The Piloting of Two Instruments to Measure Elementary Methods Students’ Understanding and Attitudes About Global Climate Change

Presented at the National Association for Research in Science Teaching, March 21-24, 2010

Julie Lambert, Joan Lindgren, Florida Atlantic University
Robert E. Bleicher, California State University Channel Islands
Laura Cottongim, University of Hawaii Laboratory School,
Cyndy Leard, Science Center of Pinellas County, and
Abdou Ndoye, University of North Carolina Wilmington

Introduction

Climate change has become an important global issue, and it is critical that teachers have an understanding of the fundamental science, the natural and human-induced factors affecting climate, and the potential consequences and solutions. However, research findings indicate that the greenhouse effect and global warming, fundamental to understanding climate change, are complex phenomena that students continue to express alternative conceptions even after instruction (Mason & Santi, 1998; Rye, Rubba, & Wiesenmayer, 1997). Common trends in the findings from several studies include elementary and secondary students confusing the greenhouse effect with ozone depletion or causally attributing the former to the latter. Students commonly explain the greenhouse effect as an environmental problem rather than as a natural phenomenon. They confuse it with its consequences (e.g., increase in Earth’s mean temperature and sea level rise) (Koulaidis & Christidou, 1998, p. 560-561).

Other studies report similar findings with prospective and practicing teachers (Dove, 1996; Summers, Kruger, Childs, & Mant, 2000). Summers et al. (2000) interviewed 12 practicing teachers to explore their understanding of environmental issues, including the carbon cycle, ozone, and global warming. Only one teacher understood that the greenhouse effect was a cause of global warming. The teachers also expressed naïve conceptions and misconceptions, (e.g., the “holes in the ozone” causing global warming). Papadimitriou (2004) used an open-ended questionnaire to explore climate change misconceptions and misunderstandings of 172 Greek preservice elementary teachers. The findings support earlier studies and include the following: confusing weather with climate; incorrectly relating climate change to environmental pollution and acid rain; and incorrectly relating climate change to ozone layer depletion. Another study by Michail, Stamou, and Samou (2006) used a closed-form questionnaire to study the knowledge of 155 practicing Greek teachers. Study results also support earlier research with regard to knowledge gaps concerning acid rain, ozone depletion, and the greenhouse effect. In addition, this study indicated that study participants derived most of their environmental knowledge from media. This compounds the problem because media generally represent environmental issues as risks rather than reporting from a scientific viewpoint. In addition, Daskolia, Flogaitis, and Papageorgiou (2006) studied 159 Greek kindergarten teachers’ understandings of ozone layer depletion through a free word association methodology. Again, well-known misconceptions appeared in this study along with an overemphasis on the potential hazards of ozone layer depletion to human health. The aforementioned studies emphasize the importance of educating teachers about complex climate issues and how to ameliorate student misconceptions since these often reflect the teachers’ own misunderstandings. Consequently, this research focuses on developing and piloting two instruments that identify elementary education students’ knowledge and attitudes about global climate change.
Methodology

Design

The design of this research is based on the curriculum-instruction-assessment triad, which is central to providing effective learning environments (Pellegrino, 2004). Assessment refers to the measurement of the achievement and attitudes of students with regard to important knowledge and competencies. Curriculum refers to the knowledge and skills of a subject matter content area. Instruction refers to teaching methods and the learning activities used to help students master the content and objectives specified by the curriculum. Hence, the development of the assessments, curriculum and instructional intervention are embedded within the research design.

Participants

The 149 participants were enrolled in either an undergraduate or a graduate level science methods course taught by the researchers at two different universities. The 126 undergraduate students were enrolled at a large southeastern Hispanic-serving university, while the 23 graduate students were enrolled at a coastal mid-Atlantic university.

The 126 undergraduate students were preservice teacher candidates and participated in the study as part of a course on methods for teaching K–8 science, which is usually taken one or two semesters prior to an internship. All but four of the students were female, and 70% were under the age of 27. Approximately 30% of the undergraduate students were Hispanic, Black, or Asian. Most students had two science courses at the undergraduate level in the biological and earth sciences.

