation of energy

$$\rho c_{\vec{v}}\frac{\partial T}{\partial t} = -\rho c_{\vec{v}}(\vec{V}\cdot\nabla)T - \nabla\cdot\vec{R} + \nabla\cdot(k_T\nabla T) + C + S$$

- Conservation of mass

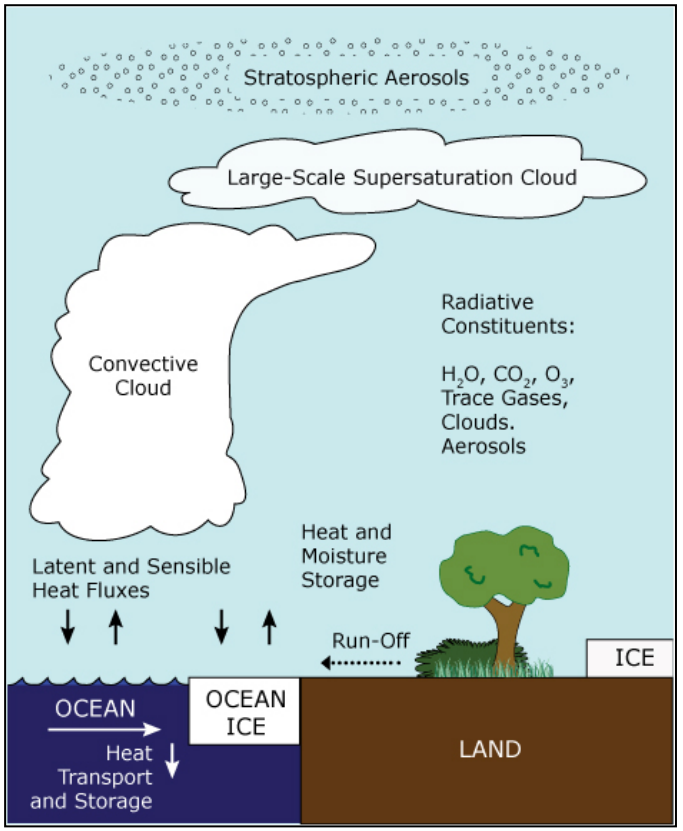
$$\frac{\partial \rho}{\partial t} = -(\vec{V}\cdot\nabla)\rho - \rho(\nabla\cdot\vec{V})$$

- Conservation of H_2O (vapor, liquid, solid)

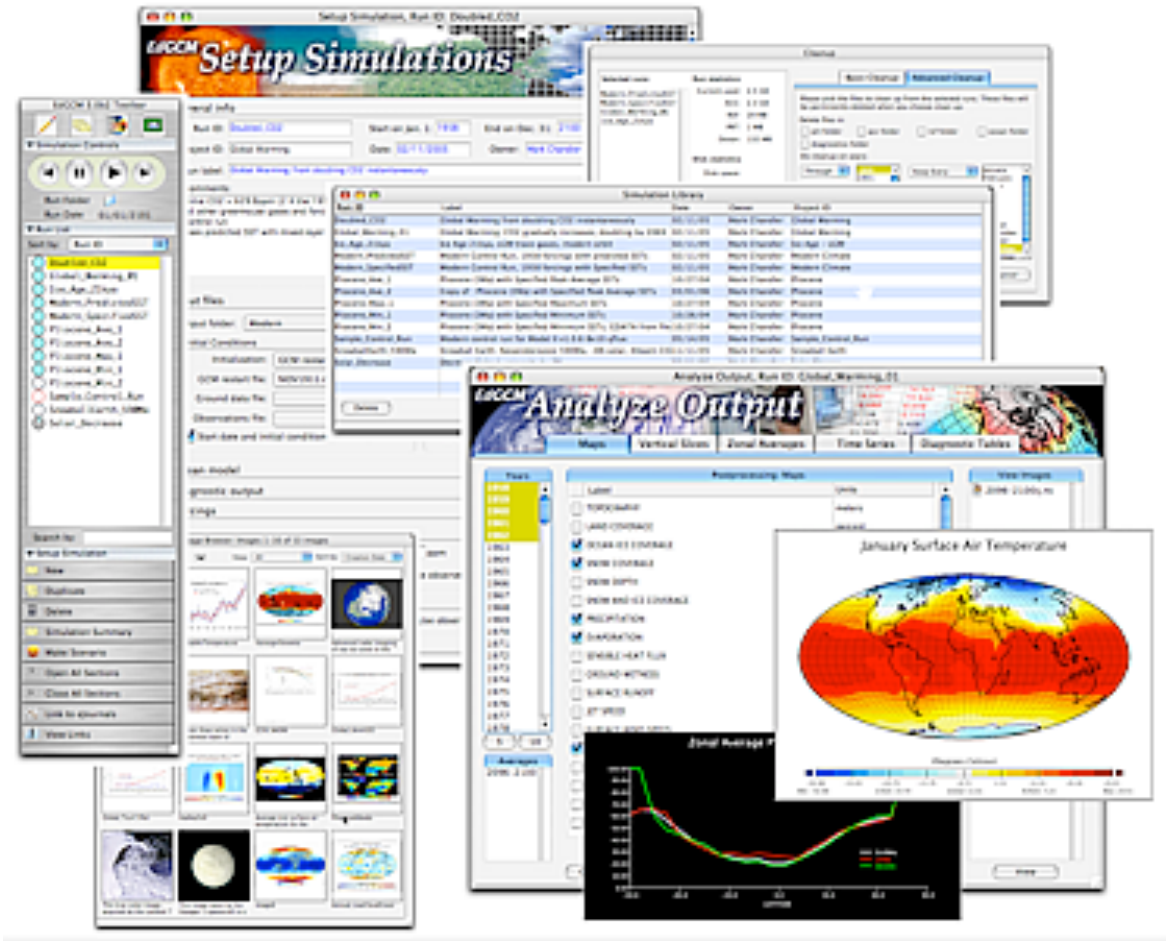
$$\frac{\partial q}{\partial t} = -(\vec{V}\cdot\nabla)q + \nabla\cdot(k_q\nabla q) + S_q + E$$

