Assessment of a Constructivist-Motivated Mentoring Program to Enhance the Teaching Skills of Atmospheric Science Graduate Students

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CMMAP Team Meeting

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“[A candidate for the Ph.D. degree] must be in touch with the most recent and most successful movements in undergraduate education, of which he [or she] now officially learns little or nothing. How should he [or she] learn about these movements? Not, in my opinion, by doing practice teaching upon the helpless undergraduate. Rather he [or she] should learn about them through seeing experiments carried on in undergraduate work by the members of the department in which he [or she] is studying.”

Robert Maynard Hutchins
inaugural address as University of Chicago president (1929)

Presentation Outline

- CC-CMMAP Undergraduate Education Initiatives
  - CMMAP Education Mission & Initiatives
  - CC Earth Systems Classes
- Mentoring Program Assessment
  - Structure & Development of Mentoring Program
  - Qualitative Methods & Results
  - Quantitative Methods & Results
- Conclusions & Future Work

CMMAP EDUCATION MISSION

Educate ... a diverse population in climate and Earth System Science by enhancing teaching and learning ... and improving science pedagogy.

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CMMAP Education & Diversity Initiatives

- **Improve undergraduate Earth Systems Science and climate education.**
- **Teach next generation of leading climate scientists to be better teachers.**
- Improve the retention of women in the science and engineering "pipeline" from middle school through graduate school.
- Improve recruitment of under-represented groups into Earth Science at the undergraduate level.

Earth System Science Education

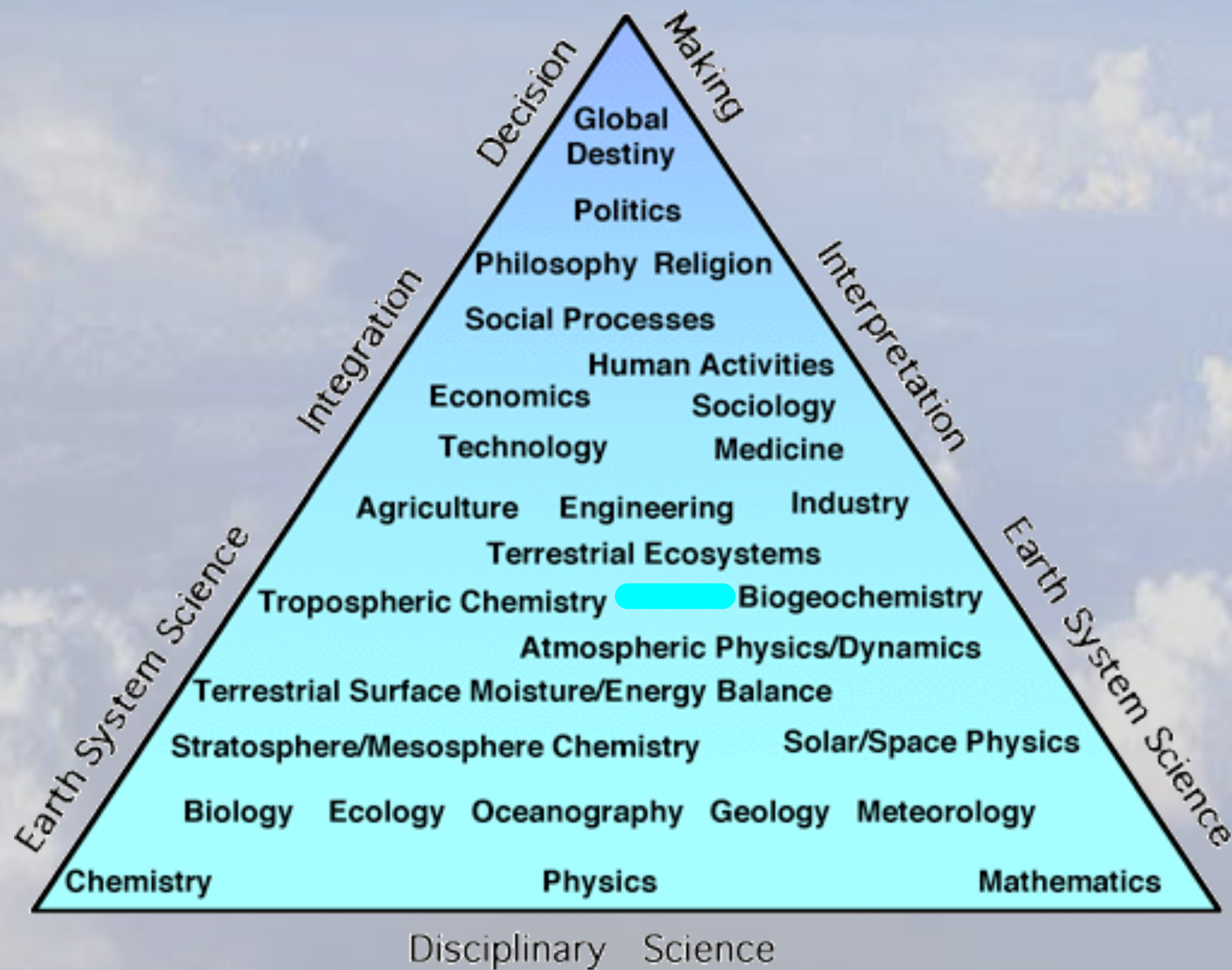
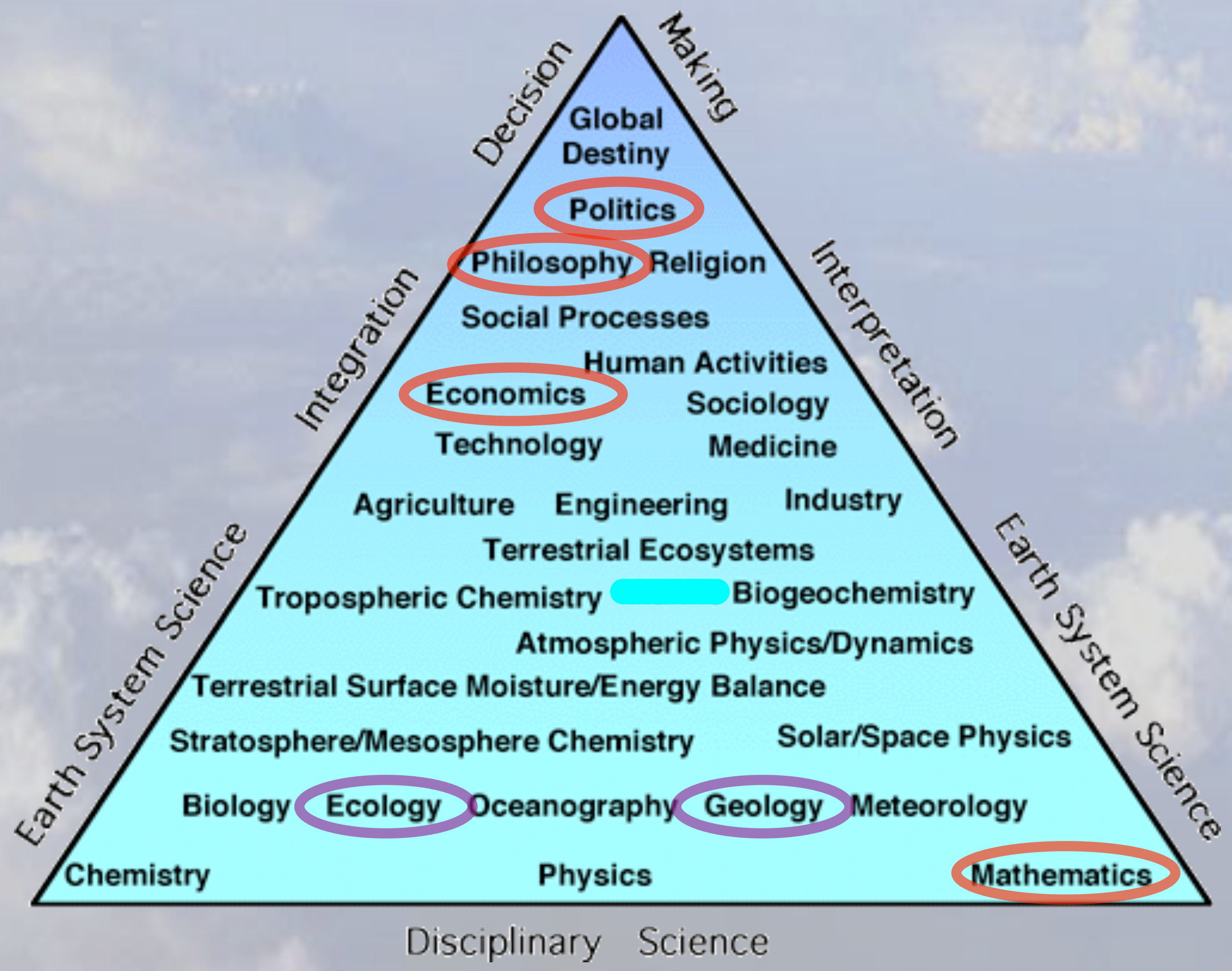