The 23 graduate students were practicing teachers with an average of nine years of teaching experience, mostly at the lower elementary level. These students were enrolled in a required course for a masters program for elementary education. All but two were female. Most (96%) were over the age of 27 and 13% were Black.

Context of the Study: The Methods Course

The curriculum and instructional materials developed for the intervention include a 25-page written guide for understanding science and climate change and several inquiry-based science lessons on concepts such as the carbon cycle, photosynthesis and respiration, the greenhouse effect, heat transfer and ocean currents, the cause of the seasons, fossil fuels and the rock cycle, the water cycle, etc. In addition, the students had an assignment to 1) view the movie, “An Inconvenient Truth”; 2) discuss specific questions on the science of climate change and the nature of science; 3) construct a concept map to demonstrate their understanding of climate change; and 4) participate in a focus group interview at the end of the course. During the movie, students were asked to describe the evidence that Al Gore presented to support his explanations.

Instruments

Two instruments (i.e., an assessment of students’ knowledge of science concepts and climate change and a survey of students’ attitudes toward science, the nature of science, and climate change) are being developed to measure the students’ understanding of and attitudes about global climate change. The following sections describe the two instruments and the reliability.

Knowledge of Global Climate Change Instrument (KGCCI)

The KGCCI was designed to measure knowledge of science concepts involved in global climate change. It was developed using the constructive modeling approach as a framework. This approach is based on four components or “building blocks” – the construct map, items design, outcome space, and measurement model (Wilson, 2005). First, a construct map, a visual representation of the content of the
construct being measured, is developed. Second, *items are designed* using an evidence-centered approach, i.e., items are designed to measure the construct in a real-world situation. In this case, students were asked extended-response and multiple-choice items to assess their overall understanding of global climate change.

The knowledge of climate change instrument was designed to measure students’ comprehension of the basic science that is needed to understand weather and climate phenomena as well as specific concepts related to global climate change. As referenced above, the instrument is based on the written guide provided to the students. Appendix A includes a sample of multiple-choice items from the knowledge instrument. Table 1 shows a summary the global climate change construct and the alignment of specific items on the assessment. The multiple-choice items count 25 points (i.e., one point for each item) and the extended response items count a total of 40 points (i.e., three or four points for each item depending on the student’s level of understanding).

**Table 1**

*Relation of Items to Overall Climate Change Construct*

<table>
<thead>
<tr>
<th>Construct Topic</th>
<th>Extended Response Items (26 – 35)</th>
<th>Supporting Multiple-Choice Items (1-25) Topic of Item</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>The Greenhouse Effect</strong></td>
<td>29. Explain Earth’s greenhouse effect. You may also include a diagram with labels. 30. What are the greenhouse gases?</td>
<td>1. (Electromagnetic radiation) 2. (Sun’s energy) 3. (Composition of atmosphere) 4. (Difference between ozone layer and greenhouse effect)</td>
</tr>
<tr>
<td><strong>The Carbon Cycle</strong></td>
<td>33. Explain how the carbon cycle is connected to global warming. You may also include a diagram with labels.</td>
<td>8. (Carbon cycle) 10. (Cellular respiration) 12. (Fossil fuels and sedimentary rocks)</td>
</tr>
<tr>
<td><strong>Consequences of Climate Change</strong></td>
<td>34. How do the oceans affect climate on Earth? 35. What are some potential impacts of climate change?</td>
<td>5. (Surface winds) 6. (Water cycle) 7. (Local winds) 17. (Ice and solar radiation) 18. (Coastal climate) 19. (Surface currents) 20. (Surface currents) 21. (Deep density currents) 22. (El Niño) 23. (Sea level and ice ages)</td>
</tr>
</tbody>
</table>

The third component, the *outcome space*, is defined as a set of categories that is well defined, finite and exhaustive, ordered, context-specific, and research-based (Wilson, 2005, p. 62). A scoring guide or rubric is an example of an outcome space. (See Table 2.) Students received a score based on his
or her level of understanding. A student’s score was reduced by one point if he or she included an alternative conception within a partially correct response. Items 26 – 35 were scored using a scoring guide.

