Evaluation of CReSIS Education Programs: REU and K-12 Outreach

Dana Atwood-Blaine

Center for Remote Sensing of Ice Sheets
University of Kansas
2335 Irving Hill Road
Lawrence, KS 66045-7612
http://cresis.ku.edu

Technical Report
CReSIS TR 144

April 6, 2010

This work was supported by a grant from the National Science Foundation (#ANT-0424589).
CONTENTS

I. An Introduction to the CReSIS Education Program

II. Summer Research Experience for Undergraduates
   - Program Overview
   - Activities and Characteristics of Research Experiences
   - Evaluation Objectives and Methods
   - Results
     - REU Focus Skills
     - REU Tutorial Evaluation
     - REU Perceptions of Research Experience
     - Effects of Research Experience
   - Summary of REU Program Evaluation

III. K-12 Outreach
   - Overview
   - Professional Development Workshops for K-12 Educators
     - Overview
     - Teaching About the Cryosphere
     - The Heat is On: Confronting Climate Change in the Classroom
     - 2008
       - Participants
       - Evaluation Objectives and Methods
       - Outcomes
     - 2009
       - Participants
       - Online Workshop Evaluation
   - Summary of Outcomes and Impacts
   - 2010
     - Classroom-based Outreach: Ice, Ice Baby Program
     - Participants
     - Ice, Ice Baby Evaluation Summary
   - Other Formal Education Outreach
   - Informal Education Outreach

IV. Overall Summary of CReSIS Education Program Evaluation
   - Strengths
   - Weaknesses and Future Efforts
I. An Introduction to the CReSIS Education Program

The Center for Remote Sensing of Ice Sheets (CReSIS), an NSF Science and Technology Center (STC), was established in 2005 with a mission to develop tools and techniques to collect data needed to improve our understanding of the processes of rapid changes being observed in polar ice sheets for developing improved ice-sheet models. Additionally, CReSIS Education mission is to train next-generation scientists and engineers taking diversity of the nation into account. The center’s education and outreach program is broad and extends from K-12 to post-doctoral training in engineering and science.

During Phase I, the Center’s educational activities included the following:
1) a graduate curriculum to provide training across disciplinary boundaries;
2) integration of research into undergraduate and graduate courses in engineering;
3) annual intensive summer research experience for undergraduates (REU) programs with a nation-wide recruitment effort and a focus on diversity and quality; and
4) a K-12 outreach program consisting of unique and effective professional development opportunities for school teachers; development and delivery of classroom-tested lessons on polar science and climate change; and participation in many formal and informal science programs.

This report provides a summary of the CReSIS REU program and K-12 educational activities, the objectives, the internal evaluation process conducted for these activities, and the evaluation results. A Phase I education program evaluation summary, which includes the overall strengths and weaknesses for each activity, as well as suggested adjustments for future efforts, is provided in the final section of this report.

II. Summer Research Experience for Undergraduates

Program Overview

The Research Experience for Undergraduates (REU) at CReSIS is an intensive, 8-week summer program that offers supervised research opportunities for students entering their junior or senior year. REUs are recruited nation-wide and are selected on the basis of their academic background, research interests, and alignment with available faculty advisors and current research projects. REU students are paired with a faculty advisor and, in most cases, a Graduate Research Assistant (doctoral student) mentor. The REU Program fulfills several Education Program objectives stated in the Center Strategic and Implementation Plan [www.cresis.ku.edu]:

A. Assist undergraduate students in developing appropriate theoretical and practical content knowledge;

B. Assist undergraduate students to develop skills sufficient to conduct supervised research; and

C. Model career paths available to scientists and engineers in STEM fields.

In addition to conducting a supervised research project, REU students attended three weekly “tutorials” presented by CReSIS faculty and graduate students. These 1-hour presentations were designed to provide REU participants an overview of the science and technology activities at CReSIS. The tutorials are listed in Table 4.

Throughout the summer, as the REU students conducted their research, they developed and wrote a technical paper on their research project. As a culminating event, REU students presented their work both as a 15-20 minute talk and digital slide-show to CReSIS faculty, staff, and students; and also at a university-wide poster session hosted by KU for the undergraduate summer researchers in all departments.
Additionally, REU students often had an opportunity to present their summer research at a scientific conference or meeting during the subsequent academic year.

### 2006-2009 REU Profile and Characteristics

Over the course of four summers during Phase 1, CReSIS provided supervised research experiences for 45 undergraduate students, 56% (25) of whom were female and 76% of whom came from groups typically underrepresented in STEM fields (including female). One third (15) of these students came from CReSIS partner, Elizabeth City State University (ECSU), a Historically Black University, while the remaining REU students came from non-partner institutions. 80% (36) of the REU students did research at CReSIS headquarters at the University of Kansas (KU), while the remaining 20% (9) were placed at CReSIS’ partner institution, Pennsylvania State University (PSU). REU students represented a range of STEM majors, including mechanical engineering, earth sciences, computer sciences, electrical engineering, physics, aerospace engineering and mathematics. The average GPA of CReSIS' REUs was 3.49.