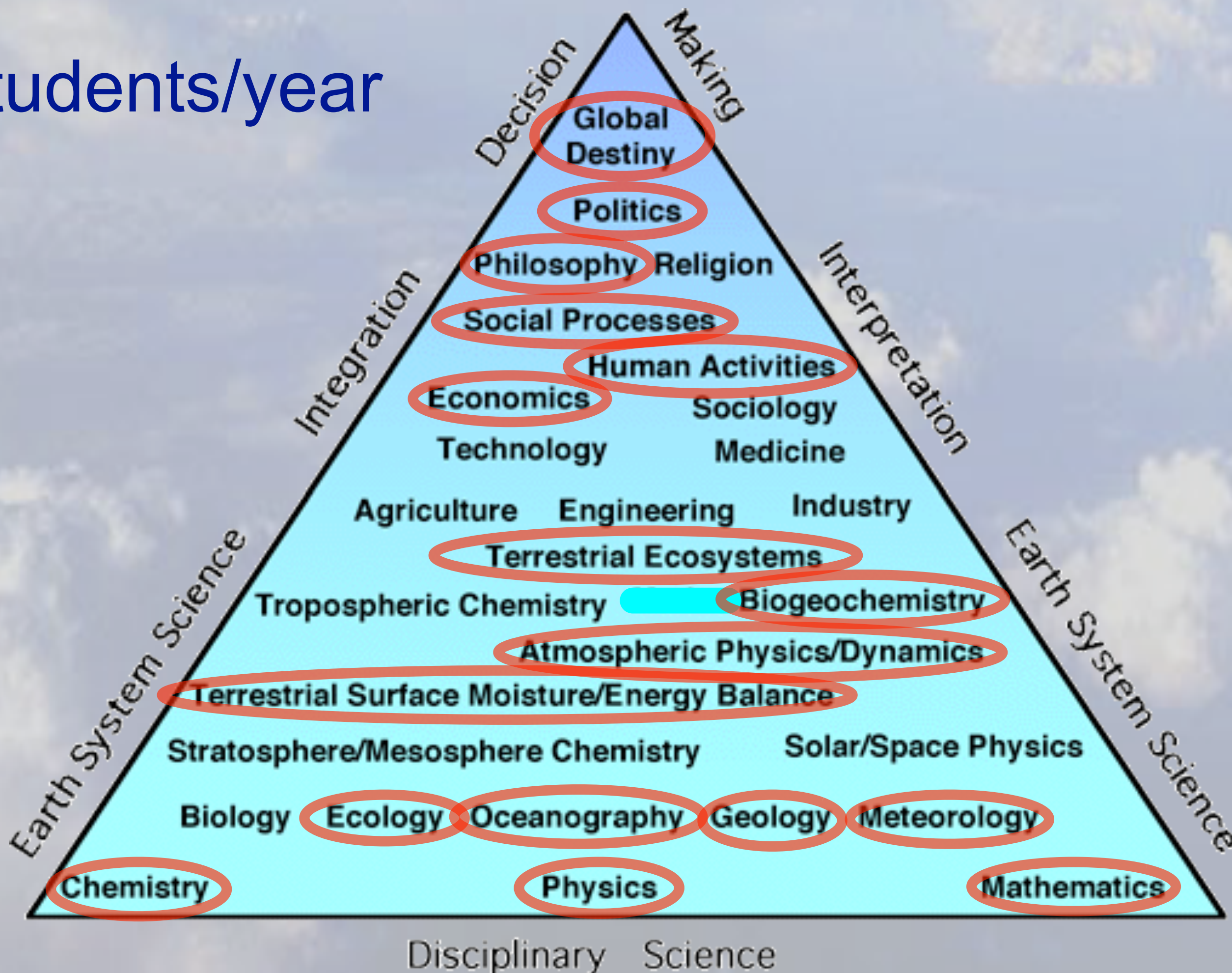
Image from ESSE 21, *Earth System Science in a Nutshell*:
http://serc.carleton.edu/introgeøearthsystem/nutshelłindex.html

