

RUNNING HEAD: A Curriculum Experiment in Climate Change Education...

**A Curriculum Experiment in Climate Change Education
Using an Integrated Approach of Content Knowledge
Instruction and Student-Driven Research, Year 2**

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Abstract

One of the greatest challenges facing the world is climate change. Coupled with this challenge is an under-informed population that has not received a rigorous education about climate change other than what is available through the media. Fort Hays State University is in a second year of piloting a course on climate change targeted to students early in their academic careers. The course is modeled after our past work (NSF DUE-0088818) of integrating content knowledge instruction and student-driven research where there was a positive correlation between student research engagement and student knowledge gains. The second pilot offering utilizes a mix of inquiry-based instruction, problem-based learning, and student-driven research to educate and engage the students in understanding climate change. The course was collaboratively developed by a geoscientist and science educator. The course model is unique in that 50% of the course is dedicated to developing core knowledge and technical skills (e.g. global climate change, critical analysis, writing, data acquisition, data representation, and research design), and 50% to conducting a research project using available data sets from federal agencies and research groups. A key element of the course is a focus on data sets to make climate change relevant to the students. The impacts of course changes from the first offering to the second offering significantly improved student performance in research and understanding of climate change concepts. The course design has potential to improve student understanding and research skills in undergraduate students at other institutions.

Introduction

Global climate change is one of the most significant scientific, social, and political issues facing our species, and indeed poses a threat to the Earth's entire biosphere. Yet, despite the imperative to understand and act on global climate change, individuals across all subgroups in society lack knowledge of the key scientific issues, how to access and interpret data, and how to develop appropriate mitigation and adaptation strategies. For these reasons, the growing concern about global climate change is mixed with uncertainty and misinformation. In recognition of these concerns, NOAA organized a three-day workshop in April 2007 to develop guidelines for climate literacy (see www.climate.noaa.gov/education). The resulting document, *Climate Literacy: The Essential Principles of Climate Sciences* (February 2009) defines climate literacy as being able to:

1. Understand the essential principles of all aspects of the Earth system governing climate patterns.
2. Know how to gather information about climate and weather, and how to distinguish credible from non-credible scientific sources on the subject.
3. Communicate about climate and climate change in a meaningful way.
4. Make scientifically informed and responsible decisions regarding actions that may affect climate.

Despite a recognition of the growing importance of climate change as an environmental and political issue, the general population in the United States remains under-informed and misinformed about climate change. Their knowledge of the related science is limited to what is available through the popular news media. Fort Hays State University is piloting a course on climate change targeted to students early in their academic careers. The course is modeled after our past work (NSF DUE-0088818) of integrating content knowledge instruction and student-driven research which showed a positive correlation between student research engagement and student knowledge gains. The current course utilizes a mix of inquiry-based instruction, problem-based learning, and student-driven research to educate and engage the students in understanding climate change. The course was collaboratively developed by a geoscientist and science educator who are both active in promoting citizen science programs. The emphasis on civic engagement by students is reflected in the course structure. The course model is innovative in that 50% of the course is dedicated to developing core knowledge and technical skills (e.g. critical analysis, writing, data acquisition, data representation, and research design), and 50% to conducting a research project using available data sets from federal agencies and research groups. A key element of the course is a focus on local and regional data sets to make climate change relevant to the students. The research serves as a means of civic engagement by the students as they are tasked to understand their role in communicating their research findings to the community and coping with the local and regional changes they find through their research.

Course Description

A. Course Design

The objectives of this course are to (a) acquaint students with the current state of knowledge regarding climate change and (b) provide students with the skills required to do university-level scientific research.

The course was offered as a three credit hour course meeting two times a week. No text was used.

Content Lectures:

- Viewing an *Inconvenient Truth* [Paramount 2006] and readings *Physics for Future Presidents*, [Muller, 2009]
- Nature of Science & Development of Hypotheses
- Units, size and scale: Powers of Ten and Fermi Questions
- The Sun and the Earth: Energy and Energy Balance
- Sources of Climate Information and Errors
- Climate Forcing: Greenhouse gases and the carbon cycle
- Paleoclimate: Proxy Records
- Climate Modeling
- Scientific Literature: Reading and Abstracting
- Data Acquisition and Analysis

Exploratory Activities:

- Compare and contrast the views of climate change from two perspectives
- Hypotheses, falsifiability, and verifiability: Case Studies
- Abstract Writing & Scientific Writing
- Fermi Questions on Carbon Footprints
- Surface Albedo
- Greenhouse Effect with Carbon Dioxide
- Calibration, Accuracy, & Precision