<table>
<thead>
<tr>
<th>Summer</th>
<th># of REUs</th>
<th>Average GPA</th>
<th>Male</th>
<th>Female</th>
<th># from Underrepresented Groups (including female)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>6</td>
<td>Unknown</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>2007</td>
<td>20</td>
<td>3.32</td>
<td>9</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>2008</td>
<td>10</td>
<td>3.56</td>
<td>4</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>2009</td>
<td>9</td>
<td>3.60</td>
<td>3</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>45</td>
<td>3.49</td>
<td>20</td>
<td>25</td>
<td>31</td>
</tr>
</tbody>
</table>

### Activities and Characteristics of Research Experiences

Each summer during Phase 1, CReSIS REU students were involved in a range of STEM learning and research experiences. In general, REU students reported to CReSIS five days a week, for eight hours each day. The one-hour tutorial sessions with CReSIS faculty or graduate students were offered three mornings each week. For the remainder of each week, REU students worked on their supervised research project and some REU students also enrolled in summer courses at their host university. Each REU student worked closely with an assigned faculty advisor and a graduate student mentor. Some of the research projects conducted by REU students included:

**Aerospace Engineering**
- *A Lateral-Directional Simulation of the Yak-54 RC Model Aircraft* (2008)
- *Dynamic Analysis of the Meridian UAV Using Sensitivity Analysis Techniques*(2009)

**Computer Science**

**Earth Science/Geography**
- *Coastal Inundation of the United States* (2008)
Evaluation Objectives and Methods

To further evaluate the contribution of the REU program to overall Education Program Objectives, the 2007-2009 REU program evaluation effort consisted of two additional and specific areas of interest:

1. Participants’ self-confidence in seven “focus skill” areas:
   - performing supervised research,
   - writing a technical report,
   - giving an oral presentation about research,
   - using Matlab to support research,
   - attending graduate school in a STEM field,
   - earning an MS in a STEM field, and
   - earning a PhD in a STEM field.

2. Participants’ attitude toward and satisfaction with the CReSIS summer research experience.

Measures of self-confidence in the focus skills were collected both for pre- and post-REU experience and were intended to provide evidence for use in evaluating the extent to which the Program contributed to participants “developing appropriate theoretical and practical content knowledge; developing skills sufficient to conduct supervised research; and, modeling career paths available to scientists and engineers in STEM fields.” Students were asked to complete a pre-experience survey, intended to provide a baseline measurement of their self-confidence in the REU focus skills, when they first arrived on campus. The same survey was administered at the end of the REU program, just before students left the campus, to assess if there had been any change in self-confidence in those focus areas as a result of participating in the CReSIS REU program. The survey consisted of seven Likert-scale items corresponding to the focus skills. The Likert-scale survey items had four levels of confidence: (4) very confident, (3) somewhat confident, (2) unsure and (1) not at all confident.

During the first three years of the program (2006-2008), participants were also asked to rate the extent to which the tutorials helped them better understand key CReSIS topics and concepts. The tutorials were evaluated using a 5-level Likert survey (1=strongly disagree to 5=strongly agree) after each tutorial. In 2009, in an effort to focus evaluation efforts where they were most useful, individual tutorial evaluations were discontinued. Only the Matlab tutorial continued to be evaluated as part of the pre- and post-“REU Focus Skills” evaluation survey.

In addition to the Likert-scale items, both pre- and post-surveys included five short-answer items that addressed attitude toward and satisfaction with the REU experience. All surveys were administered through the online survey tool, Survey Monkey, and were completed by participants anonymously. Finally,
exit interviews were conducted with the 2008 REU students (Yr3) to glean more qualitative information about how they felt the REU experience had affected them and what impact they saw it having on their future.

**Results**

**REU Focus Skills**

When evaluating the impact of the REU program on participants’ self-confidence in the specific focus skill areas, we looked at the change in participants’ self-confidence before participating in the program and then again afterward. Although REU students showed an increase in self-confidence in most focus skills from pre-measure to post-measure, there were a few noteworthy or unanticipated results. There was a large improvement in participants’ self-confidence using Matlab after 2007, which we expected after changing the Matlab tutorial from presentation-lecture format to a hands-on laboratory format in 2008. An unanticipated result was that across all three years, 2007-2009, participants indicated a decrease in confidence that they would go on to earn a PhD in a STEM field. At this time, we do not have follow-up data on former REU participants to validate how well these survey results predict the actual likelihood that a participant would go on to pursue and/or earn an advanced degree in a STEM field. Interestingly, participants indicated a greater likelihood that they would attend graduate school in a STEM field than that they would earn an advanced degree. This may indicate a lack of self-confidence in one’s ability to complete the degree program. The table below gives the average pre- and post-scores in order of descending effect.