Discipline-Based Classes



EV 128
Introduction to Global Climate Change

~100 students/year



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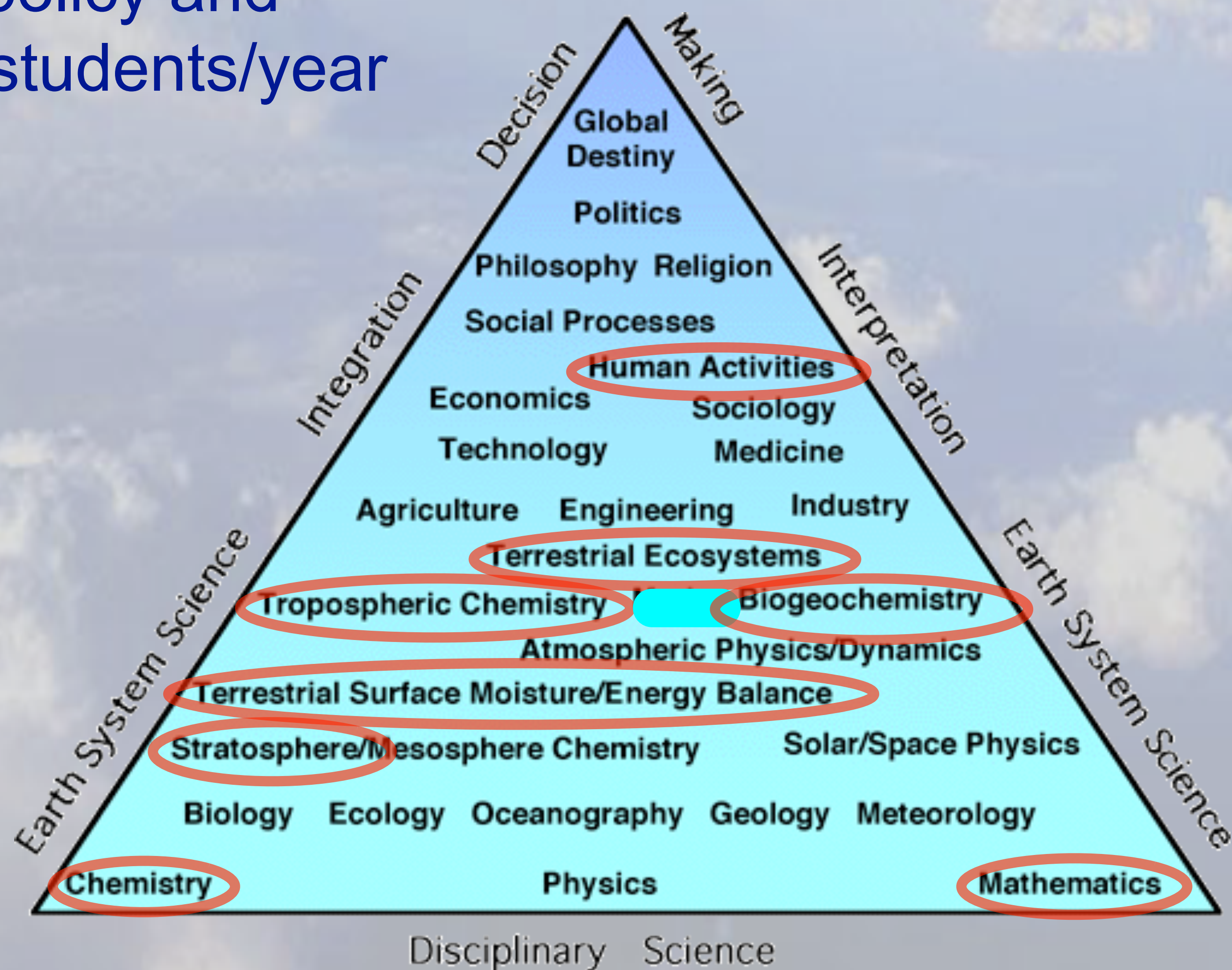
EV 128
Introduction to Global Climate Change

Some Key Questions:

- How do scientists deal with uncertainty?
- Does science provide the “correct” answers?
- How do scientists reach a consensus?
- What can science provide to policy makers?
- What ethical issues relate to climate change?