- Data Acquisition and Analysis: Paleoclimate and Datasets
- Climate Modeling

Proposal Writing and Development (8 Weeks)

- Types of investigations in climate research: Choosing a topic
- Proposal development and peer review
- Proposal Revisions and peer review
- Research
- Proposal Revisions and peer review

B. Research Questions

The instructors of the course were conducting action research to determine if they were being effective in their instruction. The course was offered in the fall of 2009 for the first time to a group of 30 students at the Freshman level. Results from this experience were used to modify the course for offering in 2010. The primary changes in the course were structural in terms of changing content emphasis and organization for the student research project. The research questions in 2010 were to address our concerns about course improvement.

The research question driving the investigation of the course were:

1. Does the course content improve student understanding of climate change issues, specifically the greenhouse effect?
2. Is the course effective in developing positive attitudes towards science?
3. Does the course enhance student ability to conduct research?

Methods

Three measures were used to determine course effectiveness.

- Greenhouse Effect Concept Inventory (GECI) (Keller, 2008). GECI identifies common student misconceptions regarding the greenhouse effect. GECI was administered as a pre/post test. The purpose of this measure was to determine if we were improving student content knowledge relative to climate change issues surrounding global climate change.
- Test of Science-Related Attitude (TOSRA) (Fraser, 1981). TOSRA is designed to measure science-related attitudes: social implications of science(S), normality of scientist(N), attitude to scientific inquiry(I), adoption of scientific attitudes(A),

enjoyment of science lessons(E), leisure interest in science(L), & career interest in science(C). The purpose for this measure was to determine if we were having a positive or negative impact on student attitude towards science.

- Climate-Related Scientific Project Proposals Evaluation using an internally developed rubric. A core goal of the class is to develop students ability to conduct independent research. Though climate change is the focus, developing research skill is the critical for the curriculum of the students in the class.

C. Findings

1. Greenhouse Effect Concept Inventory (GECI)

The students showed a significant gain using a t-test ($p < 0.001$) from the pre- to post-test in both 2009 and 2010. The importance of the GECI is determining where students are having difficulty to improve instruction. While both years showed improvement in understanding, the two groups showed differences as illustrated below.

Questions that show low improvement in comparison between 2009 and 2010.

Q: Which of the following is a primary characteristic of greenhouse gases?

A: They are transparent to some forms of energy but not all.

'09: 76% on post; '10 : 32% on post

Q: Earth's surface is heated mainly by which two forms of energy?

A: infrared and visible

'09: 51% post; '10: 36% post

Question which showed greatest improvement for 2010 over 2009.

Q: During the nighttime, Earth's surface mainly gives off (radiates) which form of energy?

A: infrared

'09: 86% POST, '10: 14% POST

Question which has the lowest correct rate in both years.

Q: Due to the greenhouse effect, Earth's overall surface temperature is affected primarily by

A: an increase in the amount of energy exchanged between the surface and atmosphere.

'09: 14% post; '10: 14% post

Students in 2010 started with a lower overall average on the pre-test as compared to the 2009 class average. The final post-test averages in 2009 and 2010 were the same.

To compare the performance between the two years, differences between the pre- and post-test values were determined and graphed. The results are shown in Figure 1.