Table 2. Change in REU “Focus Skill” Scores

<table>
<thead>
<tr>
<th>REU Focus Skill</th>
<th>PRE</th>
<th>POST</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Matlab</td>
<td>2.31</td>
<td>3.08</td>
<td>+0.77</td>
</tr>
<tr>
<td>Attend Graduate School in STEM</td>
<td>3.15</td>
<td>3.60</td>
<td>+0.45</td>
</tr>
<tr>
<td>Technical Report Writing</td>
<td>3.00</td>
<td>3.41</td>
<td>+0.41</td>
</tr>
<tr>
<td>Perform Supervised Research</td>
<td>3.49</td>
<td>3.79</td>
<td>+0.30</td>
</tr>
<tr>
<td>Give Oral Presentation</td>
<td>3.36</td>
<td>3.55</td>
<td>+0.19</td>
</tr>
<tr>
<td>Earn an MS</td>
<td>3.21</td>
<td>3.37</td>
<td>+0.16</td>
</tr>
<tr>
<td>Earn a PhD</td>
<td>3.04</td>
<td>2.79</td>
<td>-0.25</td>
</tr>
</tbody>
</table>

Based on a 4-point Likert-type scale in which 1=Not at All Confident, 2=Unsure, 3=Somewhat Confident, and 4=Very Confident

Consistently across the pre-measures for all years (2007-2009), REU students reported the lowest self-confidence in their ability to use Matlab to support their research, with an average reported score of 2.31 on a 4-point scale, which falls less than halfway between “Unsure” and “Somewhat Confident.” In 2007, the Matlab tutorial was presented in a lecture presentation format and evaluation feedback from the REU participants identified this format as ineffective; self-confidence scores for using Matlab only increased 0.27 points from 2.46 to 2.73 after participation in the REU program. Since the ability to use software such as Matlab is a critical factor for success in graduate research in many (if not most) STEM fields, it was decided that the Matlab tutorial should receive more emphasis as a hands-on laboratory tutorial, rather than a lecture-style tutorial. In the subsequent summers of 2008 and 2009, the hands-on Matlab tutorial was identified by the REU participants as very effective and the most effective tutorial offered during the REU program; post-measure scores of self-confidence using the software increased an average 1.03 points, from 2.24 in 2007 to 3.26 for 2008-2009. The table below breaks out the survey results year by year, which highlights the difference in experience with Matlab.
REU Tutorials were evaluated separately during the summers of 2006-2008. They were evaluated using a 5-level Likert survey (1=strongly disagree to 5=strongly agree) after each tutorial. In 2009, in an effort to focus evaluation efforts where they were most useful, individual tutorial evaluations were discontinued. The survey asked participants to “…indicate the extent to which you agree or disagree that the tutorial helped you better understand [Tutorial Topic].” REU students agreed that the tutorials effectively contributed to their learning of Center-related content. Increasing scores over Yrs 2-4 may indicate that the tutorials are becoming more effective.

Table 3. Average Scores for REU Tutorials, Years 2-4

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>perform supervised research</td>
<td>3.38</td>
<td>3.80</td>
<td>0.42</td>
<td>3.43</td>
<td>3.57</td>
<td>0.14</td>
<td>3.67</td>
<td>4.00</td>
<td>0.33</td>
</tr>
<tr>
<td>write technical report</td>
<td>3.15</td>
<td>3.60</td>
<td>0.45</td>
<td>2.86</td>
<td>3.00</td>
<td>0.14</td>
<td>3.00</td>
<td>3.63</td>
<td>0.63</td>
</tr>
<tr>
<td>oral presentation</td>
<td>3.31</td>
<td>3.33</td>
<td>0.02</td>
<td>3.43</td>
<td>3.57</td>
<td>0.14</td>
<td>3.33</td>
<td>3.75</td>
<td>0.42</td>
</tr>
<tr>
<td>Matlab</td>
<td>2.46</td>
<td>2.73</td>
<td>0.27</td>
<td>2.14</td>
<td>3.14</td>
<td>1.00</td>
<td>2.33</td>
<td>3.38</td>
<td>1.05</td>
</tr>
<tr>
<td>Graduate school in STEM</td>
<td>3.23</td>
<td>3.73</td>
<td>0.50</td>
<td>2.71</td>
<td>3.57</td>
<td>0.86</td>
<td>3.50</td>
<td>3.50</td>
<td>0.00</td>
</tr>
<tr>
<td>Earn an MS</td>
<td>3.31</td>
<td>3.40</td>
<td>0.09</td>
<td>3.14</td>
<td>3.71</td>
<td>0.57</td>
<td>3.17</td>
<td>3.00</td>
<td>-0.17</td>
</tr>
<tr>
<td>Earn PhD</td>
<td>3.38</td>
<td>3.33</td>
<td>-0.05</td>
<td>2.57</td>
<td>2.29</td>
<td>-0.28</td>
<td>3.17</td>
<td>2.75</td>
<td>-0.42</td>
</tr>
</tbody>
</table>

Based on a 5-point Likert-type scale in which 1=Not at All Confident, 2=Unsure, 3=Somewhat Confident, and 4=Very Confident

REU Tutorial Evaluation

REU tutorials were evaluated separately during the summers of 2006-2008. They were evaluated using a 5-level Likert survey (1=strongly disagree to 5=strongly agree) after each tutorial. In 2009, in an effort to focus evaluation efforts where they were most useful, individual tutorial evaluations were discontinued. The survey asked participants to “…indicate the extent to which you agree or disagree…that the tutorial helped you better understand [Tutorial Topic].” REU students agreed that the tutorials effectively contributed to their learning of Center-related content. Increasing scores over Yrs 2-4 may indicate that the tutorials are becoming more effective.
REU Perceptions of Research Experience

Through formal exit interviews and responses to the open-ended questions on the post-survey, REU participants provided feedback and insight into their experience in the REU program.