**Table 2**

*Scoring Guide for Item 31: What do many scientists think is causing the current warming trend?*

<table>
<thead>
<tr>
<th>Level</th>
<th>Characteristics</th>
<th>Exemplar Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>identify cause as overproduction of carbon dioxide <strong>AND</strong> correlate the increase in carbon dioxide to a specific human activity <strong>AND</strong> to a stronger greenhouse effect.</td>
<td>The more carbon dioxide is produced, the thicker the layer of greenhouse gases causing an enhanced greenhouse effect. Thus more infrared radiation is trapped, and the more earth’s temperature increases, the greater the climate’s temperature rises. This can be caused by burning fossil fuels, deforestation or cattle farming.</td>
</tr>
<tr>
<td>3</td>
<td>identify cause as overproduction of carbon dioxide <strong>AND</strong> correlate the increase in carbon dioxide to a specific human caused activity <strong>OR</strong> to a stronger or enhanced greenhouse effect</td>
<td>The more carbon dioxide is produced the greater the climate’s temperature rises.</td>
</tr>
<tr>
<td>2</td>
<td>identify cause as overproduction of carbon dioxide, or list 2 or more human influenced processes which would cause an increase in the amount of greenhouse gases.</td>
<td>Too much carbon dioxide is being produced.</td>
</tr>
<tr>
<td>1</td>
<td>identify cause as either overproduction of greenhouse gases, or any human influenced processes which would cause an increase in the amount of greenhouse gases, or a stronger greenhouse effect</td>
<td>Too many greenhouse gases are being produced, <strong>OR</strong> burning fossil fuels</td>
</tr>
<tr>
<td>0</td>
<td>Irrelevant, Totally Incorrect, or no Response</td>
<td>NA</td>
</tr>
</tbody>
</table>

Level 1 - Partial, Level 2- Essential, Levels 3 or 4 - Complete Understanding

**Attitude Instrument**

A modified version of the constructive modeling approach was used to develop an instrument to measure students’ attitudes toward science, the nature of science, and climate change. Because climate change involves biological, physical, and earth science, students may become more interested in science in general and confident in science. Climate change is also an issue that is especially useful for teaching about the nature of science. And finally, due to the nature of climate change issues, it seemed important to know students’ views on the cause, significance, and certainty of climate change.

The 25-item survey is divided into three constructs (i.e., interest and confidence in science, views on the nature of science, and views on climate change). Appendix B provides a sample of items on the attitude instrument. Each item was scored on a Likert-scale of 1 (strongly disagree) to 5 (strongly agree). The most points a student could have is 125 score on the attitude survey.

**Reliability of Instruments**

Reliability of the instruments was determined using the Cronbach alpha (α). The reliability of the KGCCI was 0.82 (n = 127). Reliability of the Attitude Survey was 0.81 (n = 121). The Attitude Survey contained three sections: interest and confidence in science; views on the nature of science; and views on global climate change. The reliability of each of these sections was 0.51, 0.54, and 0.75 respectively.

4
Findings

Overall, students increased in their knowledge of global climate change science after participating in the methods course. In addition, they developed more interest and confidence in, as well as, more positive views on the nature of science and global climate change. The following sections discuss the quantitative results of the knowledge of global climate change instrument, patterns of students’ ideas in the extended responses, psychometrics of the GCCKI, and the quantitative results of the attitudinal instrument.

Knowledge of Global Climate Change

The descriptive statistics and results of the paired-sample t-test are summarized in Table 3 following. The first row provides the overall GCCKI results and the following four rows contain the constructs that together compose the entire instrument.