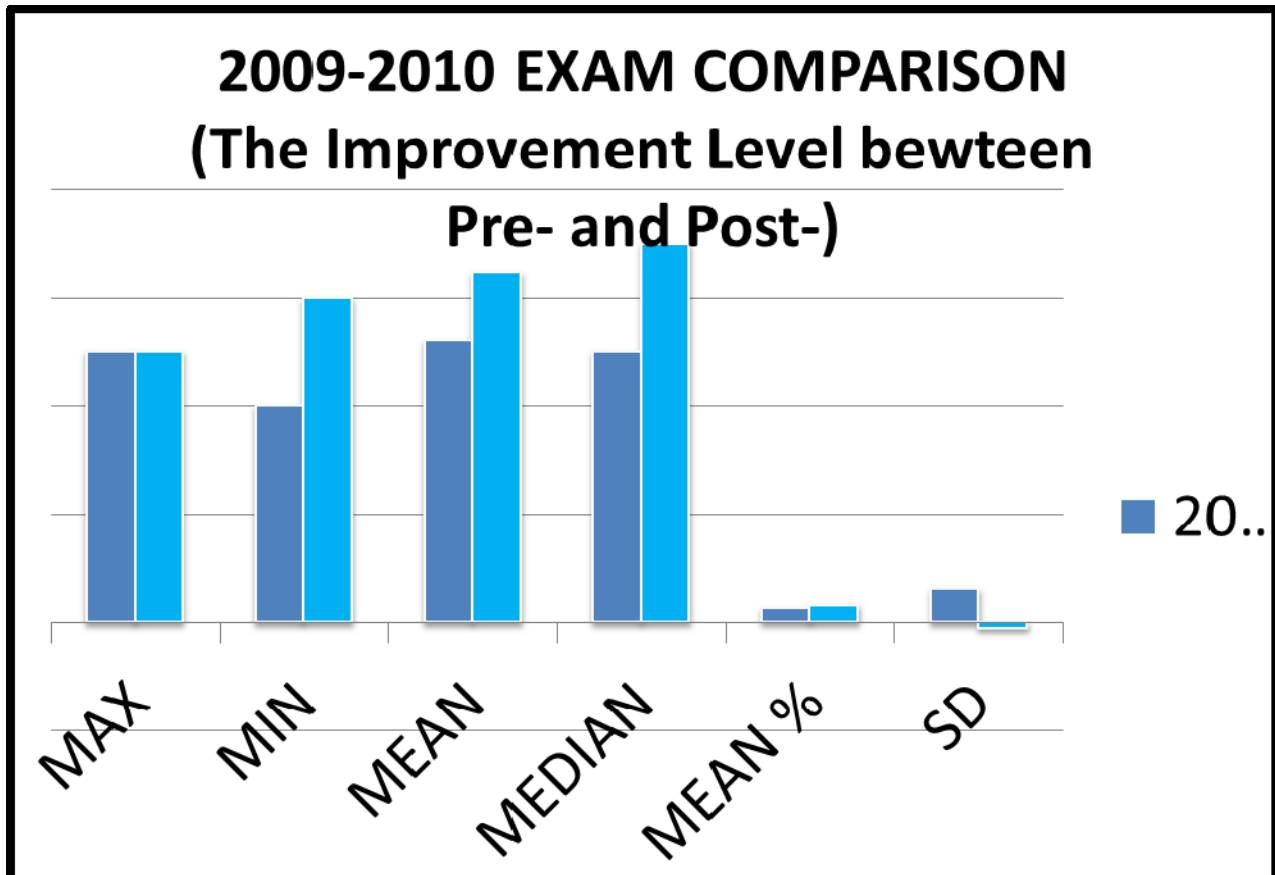


Figure 1: Comparison of the Improvement Differences (Post-test value – Pre-test value) - from 2009 to 2010.

Overall the structural changes in the course were viewed as being significant in improving student gains

2. Test of Science-Related Attitudes (TOSRA)

TOSRA was introduced to examine student attitudes as an indicator of student disposition towards science and future interest in science. As shown in Figure 2, there was a gain in attitude on all seven dimensions. Overall the gain was not significant ($p= 0.052$), yet a gain over a period of three months indicates the potential for the course to influence attitudes.