- Equation of state

$$p = \rho R_d T$$



The Educational Global Climate Model (EdGCM)



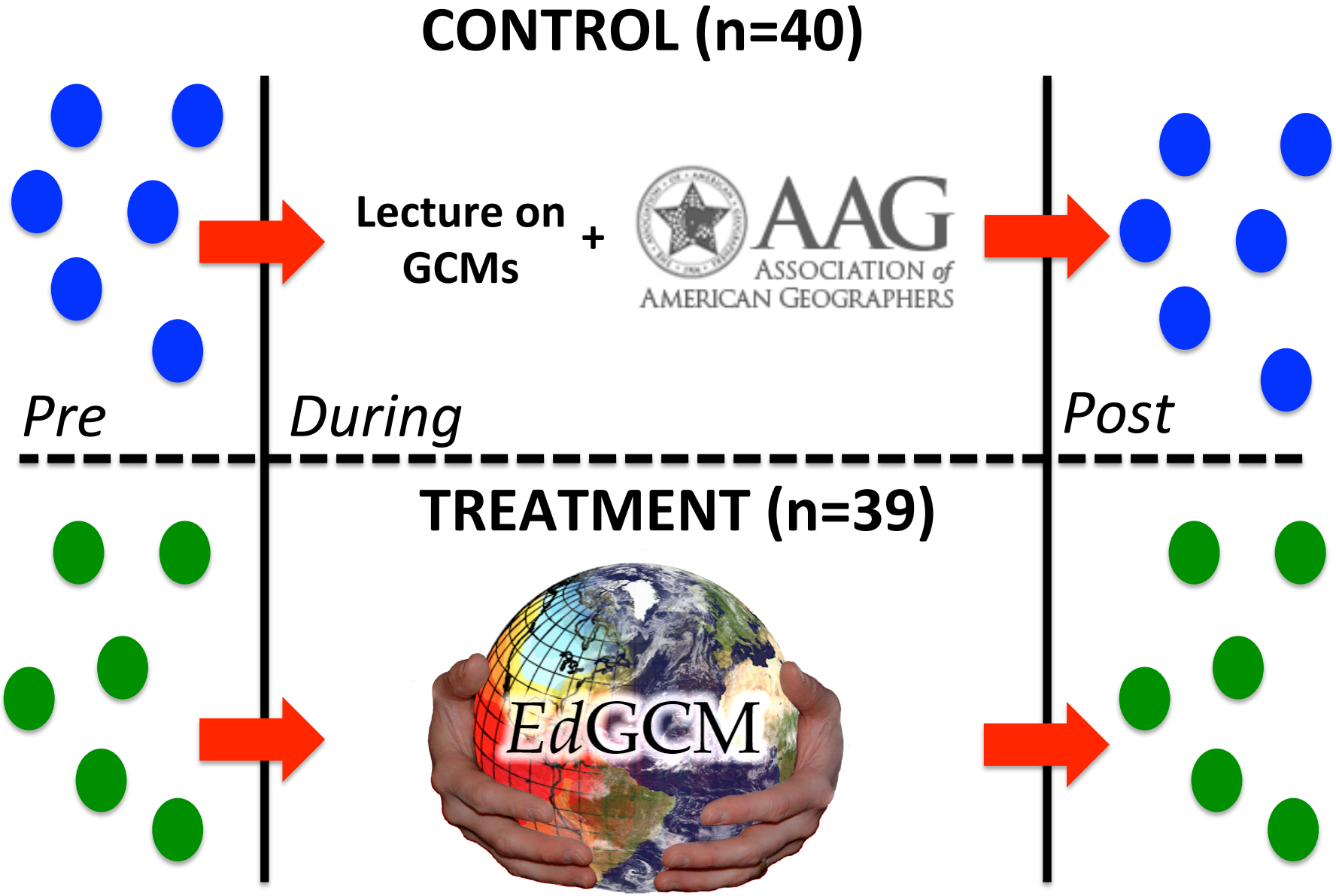
PROJECT GOALS

Allow teachers and students to run a full research version of a global climate model

- Design Experiments
- Running simulations
- Analyzing data
- Reporting on results

Demystifies how scientists forecast climate change

Experimental design



Mixed methods research

QUANTITATIVE

1. Pre/Post Diagnostic exam
2. Pre/ Post Questionnaire questions
3. Practice quizzes
4. Blog piece scores
5. Final project score