Table 3

*Paired Sample t-test (Two-Tailed) and Descriptive Statistics for the GCCKI*

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>SD</th>
<th>SEM</th>
<th>t</th>
<th>p*</th>
<th>Cohen Effect Size d (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall KGCCI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>13.817</td>
<td>104</td>
<td>5.563</td>
<td>.546</td>
<td>20.675</td>
<td>.000</td>
<td>2.32 (0.76)</td>
</tr>
<tr>
<td>Post</td>
<td>31.414</td>
<td>104</td>
<td>9.157</td>
<td>.898</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Greenhouse Effect</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>1.778</td>
<td>135</td>
<td>1.342</td>
<td>.116</td>
<td>14.984</td>
<td>.000</td>
<td>1.55 (0.61)</td>
</tr>
<tr>
<td>Post</td>
<td>4.585</td>
<td>135</td>
<td>2.180</td>
<td>1.88</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Carbon Cycle</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>1.272</td>
<td>136</td>
<td>.847</td>
<td>.072</td>
<td>11.330</td>
<td>.000</td>
<td>1.27 (0.54)</td>
</tr>
<tr>
<td>Post</td>
<td>2.993</td>
<td>136</td>
<td>1.723</td>
<td>.148</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Causes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>5.630</td>
<td>127</td>
<td>2.449</td>
<td>.217</td>
<td>19.474</td>
<td>.000</td>
<td>2.08 (0.72)</td>
</tr>
<tr>
<td>Post</td>
<td>12.330</td>
<td>127</td>
<td>3.840</td>
<td>.341</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Consequences</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>4.885</td>
<td>130</td>
<td>2.394</td>
<td>.210</td>
<td>16.789</td>
<td>.000</td>
<td>1.60 (0.63)</td>
</tr>
<tr>
<td>Post</td>
<td>9.139</td>
<td>130</td>
<td>2.898</td>
<td>.254</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A comparison of pre and post scores shows that the mean score of 21.2% increased to 48.3% of the possible 65 points corresponding to a large effect size of 2.32. For each sub-construct, the mean score also significantly increased corresponding to large effect sizes. For items related to the greenhouse effect, the mean increased from 16.2 to 41.7% of a possible 11 points; the carbon cycle, from 19.4% to 42.4% of a 7 points; causes of climate change, from 18.1% to 42.7% of 29 points; and for consequences, 27.2% to 50.8% of 18 points. While the results are significant, with students’ knowledge increasing by almost 30% on the overall score, we had hoped to see more improvement.

Patterns Revealed in Extended Responses

The following describes patterns observed in the students’ answers to the extended-response items primarily on the posttest, because students had such little knowledge on the pretest. When
describing the trends, most” will refer to over 90%; “majority” to over 50%; “many” to over 10%; and “few” to less than 10%

**The Greenhouse Effect.** Most students did not express any understanding of greenhouse gases and the greenhouse effect on the pretest. On the posttest, most students listed carbon dioxide as a greenhouse gas and many students could partially explain the greenhouse effect on the posttest. Because students’ responses varied greatly on this item, we are providing examples of student responses at different levels of understanding.

**Level 4**

“The sun’ rays hit the earth and they are absorbed by the ocean landmasses and vegetation. The rays that are not absorbed bounce back into the atmosphere and become infrared. The infrared is then is trapped by the atmosphere by the greenhouse gases (water, water vapor, CO2, methane, ozone). The infrared is then absorbed and readmitted causing the earth to heat up.” (Student 633)

**Diagram by Student 411**

**Level 3**

“The sun’s infrared radiation comes to earth and some greenhouse gases in the atmosphere (CO2, methane, etc.) absorb and hold in the radiation. The rest of the radiation bounces off the earth (ice helps reflect it) and goes back into space. The radiation that remains warms the earth.” (Student 605)

**Level 2**

The earth’s atmosphere naturally contains greenhouse gases. These gases absorb the heat/infrared from the sun to keep the earth a comfortable temperature, while some if reflected back out into space. However, when there are increased amounts of carbon dioxide in the atmosphere they black the heat/infrared rays from being sent back out into space, causing earth to warm up. (Student 607) *(Note: The student did not explain that the radiation is reflected from the earth’s surface as infrared radiation.)*

**Level 1**

“Solar energy passes through the atmosphere and some energy is reflected back out to space. The greenhouse gasses trap some of the heat.” (Student 623)

While many students could partially explain the greenhouse effect, responses indicated several misconceptions and how the greenhouse effect works and the role of the greenhouse gases. The following quotes illustrate these misconceptions.
“Carbon dioxide is trapped here on earth and can’t escape.” (Student 602)

The greenhouse effect allows carbon dioxide to come in the atmosphere but not escape.

Diagram by Student 636

Diagram confusion about greenhouse gases being trapped (Student 635)

Diagram for Student 635

“Radiation is released onto earth and then released back into the atmosphere as carbon dioxide.” (Student 615).

“The gases are taken from one part of earth and moved to another.” (Student 616)

Diagram shows gases coming out of Earth (Student 621).