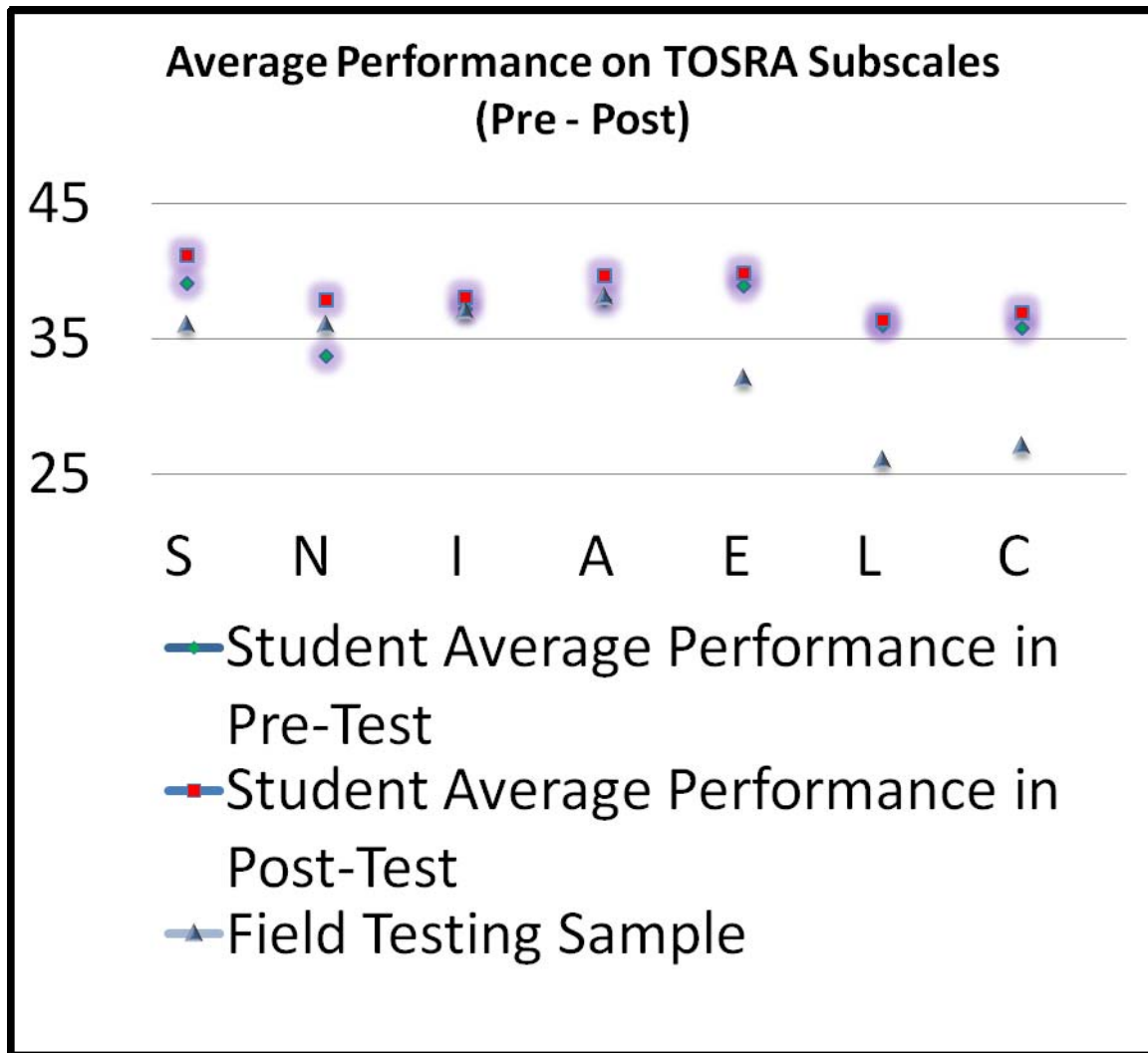


Figure 2: TOSRA Subscale Comparison

3. Climate-Related Scientific Project Proposal Evaluation

A key element of the course is a focus on data sets to make climate change relevant to students through a research project. Comparing 2010's project proposals to 2009's proposals, there was significant improvement in the scores ($p < .001$). Figure 3 presents the results.