QUALITATIVE

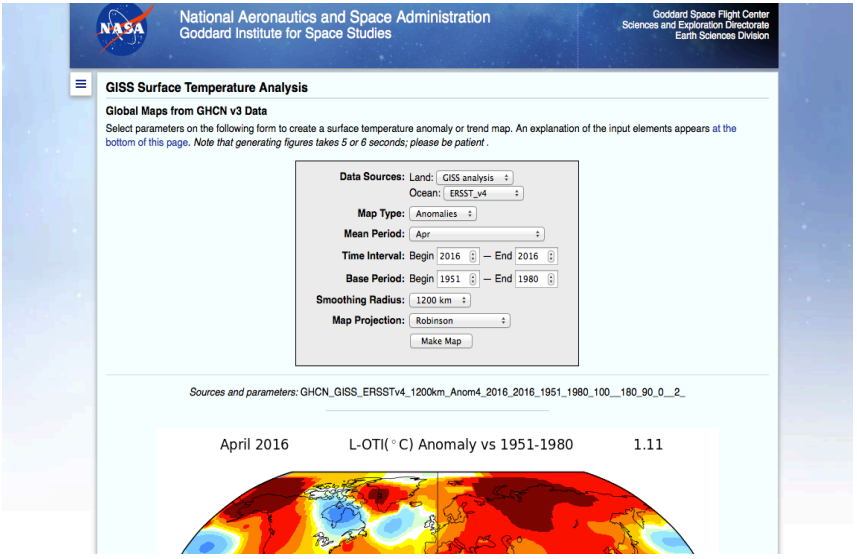
1. Exam question answer text
2. Open-answer survey questions
3. Student interviews
4. Instructor interviews
5. Blog pieces
6. Written reflections
7. Video recordings
8. Completed handouts
9. Field notes

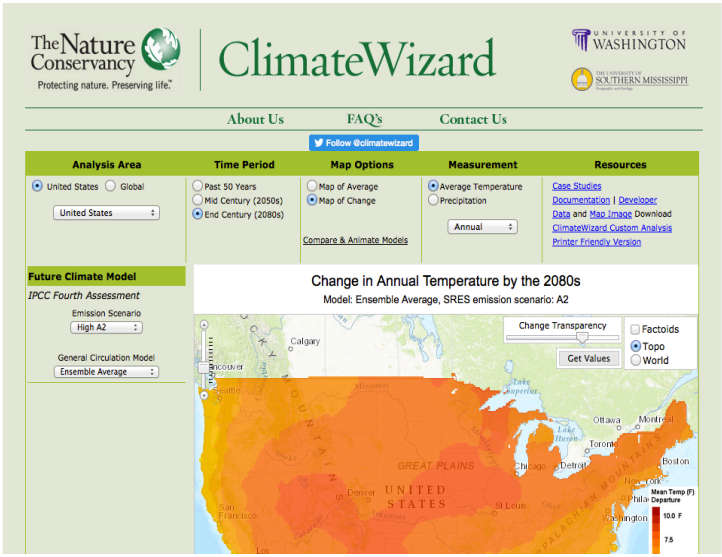
Curriculum: Inquiry-based learning

4-WEEKS: Twice weekly 80-minute class periods & two 150-minute laboratory groups of 20 students

OUTSIDE CLASS: Read articles, watched a video, and completed online research / public opinion projects on private Wordpress class blog

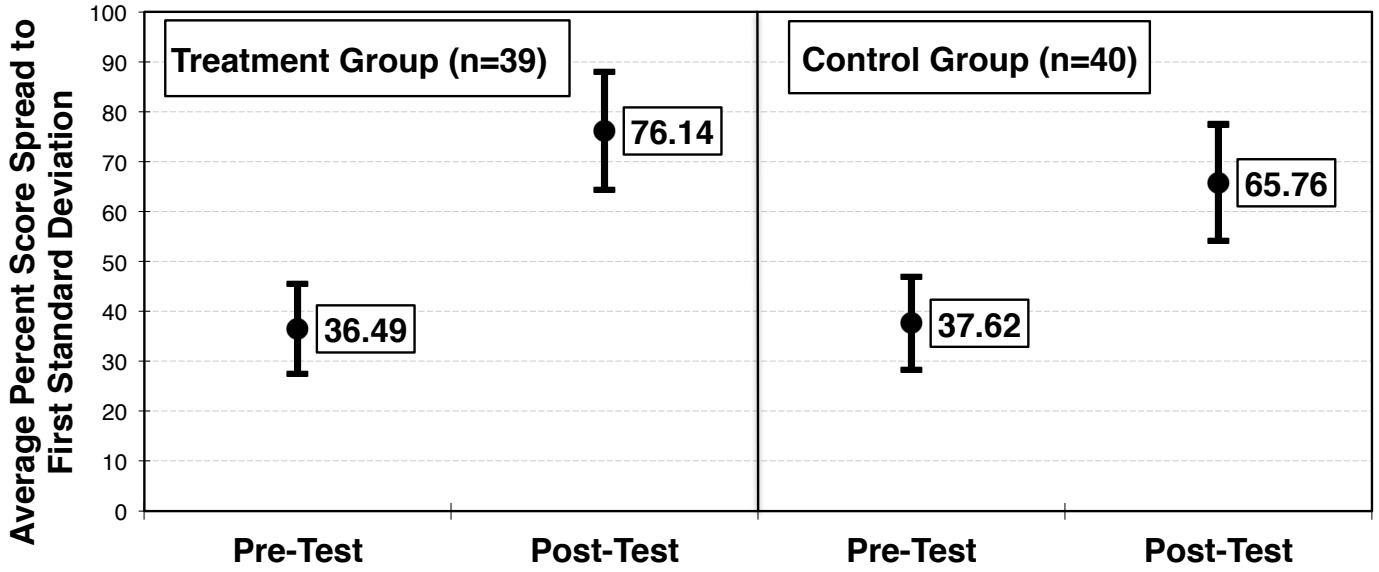
FINAL 2-WEEKS: Final projects during class and lab periods for oral and written (on our blog) presentation