Diagram by Student 621.

“The greenhouse effect is caused by gases that are released into earth and get trapped. When they can’t get released into space they case CO2 to be released in to the atmosphere causing damage to the earth.” (Student 624)
While the misconception about the ozone layer has become less prevalent over the Semesters, an idea seemed to persist for a few students. The quote from this student with a fairly good science background is one example.

“When the sun’s rays warm up the Earth it releases heat. The Green House Gases in the Ozone layer trap more of the Earth's heat, so less escapes through the Ozone Layer. This trapping of heat raises the temperatures on Earth.” (Student X-Joan’s class)

**The Carbon Cycle.** Most students were not able to describe any processes involved in the carbon cycle on the pretest. However, on the posttest, most students enrolled in the most recent semester of the science methods course demonstrated at least a partial understanding and many were able to demonstrate a complete level of understanding relative to the course expectations. The following diagram illustrates a level four response.

![Diagram of the carbon cycle](image)

In previous semesters, this was not the case. Many students revealed misconceptions regarding the carbon cycle. A few notable examples are described here. A few students thought that the carbon cycle acted as a filter.

“The carbon cycle filters the harmful elements in the air through respiration and photosynthesis as well as getting absorbed in the water (oceans). There is so much carbon dioxide gases that it can’t be filtered fast enough so global warming occurs.” (Student 1037)

“The carbon cycle helps to clean the air that we breathe – photosynthesis and respiration.” (Student 1040)

A few students also attempted to combine their responses to the greenhouse effect and carbon cycle questions, also revealing misconceptions.

Another very common pattern during the past semesters was that students did not distinguish between carbon and carbon dioxide in their explanations. This students’ response illustrates this pattern.
“The carbon cycle is connected to the greenhouse effect, because when trees/plants decompose, it releases carbon dioxide into the air but it cannot escape thus it just lingers over and then reflects back down to earth. Greenhouse effect has a dense layer in the air in which the gases cannot escape.” (Student 1001)

**Causes of Climate Change**

Several extended-response items probed students’ understanding of the causes of climate change. These items focused on the difference between weather and climate, how past climate is studied, natural and anthropogenic causes of climate change, and the processes that increase and decrease greenhouse gases.

To understand the causes of climate change, a person should first be able to recognize the difference between weather and climate. One surprising finding was the students’ confusion over weather and climate even at the end of the course. On the pretest, many of the students demonstrated a partial or level one understanding, but very few really understood the difference. On the posttest, the majority of students were able to differentiate between weather as short-term and climate as long-term. Several students were able to recognize the weather had more to do with short-term events and climate more to do with long-term. However, several students tried to distinguish between weather and climate as local versus regional characteristic. Most students did not associate climate with precipitation patterns, but many students mentioned temperature.

Most students did not have any ideas of how scientists study past climates before humans kept records. The majority of students were able to identify at least one from of proxy data. One example of a level 3 understanding is represented by this quote.

> “Scientists can study the past climate by drilling for ice cores and examining the trapped air bubbles inside. These trapped air bubbles allow the scientists to observe the climate, what time period, and what gases were in the atmosphere when those air bubbles were trapped. Another way is by studying the rings on tree trunks. The rings determine a trees age. Scientists can determine the climate because they can see how quickly the tree grew. Trees grow quicker in the warm, wet climates.” (Student 607)

Overall, the responses to this question on the posttest did not reveal misconceptions and the majority of the students identified ice cores as proxy data.

Most students had no prior knowledge of natural causes of climate change and by the end of the course, just over 50% of students had a partial understanding of natural causes. No students expressed a complete understanding at a level four, and only a few scored a level three. On the pretest, many students interpreted the question as what naturally causes of the change of seasons rather than of climate. Interestingly, many students wrote about the zigzag in the Keeling curve. A few indicated that they understood why this occurs (i.e., the increase in carbon dioxide during the northern hemisphere’s winter months when plants are not using carbon dioxide for photosynthesis and vice versa). Most, however, revealed misconceptions that seemed to arise from viewing “An Inconvenient Truth.” A few quotes highlight the students’ misconceptions.