EV 211
Human Impacts on Biogeochemical Cycles

~50 policy and
science students/year



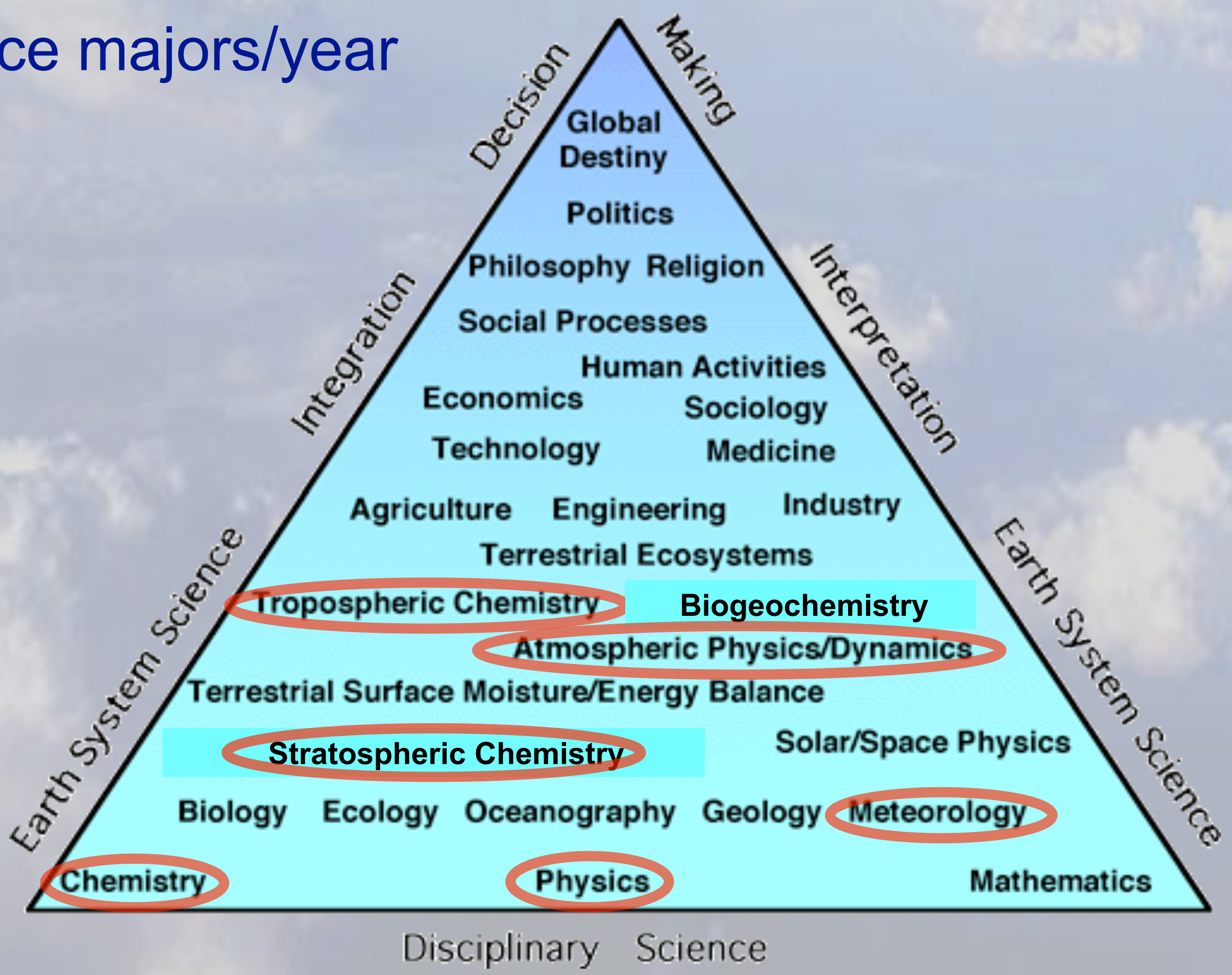
EV 211
Human Impacts on Biogeochemical Cycles

Some Key Questions:

- How do we build mathematical models?
- How does general chemistry inform the Earth system?
- What are some surprising effects of feedback?
- How sensitivity is the model to select parameters?
- How do we evaluate the quality of data?
- Why do systems often display complex behavior?

EV 431:Air
Atmospheric Physics & Chemistry

~20 science majors/year

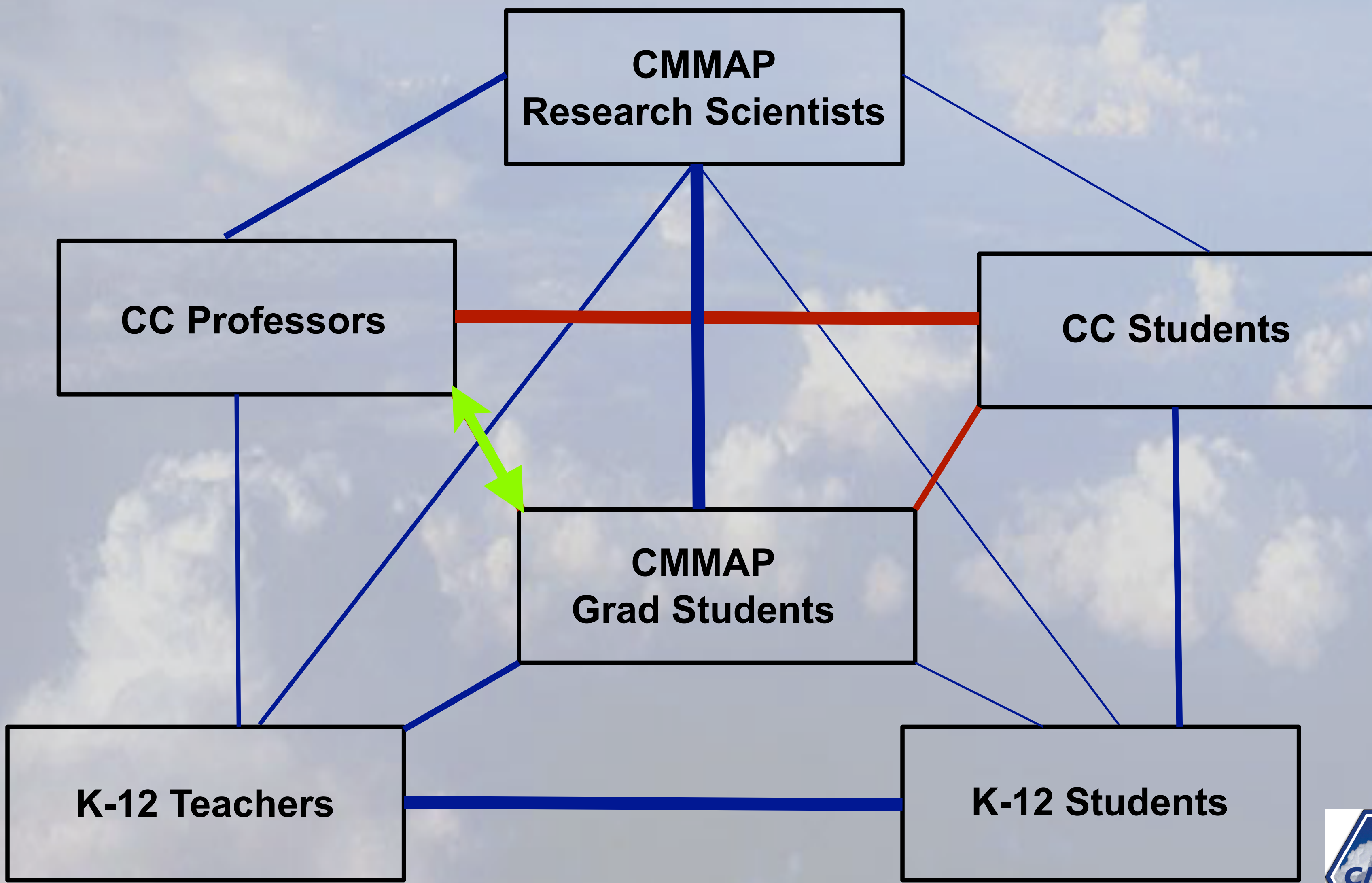


EV 431:Air
Atmospheric Physics & Chemistry

Some Key Questions:

- How do we describe atmospheric dynamics?
- How do we predict the weather?
- Why does ozone chemistry appear to change in different regions of the atmosphere?
- How do we measure local air quality?