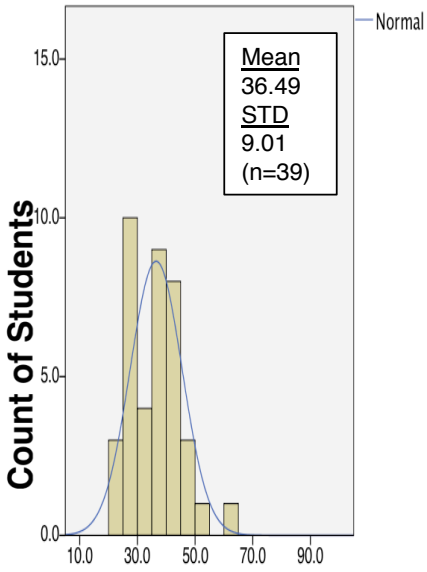


Pre/Post diagnostic exams

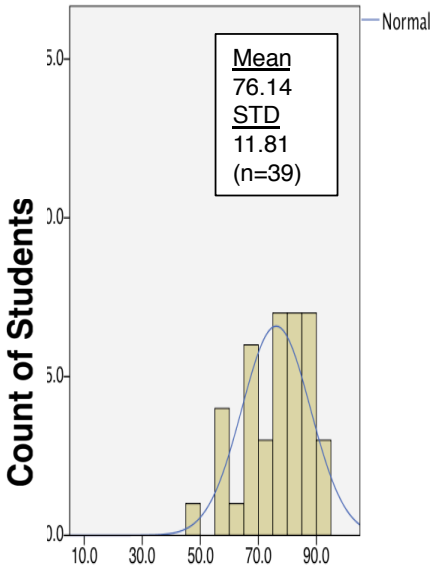
a



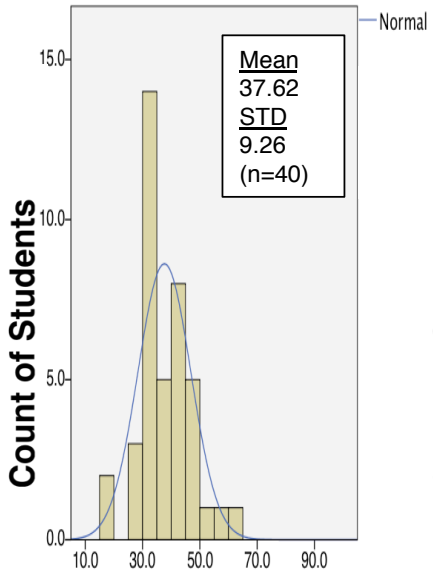
b



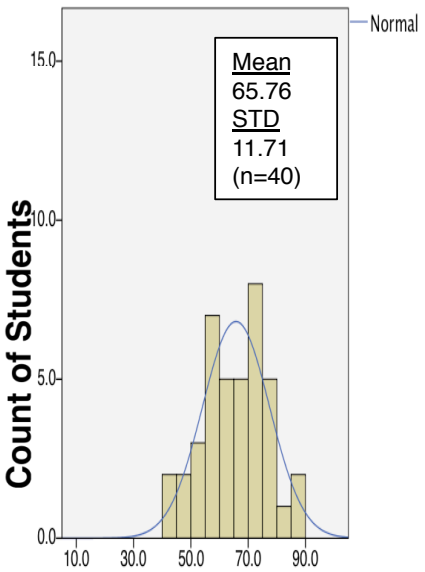
Distribution of Treatment Pre-Test Scores