As a group, the REU students reported gaining practical research experience in their chosen field of study as well as learning about other fields they had not considered. They were excited to be involved in a meaningful project directed at learning more about climate change. All of the REU students felt very accomplished at the end of the program and expressed deep satisfaction at having something useful and meaningful to show for their work by the end of the summer. Some of the research products REU students’ completed were even used in Greenland field research. Most of the participants used the REU experience as a way to find out if a career in research or academia was “right for them,” to build up their resumes, and to become better prepared for graduate school.

“This REU confirmed my desire to earn a PhD at KU. I loved being at KU and enjoyed interacting with my professor/graduate student to work towards our projects’ objective. I feel that I am better prepared to deal with some of the challenges of graduate school, particularly how to handle problems as they arise while working.”

“I have accomplished so much in this REU. I have made my first paper and completed my very first official research. This has been an excellent experience for me.”

“This experienced truly enriched me in several ways. Certainly the most important things accomplished included gaining experience in the laboratory, developing research methods and adopting a new level of confidence that I did not have when I started. I found a path that I plan to pursue at the graduate level and I intend to pick up where I left off.”

[The REU experience] “allowed me to explore my options for my future and also widen my perspective of what is possible in it.”

Many also expressed that they enjoyed seeing how everyone works together on the different projects taking place at the Center and that they appreciated the opportunity to be exposed to fields other than their own in this interdisciplinary research environment.

Summary REU Program Evaluation

During Phase 1 of the Center, the REU programs conducted during the summers of 2006 through 2009 effectively met CReSIS education goals as stated in the CReSIS Strategic Plan:

Assist undergraduate students in developing appropriate theoretical and practical content knowledge.

The REU Program provided undergraduate students with access to theoretical and practical content knowledge through the summer tutorials and an advisor/mentor relationship with both a faculty member and a graduate student. REUs agreed that the tutorial sessions were effective at helping them better understand each of the CReSIS related tutorial topics. Overall tutorial scores ranged from 4.17 to 4.44, where 1 is “strongly disagree” and 5 is “strongly agree.” The redesigned Matlab tutorials went from a lecture/presentation format in 2006-2007, to a hands-on lab format in 2008-2009 and this change resulted in a significant increase of REU confidence in using Matlab for research.

Assist undergraduate students to develop skills sufficient to conduct supervised research.

As reported in exit interviews and the responses to the open-ended questions on the post-survey, REU students valued the opportunity to gain practical research experience in their chosen field of study. All REU students conducted a supervised research project; wrote a technical paper about their research; gave an oral presentation to CReSIS faculty, staff, and students; and presented a poster highlighting the results of
their summer research at a campus-wide event. When the differences between the pre- and post-surveys were averaged for 2007 through 2009, REU students exhibited an increase in confidence in their ability to perform supervised research (+0.30), write a technical report (+0.41), and give an oral presentation about their research (+0.19). REU students did report feeling very accomplished at the end of the program and expressed deep satisfaction at having something useful and meaningful to show for their work at the end of the summer.

*Model career paths available to scientists and engineers in STEM fields.*

REU students expressed appreciation for the opportunity to learn about other [STEM] fields they had not considered. They enjoyed seeing how everyone works together on the different projects taking place at CReSIS. Thrice weekly tutorials presented by various CReSIS faculty and graduate students exposed REU students to many different fields and professionals involved in CReSIS research. REU students reported an increase in their likelihood to pursue graduate education in a STEM discipline as a result of the REU experience (+0.45); however, they also reported a slight decrease in likelihood of pursuing a PhD in their chosen field (-0.25). These results were consistent across all three summers, 2007 through 2009.

*Support and supervise student research experiences.*

Forty-five undergraduates were placed in supervised research experiences at two CReSIS institutions, the University of Kansas and Pennsylvania State University. Each REU student was matched with a faculty advisor and usually also with a doctoral student mentor. REU students conducted supervised research for 8 weeks, wrote a technical paper, and presented the results of their research in oral and poster presentations at the end of the summer. CReSIS paid for travel expenses to the Center at the beginning of the summer and home at the end of the REU program; room and board for 8 weeks; as well as a $3,200 stipend to each REU student.

*Provide research opportunities for underrepresented student populations at CReSIS partner institutions.*

Thirty-one (76%) of the forty-five REUs from 2006 through 2009 were from groups typically underrepresented in STEM fields. Fifteen REU students (33%) were African-American from CReSIS partner institution, Elizabeth City State University. Twenty-five (56%) of the REUs were women.

Overall, the REU Program was very successful in meeting its stated objectives during Phase 1. Future REU evaluations and follow-up surveys with former REU students will continue to examine the impact of the REU program on a student pursuing a PhD in their chosen field. We continue to keep in contact with former REU students, and to track their educational or professional progress in STEM fields, helping us evaluate the ultimate impacts of the REU program. In particular, these longitudinal data allow us to investigate the correlation between a former REU student’s self-reported confidence in the focus skills (i.e. attending graduate school and/or earning a PhD) and the actual pursuit and success in earning a graduate degree in a STEM field.