Educational Objectives Integration



Preparing Future Faculty Members
What Works?

Among the alternatives for training graduate students to teach, mentoring relationships seem to have the best success (1, 2).

The Preparing Future Faculty initiative suggests:
"a particularly underutilized source of expertise is faculty members in other geographically accessible institutions, particularly those who are recognized as successful teachers and who use innovative and engaging approaches to teaching and learning." (3)

1. Boyle, P. and B. Boice (1998). "Systematic Mentoring for New Faculty Teachers and Graduate Teaching Assistants." ***Innovative Higher Education*** **22(3): 157-179.**

2. McComas, W. F. and A. M. Cox (1999). "Enhancing undergraduate science instruction through science education partnerships: The G-Step method." ***Journal of College Science Teaching*** **29: 120-125.**

3. Adams, K. A. (2002). ***What Colleges and Universities Want in New Faculty*****. Washington DC, Association of American Colleges & Universities.**

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CMMAP Graduate Student Teaching Fellows

- **Luke Van Roekel** (EV 431-07): Drossman
- **Jim Benedict** (EV 431-08): Drossman
- Kate Thayer-Calder (EV 128-08): Leonard
- **Kelley Wells** (EV 431-09): Drossman
- Rachel McCrary (EV128-09): Taber
- Anna Harper (EV 128-09): Fricke
- Kate Thayer-Calder (EV 128-09):Taber
- Ian Baker (EV 211-09): Drossman
- **Erica McGrath-Spangler** (EV431-10): Drossman
- Mari Titcombe-NCAR (EV 211-10): Drossman
- Kat Huybers-UW (EV 128-11): Kummel

Synergistic Mentoring Relationships

CMMAP Graduate Students

- Gain exposure to teaching undergraduate students;
- Work hand-in-hand with experienced liberal arts teaching mentors;
- Become involved in the scholarship of teaching and learning (SOTL).

CC Mentors

- Learn more about current scientific research
- Enhance knowledge of complementary areas of environmental science.

Undergraduate Students

- Benefit from the complementary skills of the team teachers;
- Have younger faculty role models;
- Learning with new curricular developments;
- Peer undergraduate student helper.

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Mentoring Process

Formal job application

On-campus interview

Teaching Preparation

Course Teaching (POGIL)

Reflection

Mentoring Program Assessment

	Interior	Exterior
Individual	What experiences affect how I teach?	What observable evidence exists for students' learning?
Collective	How does culture affect my teaching?	Do 'classroom experiments' help mentors learn to teach? Do 'classroom experiments' hinder students' learning?

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“Classroom Experiment”
Process Oriented Guided Inquiry Learning (POGIL) Approach

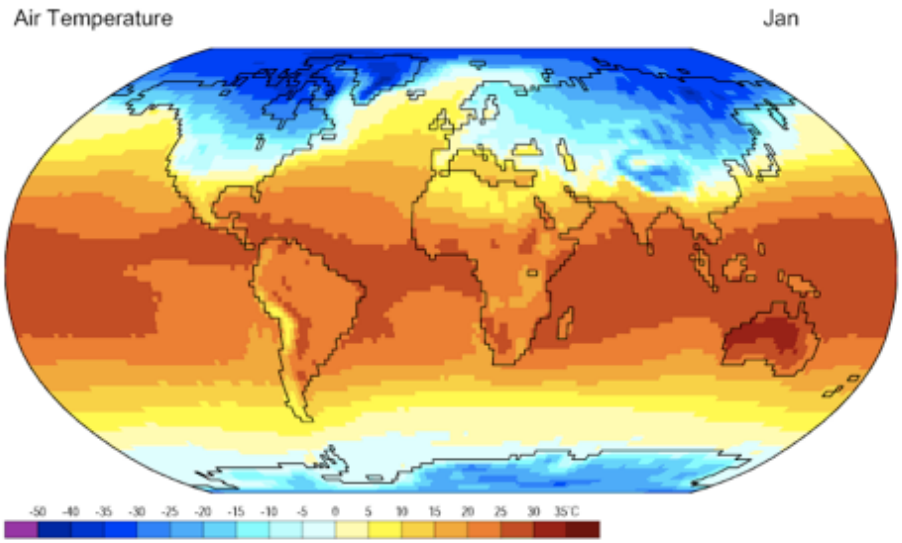
Students work in small groups in well-defined roles on carefully designed guided inquiry materials.

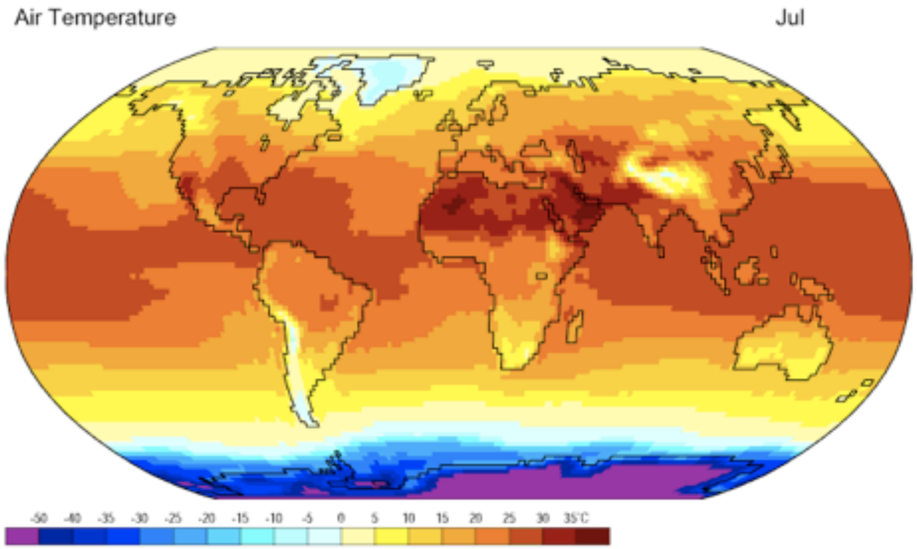
Materials provide data or information followed by leading questions that assist them toward formulating their own concepts.

Instructor acts as facilitator rather than lecturer; primary role to observe and address group and classroom-wide needs as required.

POGIL MODEL

Below is the average global surface temperature for January and July (averaged from 1959 – 1997). Purples are the coldest temperatures and reds are the warmest.