Distribution of Treatment Post-Test Scores

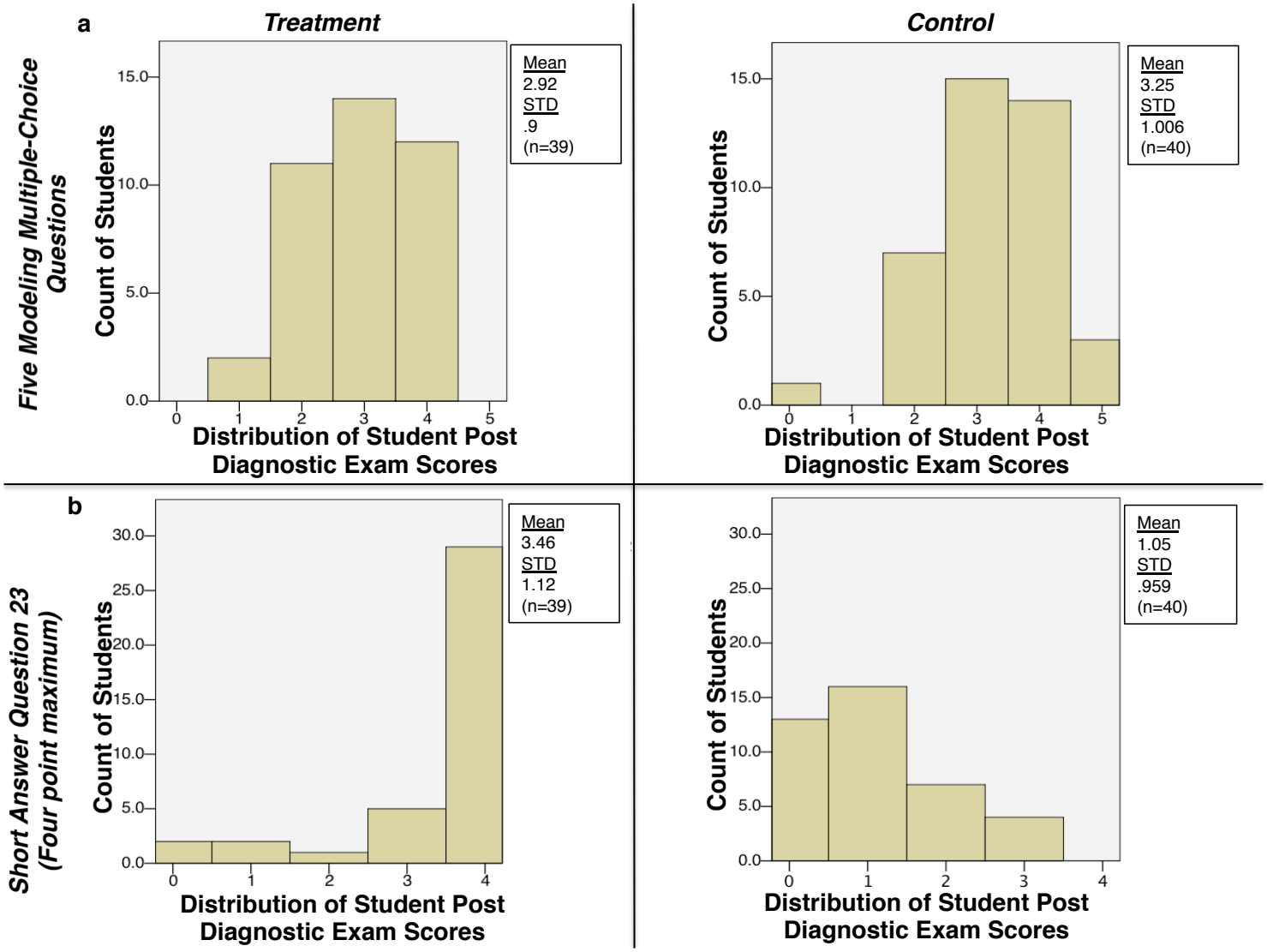


Distribution of Control Pre-Test Scores



Distribution of Control Post-Test Scores

Pre/Post diagnostic exams



Pre/Post diagnostic exams
Climate forcings essay question

	Treatment
Number of students answering/class size	26/39
Change in students answering this question pre to post	-5.2%
Mean Post Score (15 point max)	10.34615385
Standard Deviation	3.772980866

Control
27/40
7.5%
7.777777778
3.826359319

"The first factor is humans releasing greenhouse gases into the atmosphere. Due to the GHGs being released and their resonance time, they trap the infrared radiation from the sun causing global climate change (GHG effect)."

"The greenhouse effect is essentially the process by which solar radiation reflected off the Earth's surface, and radiation emitted by the Earth itself are "bounced" back down and "trapped" by GHG in the atmosphere..."

Pre/Post diagnostic exams
Global climate models essay question

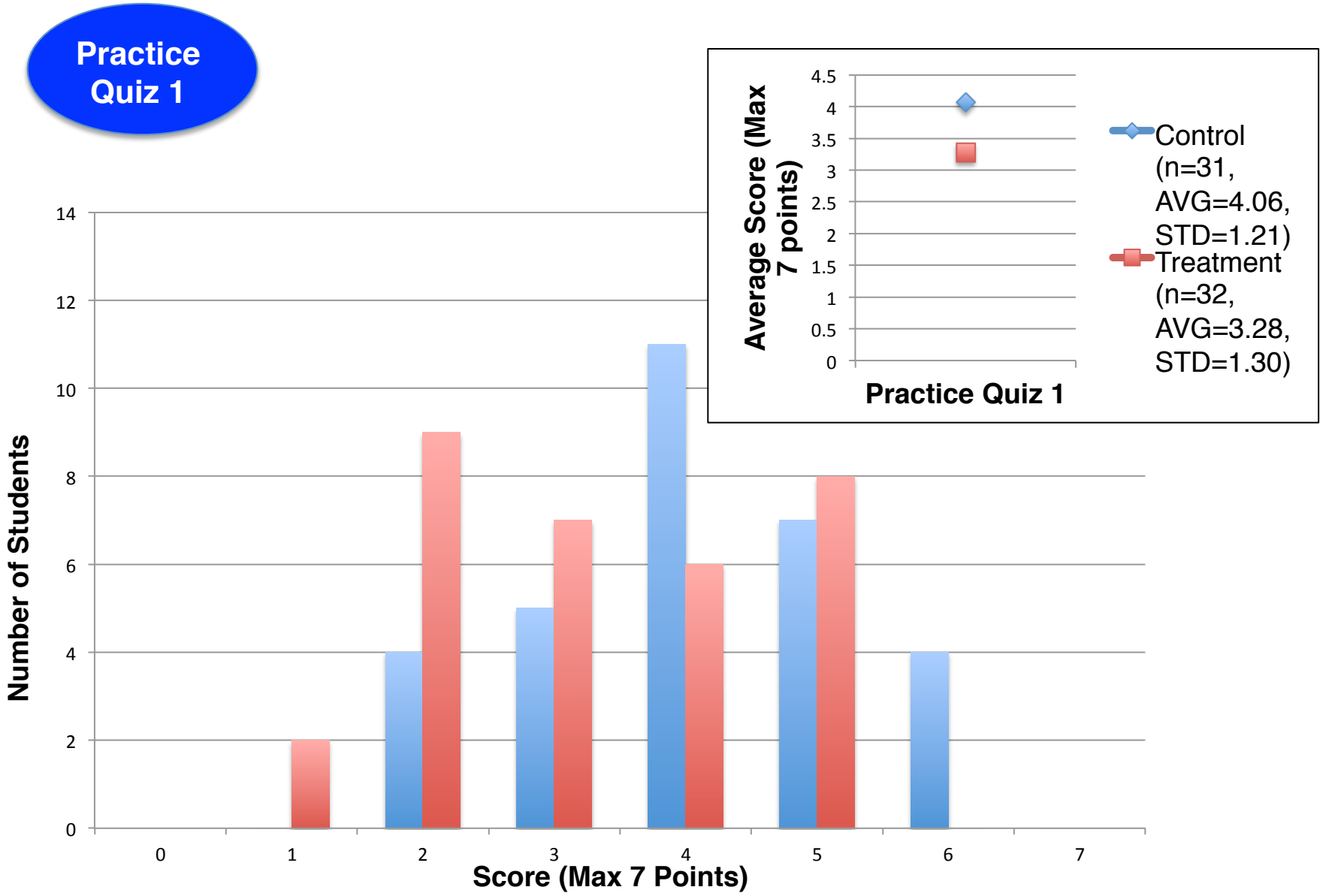
	Treatment
Number of students answering/class size	12/39
Change in students answering this question pre to post	26%
Mean Post Score (15 point max)	11.16666667
Standard Deviation	3.904154741