**III. K-12 Outreach**

**Overview**

The objective of CReSIS’ K-12 Outreach Program is to inspire and educate the next generation of polar scientists. Toward this end, our outreach program has focused on interacting directly with students as well as providing professional development for teachers interested in learning more about polar science and climate change. The CReSIS K-12 program impacts students directly through classroom visits, an afterschool program, and participation in family science night events. We reach students indirectly through *The Heat is On* summer teacher workshop, and by presenting hands-on workshops at regional and national science teacher conferences. By all evaluative measures, the CReSIS K-12 Outreach Program has been very successful.
Professional Development Workshops for Educators

Overview

CReSIS offered several professional development workshops for K-12 teachers during the Center’s first five years. Summer workshops were held at both the Ohio State University and at the University of Kansas. In 2010, a summer workshop for teachers will be held at CReSIS partner institution, Pennsylvania State University. CReSIS has offered workshops in both face-to-face and online formats. Evaluation results from the teachers indicate that the more successful professional development experiences are those that are face-to-face for the majority of the workshop.

Teaching About the Cryosphere

During the summers of 2006 and 2007, CReSIS partner The Ohio State University with Byrd Polar Research Center hosted a face-to-face professional development workshop for K-12 teachers entitled “Teaching About the Cryosphere.” OSU’s 2006 workshop only enrolled four teachers and evaluation results attributed this under-enrollment to the fact that teachers could only receive partial tuition support for the CReSIS workshop, while they could receive tuition-free credits at professional development workshops offered elsewhere. In 2007, the same workshop was offered again with full tuition support and was fully enrolled with 24 teacher participants. Participants’ understanding of polar science content was evaluated using a pre- and post-test of eight open-ended essay items. Each item on the tests was scored with a 4-point rubric. Results showed participants demonstrated an increase in polar science content knowledge from 11.8 points on the pre-test to 21.4 points on the post-test, an increase of 30%. Additionally, participants’ attitudes toward the workshop were evaluated qualitatively through a survey of open-ended questions. The most salient point gleaned from the attitude survey was that, although participants found the workshop highly effective and valuable, they experienced too much passive listening and not enough active learning. The lessons learned from the OSU workshops were subsequently applied to The Heat is On: Confronting Climate Change in the Classroom teacher workshop offered at CReSIS Headquarters at the University of Kansas in the summer of 2008.

The Heat is On: Confronting Climate Change in the Classroom

2008

During the summer of 2008, CReSIS hosted a professional development workshop for K-12 science teachers titled The Heat is On: Confronting Climate Change in the Classroom. The two main objectives of this workshop were to increase participating teachers’ content knowledge about the science of climate change and to enhance their pedagogical knowledge of how to address climate change in the classroom. The workshop focused on global climate change, its interactions with the cryosphere, and the remote sensing techniques used at CReSIS. The 2008 workshop was considered a “combination” format since participants were required to complete four online assignments (via Moodle, a free, downloadable course management system) prior to attending the one week workshop on-site at CReSIS. A key component was the opportunity to meet and work with CReSIS scientists and engineers addressing climate change, remote sensing, and sea level rise. Approximately half of the time each day was spent in lectures and discussions with CReSIS scientists on topics that included An Introduction to Climate Change; Ice Sheets and Glaciers; Energy Balance and Circulation Systems; Sea Ice; Ice Cores, Proxies, and Climate; Radar and Satellite Remote Sensing; Global Climate Models; and Regional and Local Impacts of Climate Change. The other half of each day was spent on demonstrating and developing hands-on, inquiry-based ways to effectively teach climate science in the classroom. Teachers were divided into four working groups to develop lessons corresponding to the lectures and their new knowledge. There were four major focus areas of working groups: Remote Sensing, Glacier Modeling, Climate Data Analysis, and Water Budget Analysis. Participants were also expected to implement at least one of the lessons developed during the workshop in their classes the following year and to provide feedback on that lesson. Upon successful completion of the workshop and the follow-up lesson implementation in their classrooms, teachers had the option of earning
3 graduate credits or 3 continuing education units (CEUs) with an additional $400 stipend. Approximately 40% of the teachers chose the graduate credit and 60% chose the CEUs and stipend.

**Participants**
Participants in the workshop included 24 K-12 science teachers from across Kansas and the Kansas City area, 9 male and 15 female. The majority of participants taught at the secondary level with 10 high school teachers, 9 middle school teachers, and 5 elementary teachers. Two of the participating teachers were from the Kansas School for the Deaf. The teachers represented 13 school districts. The workshop participants represented school districts with a 31.26% average enrollment of students from underrepresented groups in STEM fields. This is 7.16% percent higher than the state average of 24.1%.