1. Compare the Equator-to-North Pole *T* gradient in January to the Equator-to-South Pole *T* gradient in July. Which is stronger? In which hemisphere is the Equator-high latitude *T* gradient *more* dependent on the choice of longitude? Why?

2. Using the set of equations in Model 1 and your answer to Model 2 Q2, describe the wind aloft (tropopause) in terms of speed, direction, and overall how wavy the flow is.

3. Would you expect any motion from the troposphere to the stratosphere (vertically) over the winter pole? Why or why not?

4. Based on your responses to the questions in Model 1 and Model 2, in their respective winters, do you expect the Arctic or the Antarctic to be more isolated from the rest of the Earth? Why?

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Research Methods

- Fellows read about constructivist pedagogy **after** teaching.
- Written reflections on whether the approach used for teaching the class and learning about teaching was consistent with constructivist-motivated pedagogy.
- Reflections used to identify relevant prose, repeating ideas, common themes and theoretical constructs.
- Develop hypotheses about mentoring experience.

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Analysis constraints

Each Fellow confirmed the accuracy of the list of repeating ideas by generating their own list of relevant themes.

Repeating themes grouped into several possible theoretical constructs and discussed with Fellows to achieve a consensus list.

Selection criteria

a) all common themes included no less than ten total repeating ideas from at least three of the four Fellows

b) all theoretical constructs included responses from all Fellows.

Constructivist philosophy simplified

Cognitive constructivism:
Knowledge is constructed due to active mental activity of the learner and not transferred directly from teacher to learner.

Social constructivism:
It is in the process of articulating, reflecting and negotiating that we engage in a knowledge construction process.

Mentoring Reflection Framework

	Interior	Exterior
Individual	**How did I learn to teach?** Cognitive constructivism?	**What observable evidence exists for my learning?** Mentor self-assessment Student assessment
Collective	**How did students learn?** Social constructivism? Cognitive constructivism?	**What structures affected the students' learning?** Classroom dynamics POGIL structure Class 'culture'

RESULTS:
Theoretical Construct 1

A constructivist-motivated approach to mentoring effectively allows graduate fellows to learn about constructivist-motivated pedagogy. (54)

a) Fellows' views about effective teaching significantly changed as a result of the teaching fellowship. (21)

b) Learning to teach in a real college-level course was a constructivist-motivated approach. (22)

c) Appropriate time for reflecting on their preconceptions about their teaching allowed the Fellows to gain a deeper understanding of pedagogy. (11)

Example of support for construct 1a: Changing views on teaching

"I realize that, through experience and reflection, my teaching career will be a continuing constructivist process. Gone from my mind is the image that only the first couple of years of teaching require hard work, after which a perfect lesson plan is established. Though major elements of the class may stay the same, [an effective teacher] constantly examines new methods of teaching, looks for new classroom demonstrations and new ways for the students to truly own the material [that] will benefit both the student and teacher."

Example of support for construct 1b: Teaching as constructivist activity

"Overall, we worked very hard to minimize lecture time and instead allowed students to discover and discuss key atmospheric science concepts on their own with our guidance"

"I have learned that it is necessary to consider teaching methods outside of my own comfort zone that may be different from how I have been taught and prefer to learn myself."

Example of support for construct 1c: Time for refection

"I am still thinking and reflecting on what I learned about teaching atmospheric science, … refining my ideas about effective pedagogy, and determining how much of a constructivist I became as a teacher. There was very little time to do this seriously while in the midst of teaching."

"Getting some of my ideas on paper is helping me to form and test my own hypotheses on what makes effective teaching in the atmospheric sciences, and giving me a better understanding of how my [mentored teaching] experience might inform my future teaching. It is also giving me practice using pedagogical terms…"

Theoretical Construct 2

Graduate fellows learn to formulate hypotheses related to the scholarship of teaching and learning (SOTL) by reflecting on their development and use of pedagogical innovations. (69)

a) A student-centered approach motivates learning by adapting pedagogy to their learning needs and providing appropriate time for reflection. (36)

b) The use of real world applications promotes undergraduate student learning. (14)

c) Constructivist-motivated pedagogy requires thoughtful consideration of the dialectic between process and content. (19)

Examples of support for construct 2a: Student-centered approach

"The students certainly negotiated their understanding of the content with me, but we stayed very focused on the concepts that I had previously determined I wanted them to learn."

"Wherever possible, I introduced topics in the POGIL worksheets by highlighting (and quickly debunking) common misconceptions. For example, students discovered that cloudy air at mountaintop level could actually contain less water vapor than clear but warmer air at a lower altitude. Similarly, a short exercise revealed that, all else being equal, moist air is less dense than dry air, despite our attachment to words such as 'heavy' and 'dense' when describing fog."

Example of support for construct 2b: Real-world applications

"Perhaps one of the most effective strategies of our teaching approach … was connecting classroom concepts to the outside world."

"Relevance was an important part of this course. [We] chose to focus on the 'big picture' rather than a memorization of formulas and facts and wanted to keep this 'big picture' interesting. While not everyone is thrilled to learn about adiabatic compression and latent heat, most people are interested in the weather."

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Example of support for construct 2c: Dialectic between process & content

"The use of at least some elements of constructivist pedagogy allowed students to understand fundamental concepts of atmospheric science at a deeper level than other students I have taught. However, we also covered less material than other introductory meteorology courses."

"What topics in atmospheric science did the students need to know, and can I teach such topics in less than ten days? How do I balance presenting the dull but necessary concepts with those that are more exhilarating and mysterious? Would I chastise myself with 'You forgot to teach them that?' after the class had ended?"

Theoretical Construct 3

The development and use of POGIL assignments and associated classroom pedagogy promotes graduate students' understanding of cognitive and social constructivist principles. (33)

a) The POGIL approach is an effective way to teach graduate students how to teach in ways that are consistent with a cognitive constructivist philosophy. (16)

b) The POGIL approach is an effective way to teach graduate students how to teach in ways that are consistent with a social constructivist philosophy. (17)

Example of support for construct 3a: POGIL as cognitive constructivist tool

"After working through the POGIL worksheets and putting them into practice, I think they ended up being the most constructivist element of the course. They worked well to help students draw upon their existing knowledge, apply it, and transform their point of view if and when that knowledge did not seem quite fitting within the new framework of atmospheric physics."