> “During the summer and spring, plants take in carbon dioxide and during the fall and winter they release carbon dioxide.” (Student 607)

> “The earth takes breaths each year giving off carbon dioxide into the air.” (Student 626)

> “The yearly carbon inhale and exhale due to the vegetation between the northern and southern hemispheres.” (Student 658)
When asked on what most scientists think is causing the current warming trend, most students were unable to answer the question on the pretest. Most were students received at least partial credit on the posttest. Many students were able to answer the question at a level 3, but no could answer at a level four. See Table 2 for an exemplar for level four. There were a few misconceptions. First, many students thought, on the pretest, that the warming trend was related to the ozone layer.

A typical response was the following.

“Gases and pollution from the earth escape through the ozone layer making holes, which allow more radiation from the sun to enter the planet and cause warming.” (Student 1016)

This preconception seems to have persisted even over different semesters; however, fewer students have misconceptions on the posttest.

A second misconception is related to the greenhouse effect. Approximately 10% of the students were thought that greenhouse gases, such as carbon dioxide, are trapped in the atmosphere and hence causing warming. A few said that carbon dioxide is trapped by infrared radiation – mixing up the process. When students were asked what processes increased and decreased greenhouse gases, most could not list any processes on the pretest. One the post, most students had at least a partial understanding of ways that greenhouse gases are increased and decreased. Several students listed ways that humans could reduce the amount of greenhouse gases that were emitted rather than actually reducing the concentration of greenhouse gases already in the atmosphere.

**Consequences of Climate Change.** Two items probed students’ understanding of the consequences of climate change. One item focused on the role of the oceans. Responses on the posttest revealed a variety of misconceptions (eg., currents moving weather patterns, and salinity causing storms, volcanoes, typhoons). A few students thought that tsunamis or tidal waves were related to the oceans and climate change. A few expressed misconceptions about the ocean conveyor belt.

“If the ocean has cool dense water interrupting the conveyor belt, like melting glaciers, the water cycle stops and another ice age could begin.” (Student 626)

A few students referred to ocean acidification or rising sea level. One student expressed a few misconceptions in one response.

“As a result of acidification, the oceans are becoming warmer and it is not producing as many tidal waves and ocean currents.” (Student 621)

When scoring this item, it became evident that this was perhaps too complex, and in future versions of the instrument, should be revised.

A second item specifically asked students about potential impacts of climate change. This item was the only one that a majority of students could partially answer on the pretest. On the posttest, many students were able to answer the question at a level three (complete understanding). Examples of level two responses follow.

“The impact of climate change causes weather patterns to go out of control. There are more intense hurricanes, droughts, and flooding. Each region of the world is facing some sort of impact.” (Student 628)
"Arctic is melting and the sun rays are warming. The water heats up quickly causing the polar ice caps to melt. Also, since the northern continents are warming up, mosquitoes are migrating and they are bringing diseases such as malaria. Migrating birds are leaving too soon." (Student 646)

An example of a level three response is:

"Climate change can cause melting of polar ice caps which will raise sea levels and wipe out sea level communities. Climate change will also cause certain animals and plants to become extinct and we will also see extreme weather and climate changes that will wreak havoc on humans and their needed environments." (Student 647)

Psychometrics of the KGCCI

The forth component of the constructive modeling approach is the measurement model, which relates the scored outcomes from the items design and outcome space to the original construct (Wilson, 2005, p. 85). The Wright Map is a graph designed to examine the validity of the KGCCI instruments. Figure 1, following, shows the Wright Map for this analysis.

Figure 1. Wright map for knowledge of climate change instrument.

The Wright map provides an idea of the ability of a student and difficulty of an item and is useful in designing a test that is not too difficult and not too easy. The left side is an indication of the individual students’ abilities to understand climate change. A logit range of -1 to 1 indicates average ability, and this is where most elementary methods students would be expected to fall.
The right side shows the difficulty of the item. Each item’s number is displayed on the right side. Items located with the logit range of -1 to 1 would be considered average difficulty items (i.e., meaning they are not difficult items and not easy items). For example, if there were an item at level 5 or 6, it would be a very difficult item that you would not expect very many students to be able to answer. Likewise, items at lower logit. Items at higher logits would be more difficult, and items at lower logits would be considered easy. To clarify, the X on the left side does not say anything about items 6 or 14.