**Evaluation Objectives and Methods**
Teachers’ content understanding was evaluated formatively through the use of a student response system (a.k.a. clickers) during and after each scientist’s presentation. In addition, pre- and post-content knowledge tests and a climate science teaching efficacy belief instrument were administered to gather summative evaluation data. As the capstone for the course, participants created a climate science lesson plan or unit with a scientist or engineer as an advisor. This was evaluated using a rubric designed by the CReSIS Education Team at OSU. Finally, participants were asked to complete an online evaluation survey regarding their experience in the workshop.

A paired-samples t test was conducted to evaluate the impact of participation in our teacher workshop on climate content knowledge (CC), beliefs about one’s personal efficacy in teaching climate science (PE), and beliefs about the expected outcomes of climate science teaching (OE).

<table>
<thead>
<tr>
<th>Outcomes</th>
<th>Mean (Pre)</th>
<th>Mean (Post)</th>
<th>p-level (Paired Samples t-test)</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal Efficacy</strong></td>
<td>46.5</td>
<td>53</td>
<td>0.00321</td>
<td>0.49</td>
</tr>
<tr>
<td><strong>Outcome Expectancy</strong></td>
<td>33.5</td>
<td>37.2</td>
<td>0.00121</td>
<td>0.26</td>
</tr>
<tr>
<td><strong>Content Knowledge</strong></td>
<td>8.8 (out of 24)</td>
<td>14.4 (out of 24)</td>
<td>0.00106</td>
<td>0.57</td>
</tr>
</tbody>
</table>

**Outcomes**
As we had hoped, participants showed significant improvement in all three areas. Unfortunately, out of the 24 participants, only 15 completed both the pre- and post-measures for all three instruments, so our sample size was small.

**Climate Science Teaching Self Efficacy**
A measure of personal beliefs of teaching skills, the personal efficacy score reflects the amount of personal responsibility a teacher assumes for student learning and is a positive predictor of teaching behavior. Teachers with high PE scores are likely to spend the proper amount of time to develop concepts taught in a science class and to use effective instructional strategies such as cooperative learning. In addition, teachers with high efficacy scores are more likely to implement instructional changes than those with low scores. Based on this research on self-efficacy, in the context of climate science education, we can infer that teachers with a higher efficacy score would be more likely to teach this topic than those with low efficacy scores. Therefore, we included this measure of teachers’ efficacy beliefs in teaching climate science in the evaluation of the professional development workshop at CReSIS. In 2008, the personal efficacy in climate science teaching mean score on the PE post-test (M = 53, SD = 4.77) was significantly greater than the mean score on the PE pre-test (M = 46.5, SD = 6.60), t(14) = -3.55, p < 0.01. Effect size r was 0.49, which is considered a large effect size.
Student Outcome Expectancy

The outcome expectancy measure represents a teacher’s belief about how teaching and learning are related. Research has found that teachers with low OE scores are often less effective than teachers with high OE scores, and that low OE teachers used more text-based as opposed to inquiry-based or other activity-centered instruction. The mean score on the OE post-test (M=37.2, SD = 6.61) was also significantly higher than the score on the OE pre-test (M = 33.5, SD = 6.81), t(14) = -4.04, p < 0.01. At 0.26, the effect size r is considered medium.

Climate Science Content Knowledge

Improving teachers’ climate science content knowledge was a primary goal of the workshop. Indeed, participants demonstrated significantly improved understanding of climate science concepts after the workshop. The mean score on the CK post-test (M = 14.4, SD = 3.72) was significantly higher than the mean score on the CK pre-test (M = 8.8, SD = 4.21), t(14) = -4.11, p < 0.01. An effect size r of 0.57 is considered a large effect size. Interestingly, the mean percent of items answered correctly on the pre-test was about 37%, while the mean percent of items answered correctly on the post-test was still only about 60%. Generally in education, 80% is considered the lower end of mastery.

Participant Perceptions of the Workshops

In addition to assessing participants’ personal efficacy beliefs, student outcome expectations, and content knowledge, the overall workshop was evaluated from the participants’ perspective. Post-workshop evaluation surveys were administered online via Survey Monkey at the end of the last day of the workshop. Results were consistently very positive, but the most remarkable finding was that the participants perceived the opportunity to work with CReSIS scientists as the most important and beneficial aspect of the workshop. 20 of 24 teachers responded that the “best” thing about the workshop was the interaction with the scientists:

“Being able to interact with the professionals at this high of a level is not an opportunity that is available to us in the classrooms of school very often. Thank you!!!”

“I also especially appreciated the opportunity to interact with experts in the field.”

Similarly, the teachers appreciated working collaboratively with each other and a mentor scientist to develop the lesson unit. Several comments were directed at the success of these working groups:

“Extremely valuable and effective. It’s always great to work with other teachers... especially when combined with research professionals at the university level.”

“I enjoyed working with the group to develop the lesson. I thought that the input from my peers made our lesson much stronger.”

Overall, 96% of workshop participants agreed or strongly agreed that *The Heat is On: Confronting Climate Change in the Classroom* was an effective and valuable workshop, while 92% believed that the workshop had improved their personal communications related to climate change, and 88% agreed that they now felt “confident to confront climate change in the classroom.”