"We found that some POGIL worksheets were more effective than others [at promoting concept development]. The most successful POGIL worksheets were those that involved a real scientific problem, with actual data. When the students were presented with actual data, the concept seemed to stick better … compared to other POGIL assignments."

Example of support for construct 3b: POGIL as social constructivist tool

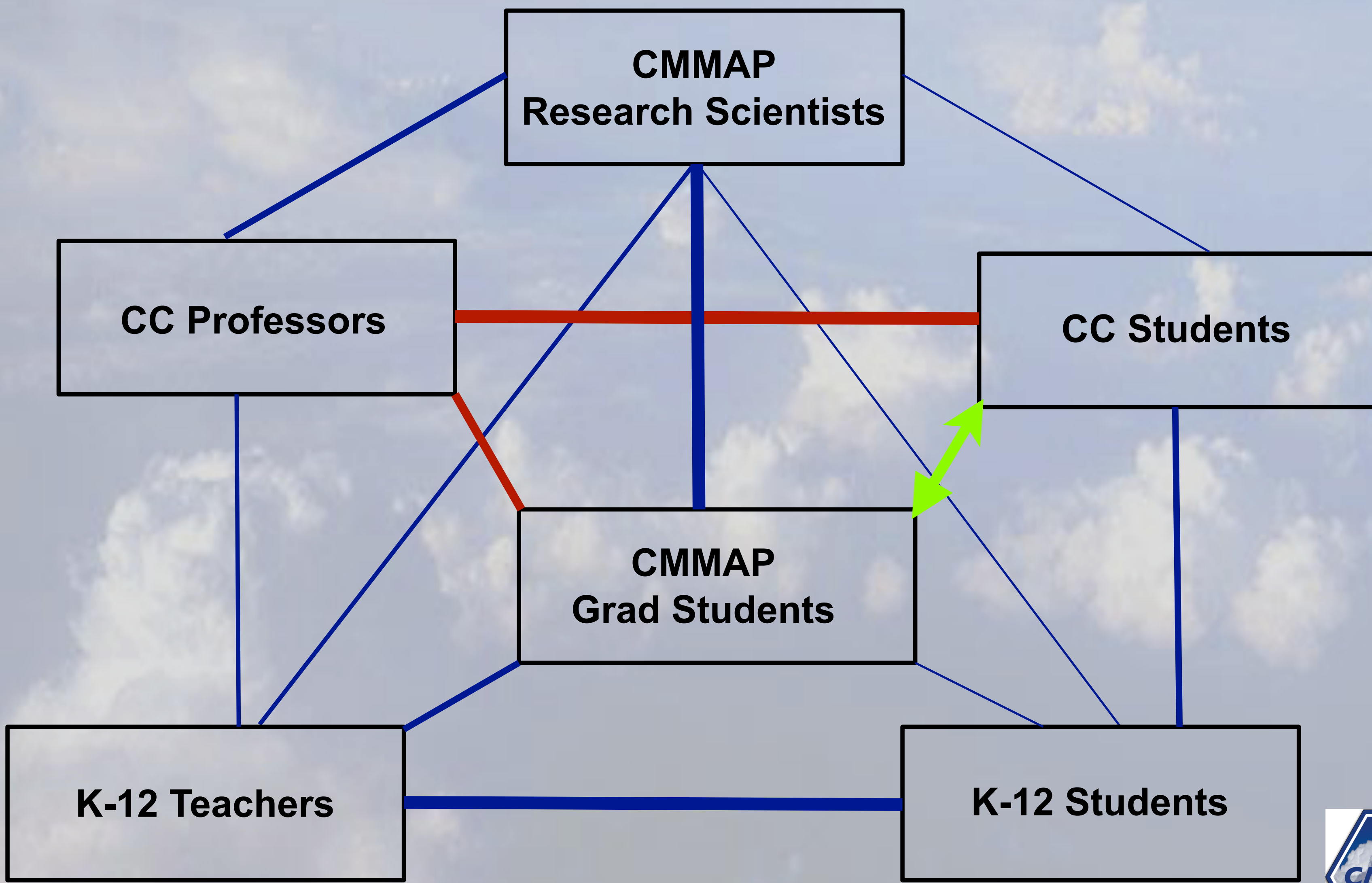
"The POGIL approach encourages students to utilize their collective knowledge base to solve problems; interpret, discuss, and scrutinize results within their group and with other groups in the class; and link ideas in order to better grasp the 'big picture'."

"The students not only preferred group work, they seemed to thrive on it. They were able to bounce ideas off one another with only occasional input from me to clarify tricky points. They felt they were able to learn best when they were explaining the material to their colleagues and were able to work together."

Summary

"… the teaching experience for … graduate students is both utterly exhausting and wholly rewarding. It is an awakening to the art and challenge of teaching, allowing the graduate students to draw upon their experiences as recent students to effectively convey the fundamental concepts to the next generation of scientists."

Educational Objectives Integration



Did 'classroom experiments' impact student learning?

	Interior	Exterior
Individual	**What inspires students to learn?** Motivation by real-world problems Metacognition	**What observations indicate individual student learning?** Homework, exams and POGILs End of class evaluation Daily "check-in"
Collective	**What inspires the class to learn?** Peer learning (POGIL) Social Interaction	**What observations indicate effective group learning?** In-class discussions Group assignments End of class evaluation

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Quantitative survey assessment

- Student Assessment of Learning Gains (SALG) for 2004, 2005, 2007-2010 classes.
- Likert response answers (1-5) to student perceptions of learning gains.
- 2004 and 2005 classes taught with experienced CC prof.
- 2007-2010 classes taught with Fellows using POGIL.

SALG Questions

Average: average score for all 60-65 quantitative questions in the survey

HOW MUCH did the following aspects of the class HELP YOUR LEARNING?