Control
20/40
17%
5.523809524
3.444111607

Part A: "Hindcasting is the process of running experiences to get maps and data from the past, then comparing it to real recorded data to evaluate the accuracy and precision of the climate model."

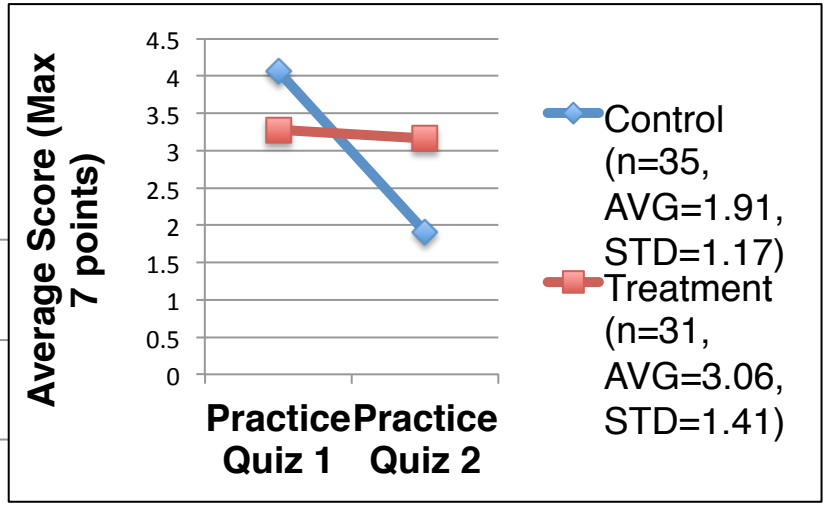
Part A: "Hindcasting makes a model for present data and goes back in time to see if the model correlates well to the real data taken in the past."

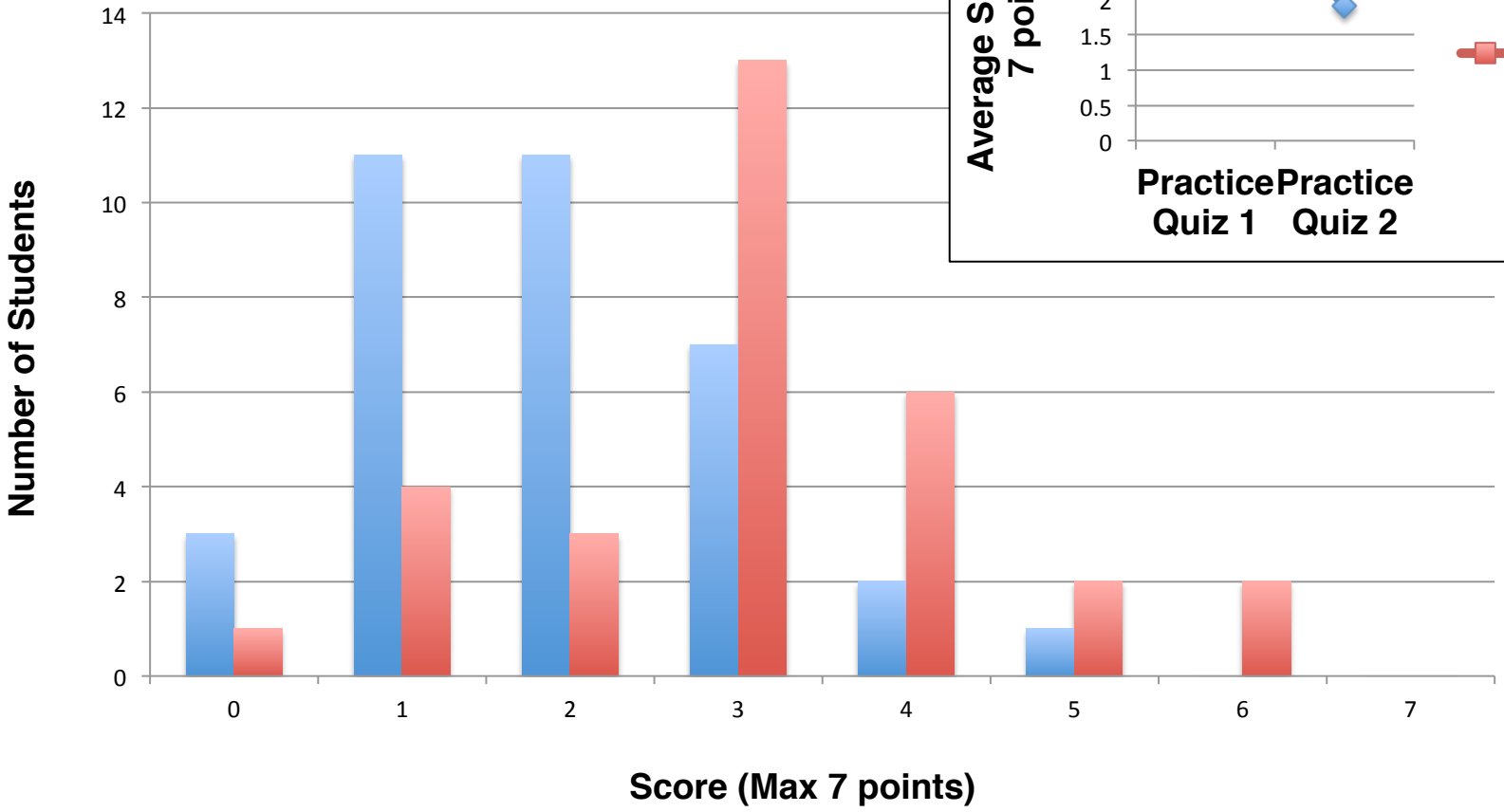
Week 2, *Quiz Topic:* Climate and Earth Science (7 MC)