2009

In an attempt to make this successful workshop available to a geographically broader audience, the Education Team converted *The Heat is On* workshop to an online course format using the familiar Moodle environment. This course utilized resources from previous workshops that had been held on-campus at KU and OSU. Because experience suggested that some, if not most, participants would be uncomfortable using
some of the technology tools required throughout the course, an on-site “kickoff” event was held on a Saturday. This face-to-face meeting also served to establish positive interpersonal relationships between participants and instructors, an important element contributing to the success of student learning. The course itself consisted of 10 online assignments spanning 20 weeks of the Spring semester and into the beginning of the Summer. A final on-site gathering was held on a Saturday at the end of the course for the science teachers to present their final projects.

Participants

Seven teachers enrolled in the workshop, which is far fewer than the number of teachers that applied to the on-site workshops in 2007 (OSU) and 2008 (KU). While we knew that an online course could not involve as many participants as an in-person workshop, we had hoped for more interest than we received. Nevertheless, the workshop began with these seven teachers. During the course of the semester, two teachers withdrew from the workshop due to busy time schedules. Also, one teacher did not participate in the assignments and discussions, and therefore was asked to withdraw or propose an alternative assignment to reflect significant learning. That teacher chose to also withdraw from the workshop. Only four teachers completed the course.

Online Workshop Evaluation

Although the participants in the 2009 The Heat is On online course completed the same evaluation instruments from the 2008 on-site workshop, the sample size of four was too small to use for valid evaluative generalizations or comparisons between the effectiveness of the on-site versus online formats. It was quite apparent that the online course was far more focused on the mastery of polar and climate science content than on the pedagogical considerations of teaching these topics to K-12 students. This was due in large part to the change in format and the low enrollment that precluded organizing collaborative working groups. The online course participants were also unable to experience firsthand all of the hands-on, inquiry-based activities that were presented during the 2008 on-site workshop; therefore, online course participants did not receive as much pedagogical instruction as the on-site participants. In the future, online professional development for K-12 Teachers will be supplemented with hands-on, inquiry-based activities. While it was hoped that the online course would draw participants from a wider geographic area, adding more on-site components could potentially exclude participants living outside a radius of a few hundred miles.

Summary of Outcomes and Impacts

All evaluation results indicate that in 2008 The Heat is On: Confronting Climate Change in the Classroom was an extremely successful professional development workshop for teachers. Teachers significantly improved their climate science content knowledge, their self-efficacy beliefs toward teaching climate science, and their beliefs regarding the expected learning outcomes for their students. In alignment with current research on professional development for teachers, the workshop participants agreed that the best part of the experience was the opportunity to work in close collaboration, not only with their colleagues, but most importantly, with CReSIS climate scientists and engineers. To build on the success of the workshop and to sustain the collaborations between the teachers, and between the teachers and CReSIS, an online “Polar Educator” forum is being developed as part of the new CReSIS website. Through efforts such as these, we will be able to nurture the development of this new community of educators who have specialized knowledge and interest in polar science and climate change. Although the 2009 The Heat is On online course was not as successful as the 2008 on-site course, it was an important first step toward providing online professional development for K-12 teachers.

It is often the case that successes are best illustrated one person at a time. In addition to the workshops offered by CReSIS, the Center has also participated in the PolarTrec program. Funded by the National Science Foundation, PolarTrec sends K-12 teachers to accompany scientific research teams to conduct polar field work. During the 2007 Antarctic field season, a local middle school teacher accompanied a CReSIS team to Antarctica. In 2008, this teacher participated in The Heat is On summer workshop and gave a presentation on his experience with PolarTrec and Antarctic fieldwork. In the fall, and still funded
by PolarTrec, this teacher accompanied the CReSIS Education Team to the National Science Teachers Association conference to assist in giving a workshop to 75+ science teachers. Throughout 2007-2010, the PolarTrec teacher cooperated with CReSIS on several outreach efforts such as local and regional Family Science Nights, Science Olympiad, local and regional Science Fairs, Kansas Association for Teachers of Science professional development camp, and regional teacher in-service days. Starting in summer of 2010, this teacher will begin working toward a PhD in Geography at KU and will join the CReSIS Education Team as a Graduate Research Assistant. Similarly, another local teacher who participated in the 2008 The Heat is On workshop went on to become a PolarTrec teacher and accompanied the CReSIS team to Antarctica during the 2009 field season. One thing that has repeatedly been observed during evaluation efforts is that the positive relationships cultivated between individuals contribute significantly to the success of the organization and all of its programs.

2010

In late July, CReSIS is partnering with NASA Space Grant to offer the face-to-face version of The Heat is On: Confronting Climate Change in the Classroom at our partner institution, Penn State University. Based on previous experience, the new improved week-long workshop has undergone a few minor changes. Rather than a broad K-12 focus, the target audience has been narrowed to teachers of grades 4-9, the age most critical for students to develop a positive and competent self-concept regarding science if they are to pursue a future in a STEM field. There will still be four weeks of online “pre-assignments” delivered via Moodle to give participants a strong, common foundation in basic polar and climate science concepts. The presentations and working group topics will be modified to reflect the expertise available at Penn State; and, in addition, some CReSIS graduate students will lead working groups and give some of the presentations. Additionally, in an attempt to bring the workshop into closer alignment with the actual operational strengths of CReSIS, the collaborative working groups will reflect a new emphasis on technology and engineering. Participants in the 2010 Workshop will receive $50 worth of text-based resources along with a stand-alone “kit” containing all of the materials needed to conduct the Ice, Ice, Baby and Climate Pathfinder activities with their students. The 2010 workshop will enroll up to 20 participants and will be evaluated using the same methods and instruments as the 2008 and 2009 workshops.