POGIL PC: POGIL Physics problems (not used in control years 2004 and 2005)

POGIL CH: POGIL Chemistry problems (not used in control years 2004 and 2005)

Lecture: Lecture and whole class discussion

As a result of your work in this class, what GAINS DID YOU MAKE in your UNDERSTANDING of:

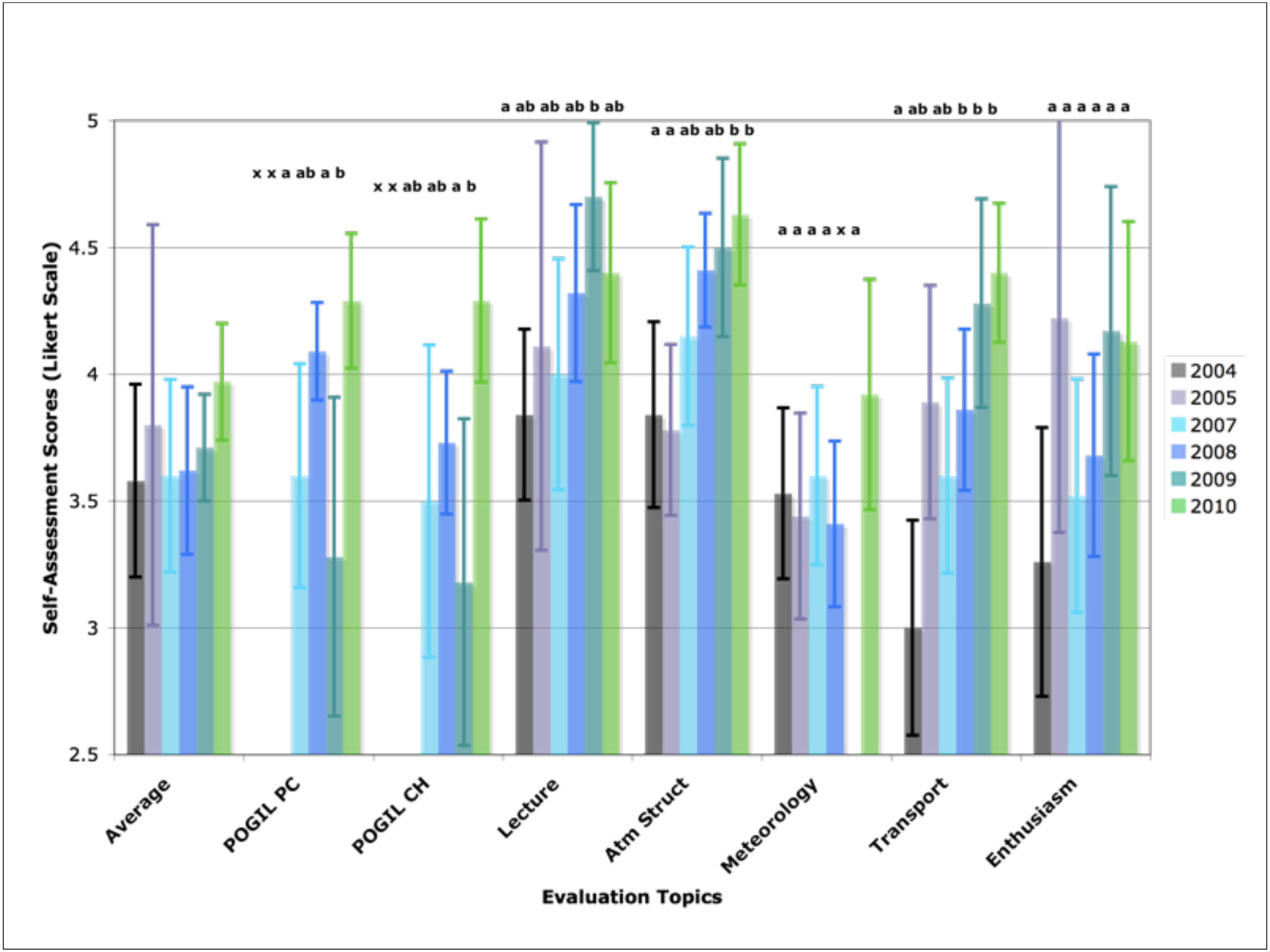
Atm Struct: Atmospheric structure (same question all years)

Meteorology: This question was not asked in 2009 and in 2010 was asked as understanding of midlatitude cyclones. All other years as understanding meteorology.

Transport: in 2009 and 2010, the topics were broken out into stability and forces and the average of the two topics is reported. For all other classes, students were asked if they understood transport as an encompassing theme.

As a result of your work in this class, what GAINS DID YOU MAKE in the following?

Enthusiasm: For 2009 and 2010, the question asked as: “Interest in discussing weather, climate and/or air quality with friends or family.” Prior to 2009, the question asked for “Enthusiasm for studying atmospheric science.”



Self-Assessment Scores (Likert Scale)
Evaluation Topics
5
4.5
4
3.5
3
2.5
Average
POGIL PC
POGIL CH
Lecture
Atm Struct
Meteorology
Transport
Enthusiasm
x x a ab a b
x x ab ab a b
a ab ab ab b ab
a a ab ab b b
a a a a x a
a ab ab b b b
a a a a a a
2004
2005
2007
2008
2009
2010

CC-CMMAP Project Assessment Strategies

- Reflective essays & Qualitative analysis
- SALG Assessment
- Demographic Surveys
- ACS Standardized Exams
- New Concept Inventories
- Literature-based evaluations
- Tracking student/intern careers

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Future Work

WHAT to disseminate

- Graduate student mentoring (JCST)
- POGIL Atmospheric materials (BAMS, Web)
- Literature-based climate change POGILs
- Class content and pedagogy
- Assessment strategies and results

HOW to disseminate

- Web
- Peer reviewed publications
- Workshops (PKAL, CUR, ACS, AGU, SENCER)


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Climate Inquiry

	Interior	Exterior
Individual	**What inspires me to take action about climate?** Understanding Motivation Connection	**What are observable data about climate change?** Climate Observations Hypothesis testing
Collective	**What inspires us to take action about climate change?** Activism Media Scientific Data	**What complex interactions affect climate?** Earth systems dynamics Human systems dynamics

Expert credibility in climate change

William R. L. Anderegg, James W. Prall, Jacob Harold, and Stephen H. Schneider

PNAS, July 6, 2010, **107**(27), 12107–12109

Although preliminary estimates from published literature and expert surveys suggest striking agreement among climate scientists on the tenets of anthropogenic climate change (ACC), the American public expresses substantial doubt about both the anthropogenic cause and the level of scientific agreement underpinning ACC. A broad analysis of the climate scientist community itself, the distribution of credibility of dissenting researchers relative to agreeing researchers, and the level of agreement among top climate experts has not been conducted and would inform future ACC discussions. Here, we use an extensive dataset of 1,372 climate researchers and their publication and citation data to show that (i) 97–98%of the climate researchers most actively publishing in the field surveyed here support the tenets of ACC outlined by the Intergovernmental Panel on Climate Change, and (ii) the relative climate expertise and scientific prominence of the researchers unconvinced of ACC are substantially below that of the convinced researchers.