The Wright map above indicates most of the items (items 25 up through items 10) are in the same logit range of the students’ abilities. The Wright map does indicate that the test has a few items (i.e., items 23, 8, and 5) that most students would be expected to get right and no items at a higher logit. The is what actually matched our results. For example, 94% of the students got item number13 correct. Item 13 was the easiest item, according to the Wright map.

Q13. The changing seasons on Earth are caused by ______.
   a. the tilt of the Earth on its axis as it orbits the sun
   b. the unequal distribution of land and water on Earth
   c. variations in the amount of energy released by the sun
   d. variations in the distance of the Earth to the sun

The question asked the students to choose the best explanation for the cause of the seasons, and most students were able to answer the question correctly. In a future revision of the instrument, item difficulty will be considered. We also plan to conduct interviews with students to assess whether our distractors are effective.

Attitude Survey Results: Interest and Confidence, Views on the Nature of Science, and Views on Global Climate Change

The attitude survey included 25 Likert-scale (5 point scale) items with a maximum possible score of 125 points. In table 4, following, the paired sample t-test results and descriptive statistics are presented. The first row is for the overall attitude survey. The subsequent rows show results for each of the 3 sections of the attitude survey: interest and confidence in GCC; views on the nature of science; and views on GCC.

Notable in the first row overall attitude survey results is that students already had a reasonably high mean score of 89 which corresponds to 72% of the maximum possible score of 125 points. After participating in the methods course, students increased to a mean score of 97, or 78% of the maximum possible positive attitude score.

Table 4

Paired Sample t-test (Two-Tailed) and Descriptive Statistics for the Attitude Survey
<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>N</th>
<th>SD</th>
<th>SEM</th>
<th>t</th>
<th>p*</th>
<th>Cohen Effect Size d (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Attitude Survey</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>89.487</td>
<td>117</td>
<td>8.103</td>
<td>.749</td>
<td>10.876</td>
<td>.000</td>
<td>0.79</td>
</tr>
<tr>
<td>Post</td>
<td>96.966</td>
<td>117</td>
<td>10.739</td>
<td>.993</td>
<td>.749</td>
<td>.000</td>
<td>(0.36)</td>
</tr>
<tr>
<td><strong>Interest &amp; Confidence</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>9.760</td>
<td>125</td>
<td>1.890</td>
<td>.1690</td>
<td>12.771</td>
<td>.000</td>
<td>1.28</td>
</tr>
<tr>
<td>Post</td>
<td>11.960</td>
<td>125</td>
<td>1.537</td>
<td>.137</td>
<td>.993</td>
<td>.000</td>
<td>(0.54)</td>
</tr>
<tr>
<td><strong>Views on NOS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>33.279</td>
<td>122</td>
<td>3.296</td>
<td>.298</td>
<td>4.745</td>
<td>.000</td>
<td>0.69</td>
</tr>
<tr>
<td>Post</td>
<td>34.811</td>
<td>122</td>
<td>3.928</td>
<td>.356</td>
<td>.749</td>
<td>.000</td>
<td>(0.33)</td>
</tr>
<tr>
<td><strong>Views on GCC</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre</td>
<td>46.488</td>
<td>121</td>
<td>5.932</td>
<td>.539</td>
<td>6.969</td>
<td>.000</td>
<td>0.58</td>
</tr>
<tr>
<td>Post</td>
<td>50.256</td>
<td>121</td>
<td>7.085</td>
<td>.644</td>
<td>.749</td>
<td>.000</td>
<td>(0.28)</td>
</tr>
</tbody>
</table>

*Level of significance, p ≤ .05

For each sub-scale, the mean score also significantly increased. For items related to the confidence and interest in science, the mean increased from 65.1% to 79.7% of 15 points; views on the nature of science, from 74.0% to 77.4%; and views specifically on climate change, from 71.5% to 77.3% of 65 points. Students came in the course with relatively positive attitudes.

The statistical analysis reveals some weaknesses with this attitudinal instrument. The instrument is actually measuring three different constructs and is not measuring a common latent trait. Additionally, some of the items within the sub-scale, views on climate change, were actually measuring knowledge of the current scientific thinking regarding climate change as opposed to attitudes. This instrument will be further revised.