Week 3, *Quiz Topic:* Climate Models (3 MC, 1 SA)

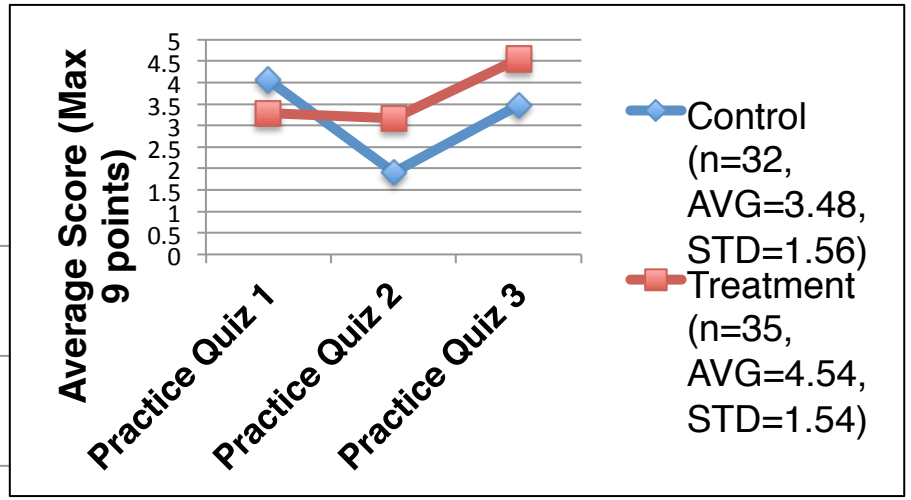
Practice Quiz 2

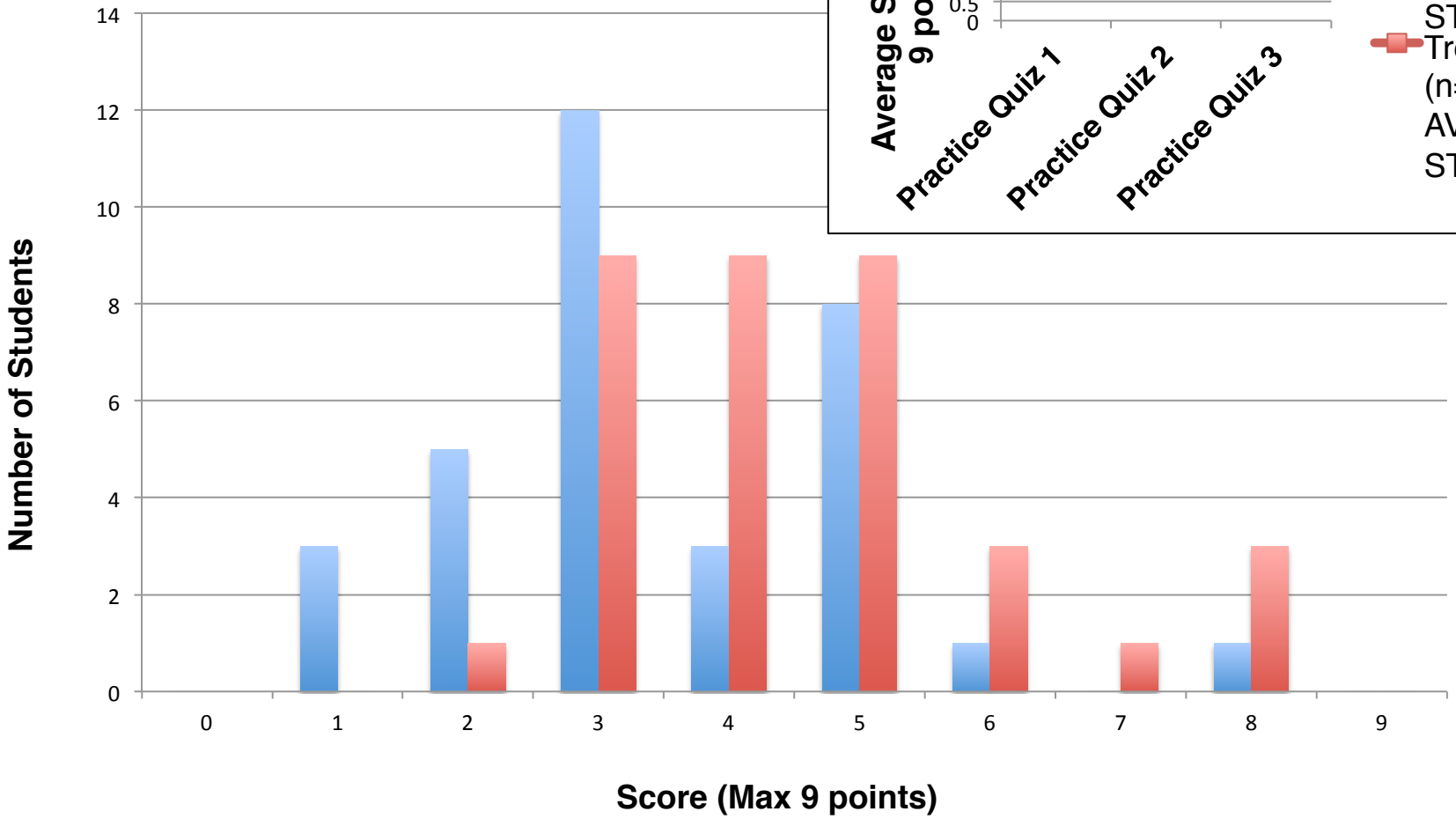




Week 4, *Quiz Topic:* Good Science, Climate Policy, and Climate Models (3 MC, 3 SA)

Practice Quiz 3





Written class reflections

CONTROL (n=32)

Before Lecture

72 percent think GCMs take an "average of the past climate" to "predict the future"

After Lecture (<80 minutes later)

44 percent unsure what users do versus the GCM

63 percent unclear GCMs use physical equations

41 erroneous ideas on how scientists conduct modeling experiments.

Written class reflections

TREATMENT

Final Project Work (n=26)

53 percent on designing scientific experiments

40 percent understanding modeling process

50 percent finding background information

Lamented the complexity of software, inadequate "available time to use EdGCM," and technical errors where the model kept "shutting down"

Initial EdGCM Lab (n=37)

12 comments on lack of user-friendliness