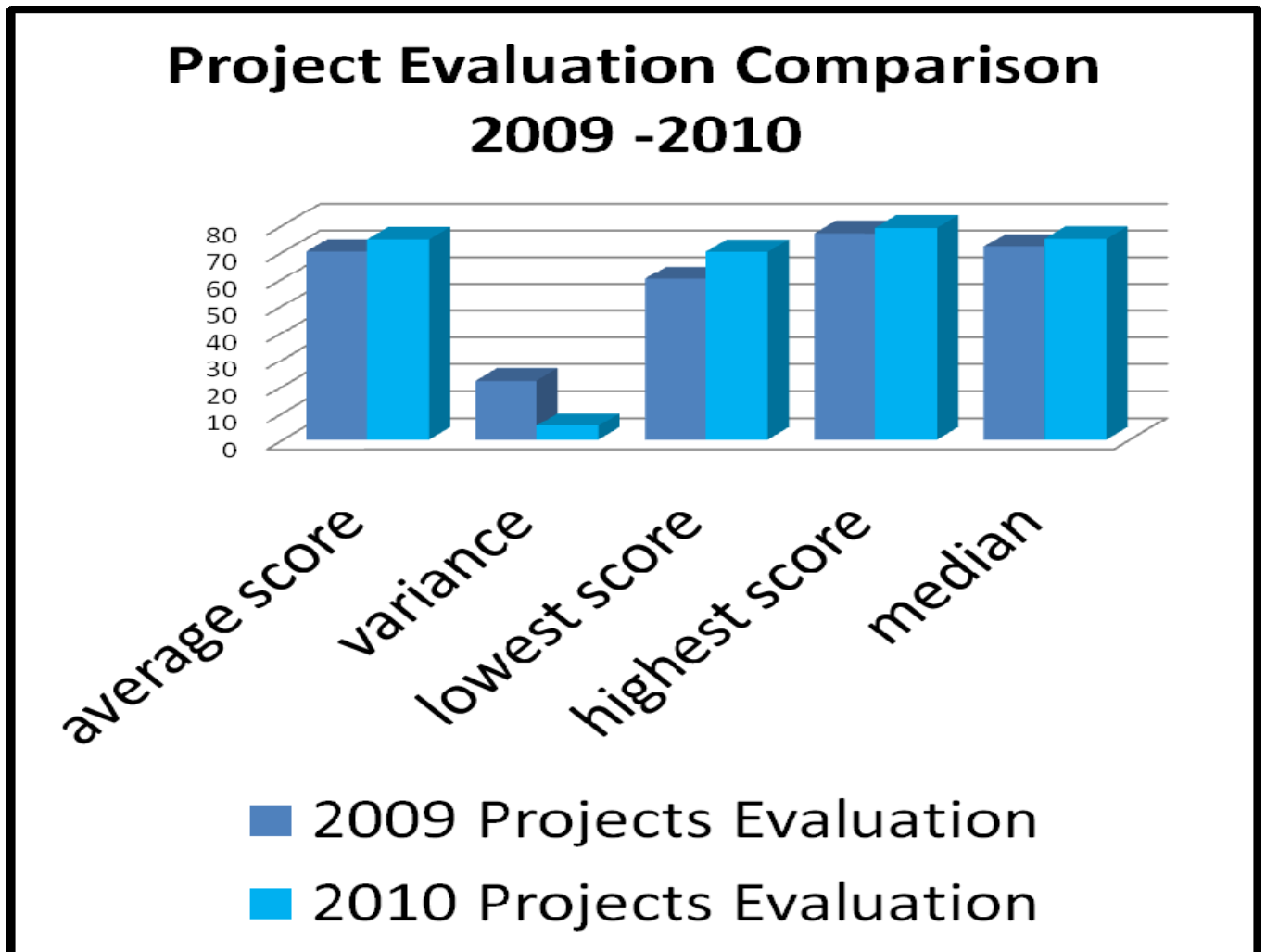


Figure 3: Overall Comparison between 2009 and 2010's Projects Evaluation.

Discussion

There were three major changes from the first to second offering of the course to improve project proposals.

1. Requiring completion the proposed research;
2. Emphasis on developing a research question early in the semester;
3. Altering from the proposal peer review to a formal proposal presentation with feedback provided by the faculty.

While these changes appear to correlate with improvement in proposal scores, there may have been a tradeoff as there was no improvement in GECI post-scores between the years. This will need to be explored in future offerings.

The course appears to have a positive impact on student attitudes towards science. Though this was not significant ($p=0.052$), the course has the potential to attract students into climate change studies.

The course was successful as a whole, but there are areas for improvement. The students were challenged and there were clear gains in understanding and scientific writing.

The use of formalized rubrics is extremely important in a course of this type. It provided a context for students to look at and discuss each other's work. For the instructors the rubrics used during group work provided formative assessment information that allows them to make improvements in the course while it was occurring thus improving the students' learning experience in the course.

Changes for future offerings of the course are:

1. Restructure the choice of the activity periods to build tools skills on developing questions, dealing with data and errors, and writing. For example, the instructors are considering making use of the Earth Exploration Tool book (<http://serc.carleton.edu/eet/>).
2. Modify the course to focus on preparing a research poster to be presented during the undergraduate research week at the university.
3. Review the content to address the glaring content issues related to the greenhouse effect and climate change. While the development of content knowledge is not at the core of the course, it is apparent that there are some fundamental concepts that were not adequately addressed.
4. Limit student data sets and regions for research. While some of the students did focus on regional climate issues, a greater effort is needed to provide a civic engagement of focusing on community or local problems that can utilize readily available data sets.

IMPLICATIONS FOR UNDERGRADUATE RESEARCH

One of the key outcomes of this process is the use of action research, even at a simple level of measuring critical elements, can help improve a course over time. The approach used by the instructors of the course, where the primary goal was not basic research but course improvement, is a model for all faculty to consider. The instructional team did not accept just status quo, but purposefully identified a few critical elements in the course that we wanted to improve. Through use of action research, and a limited set of measures we have been able to grow the course into what we envision at the outset. The third year offering was much better and produced strong knowledge gains and awarding winning projects for the students. The information from year three, not entirely processed, has is forcing us to re-conceptualize the course for the Fall of 2012.

For continuous improvement in undergraduate science education, it is imperative to consider how this mind-set and process can be brought into all teaching experiences.

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