**Conclusions and Implications**

Given the short span of the intervention, the elementary methods students were able to learn a limited number of specific concepts related to climate change and to develop attitudes more aligned with the current scientific research. Further analysis of the results will be used to revise the multiple-choice content items, extended response items, and Likert-scale survey items to increase reliability. An analysis of the extended response items revealed similar alternative conceptions as reported previously, as well as new misconceptions (i.e., students thinking that greenhouse gases are trapped instead of these gases actually being the “trappers” or absorbers of infrared).

Additional analysis of the responses will be drawn on to develop a multiple-choice version of these items for more widespread use. Throughout this process, the curriculum and instructional intervention will be revised to address alternative conceptions related to global climate change. Based on these results, more instruction on the greenhouse effect, the carbon cycle, and air-sea interactions is clearly needed.

Embedding an interdisciplinary theme, such as climate change, provides an opportunity to model inquiry-based science instruction while also reviewing fundamental science concepts from the earth, life and physical sciences. In order to develop effective teachers in this area, it is important to determine the current level of knowledge teachers have in the content areas associated with the global climate change issue as well as, appropriate instructional interventions necessary to ameliorate any knowledge shortfalls.
One way to obtain this information is to measure teacher understanding using formative and summative assessments. Future versions of the global climate change instruments can be used to further the research on learning progressions. A learning progression consists of a set of standards that can be structured into a developmental trajectory and materials that teach the standards in order to make them more educationally useful (Wilson & Bertenthal, 2005). Global climate change is an important “big idea” that could consist of multiple learning progressions, and this research aims to help teachers and ultimately their students develop a deeper understanding of such a complex issue.

References

Appendix A. Sample of Multiple Choice Items on Knowledge of Climate Change Instrument

Q2. The energy from the sun does all of the following EXCEPT _____.
   a. drives density-driven currents in the atmosphere and oceans
b. provides a source of energy for the Earth’s water cycle
c. provides a source of energy for photosynthesis
d. provides a source of heat for the Earth’s interior

Q9. In addition to sunlight, which substances are needed by the leaf to carry out the process of photosynthesis?
   a. carbon dioxide and water       c. carbon dioxide and glucose
   b. carbon dioxide and oxygen      d. glucose and oxygen

Q14. The diagram shows the Earth as viewed from space. The shaded area represents darkness.

Based on the diagram, which hemisphere would be having summer?
   a. Eastern                        c. Northern
   b. Western                       d. Southern

Q16. Climates near the Equator are generally warm with a small range of temperature variation because this region ______.
   a. Is usually closest to the Sun
   b. Reflects the greatest amount of incoming solar radiation
   c. Receives the most hours of daylight
   d. Receives the most nearly perpendicular incoming solar radiation

Q17. Under the same conditions, which surface would reflect the greatest amount of solar radiation?
   a. an area of the ocean
   b. an ice sheet
   c. a rainforest
   d. a parking lot

Q25. All of the following processes release carbon dioxide into the atmosphere EXCEPT _____.
   a. Decomposition (decay) of organic matter
   b. Burning of fossil fuels and forest fires
   c. Photosynthesis by green plants on land and algae in water
   d. Respiration by plants and animals

Appendix B. Sample of Items on Attitude Instrument

Interest and Confidence in Science
2. I understand science concepts well enough to be effective in teaching elementary science.

3. I am interested in science.

Views on the Nature of Science

4. Today’s scientific knowledge is NOT subject to change.

7. Scientific evidence can be biased (misrepresented) in the way that it is interpreted or reported.

11. Scientists can study things and events that happened in the past, even if no one was there to make observations.

12. Disagreement among scientists is one weakness of science.

My Views on Climate Change

13. I really do NOT understand the cause of global warming.

15. Human activities are a major cause of the current warming trend.

16. The global warming over the past century, as well as weather extremes, reflects nothing more than the climate system’s normal variability.

17. The current warming trend is occurring much faster than ever before seen in the geological record.

19. We are already seeing signs of climate change.

20. There is a lot of disagreement among scientists on whether the planet is warming.

25. I think that potential impact of global warming is an urgent issue for the entire planet.