16 comments on time it takes to use/operate

22 comments on it being too complicated/too many features

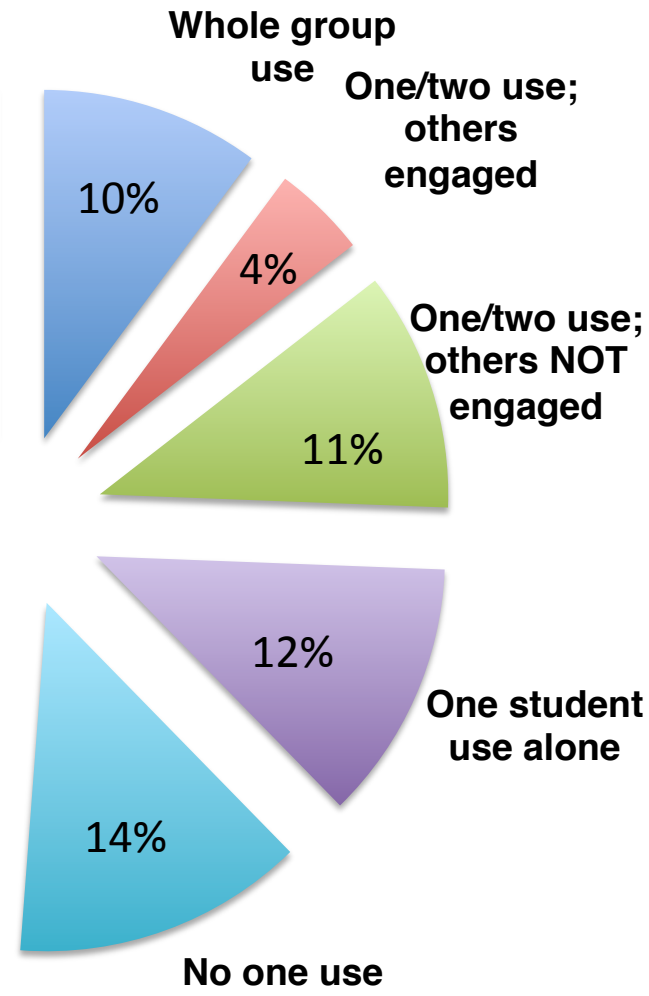
Preliminary video research

TREATMENT

- 24 Videos of 1-25 min each (2 excluded)
- *With Computers:* 12 videos, **207 min**

OTHER OBSERVATIONS:

- 13 Instructor guidance moments
- 14 Browser or Microsoft Word
- 2 Students leave
- 5 End-of-term discussions
- 57 minutes of quiet work together
- 22 camera acknowledgements & acting scenarios



Much more to come: Non-computer, tech issues, group dynamics

Conclusion & implications

1. Learning with EdGCM resulted in significant learning gains versus the control and resulted in deeper conceptual understanding

2. Disparities in this conceptual learning grew during the course, with treatment more focused on scientific/modeling process

3. Need exists for technology that NOT ONLY replicates scientific process but ALSO is simple to use

Thank you!

Questions & contact:

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