Classroom-based Outreach: The Ice, Ice, Baby Program

Ice, Ice, Baby (IIB) is a series of twenty inquiry-based lessons developed by the CReSIS K-12 Outreach Coordinator, Ms. Cheri Hamilton, to teach climate and polar science to elementary and middle school students. Ms. Hamilton has presented these 30-60 minute lessons in classrooms around the Kansas City, Topeka, and Lawrence areas. In ’07-’08, the K-12 program visited over 30 schools and 3000 students. This resulted in large numbers of students being exposed to CReSIS content through our outreach program. After evaluating the results of the ’06-’07 classroom visit program, the Education Team significantly modified the focus of in-school presentations, with more attention given to fewer schools.

In 2008-2009, the K-12 outreach program took a more focused and in-depth approach in an effort to have a demonstrable impact on student learning and engagement. During the ’08-’09 school year, Ms. Hamilton made regular, bi-weekly presentations to 13 urban elementary classrooms at three different schools in high-minority, lower-income areas of Topeka and Kansas City, Kansas. About 240 3rd, 4th, and 5th grade students were contacted each week, and during the school year each participating student had (on average) an additional 12 science lessons, that otherwise would not have occurred. Ms. Hamilton implemented the use of student science notebooks with every class to enhance student learning of science process skills in the inquiry-based Ice, Ice, Baby program. The notebooks also provided both formative and summative assessment data for evaluating the effectiveness of this outreach strategy. An example student notebook entry is shown on the next page. In addition, one 5th grade class took a Likert-scale survey to determine their attitude toward science, as well as a polar and climate science content pre-test at the beginning of the school year and then a post-test at the end of the program. Participating teachers were very positive in their appraisal of the Ice, Ice, Baby outreach program as measured by a post-program attitude survey; results are displayed below.
Table 6. Teacher Attitude toward Ice, Ice, Baby Program

<table>
<thead>
<tr>
<th>Ice, Ice, Baby Participating Teacher Survey Years 3 and 4; n=26</th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice, Ice, Baby was of significant educational value to my students.</td>
<td>23</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>My students enjoyed the program.</td>
<td>25</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>My students’ interest in polar science was piqued by the program.</td>
<td>21</td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>I would be interested in participating in the pilot-testing of new CReSIS polar science curricular materials.</td>
<td>13</td>
<td>7</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>I would be interested in attending a professional development workshop at KU’s Center for Remote Sensing of Ice Sheets.</td>
<td>10</td>
<td>8</td>
<td>7</td>
<td>0</td>
</tr>
</tbody>
</table>
This image of a student science notebook illustrates how participation in the Ice, Ice, Baby program helps students learn science process skills such as isolating variables and gathering measurable data.
During the 2009-2010 school year, Ms. Hamilton is visiting approximately 350 3rd, 4th, and 5th grade students in 17 different classrooms at three different schools. In addition to collecting student work samples, information regarding student attitude toward science, and survey data of teachers’ satisfaction with the program, a new measurement instrument has been developed that will enable CReSIS to determine whether the Ice, Ice, Baby program has any significant effect on participating teachers’ science teaching. Because Ms. Hamilton models inquiry-based science instruction for the participating teachers on an ongoing, regular basis throughout the school year, it is hoped that the program will actually have an impact on the teachers’ own science instruction. To encourage the professional development aspect of the Ice, Ice, Baby program, Ms. Hamilton provides teachers with supplemental inquiry-based activities for them to do with their classes between her visits. Before Ms. Hamilton visited each classroom for the first time, participating teachers were asked to complete a 51-item Likert-type survey that asks about their science instruction practices and the activities that their students engage in during science lessons (i.e. the “Science Teaching Survey”). The survey will then be administered to each teacher a second time at the end of the school year. It is hoped that participation in the Ice, Ice, Baby program will foster teachers’ progression toward more reform-based science instruction. Some of the more striking results of the pre-Science Teaching Survey are summarized below:

Table 7. Selected Pre-IIB “Science Teaching Survey” Results

| When you taught science most recently, about how often did STUDENTS take part in each of the following types of activities? |
|---|---|---|---|
| (n=17 unless otherwise noted) | Never or Rarely | Sometimes (e.g. every other week) | Often or Regularly (once or more per week) |
| Design or implement their own investigation (n=16) | 13 (81.3%) | 3 (18.8%) | 0 (0.0%) |
| Formulate a testable hypothesis | 12 (70.6%) | 4 (23.5%) | 1 (5.9%) |
| Conduct experiments to test different predictions | 8 (47.1%) | 7 (41.2%) | 2 (11.8%) |
| Record, represent, and/or analyze data | 9 (53.0%) | 6 (35.3%) | 2 (11.8%) |
| Write explanations about what was observed and why it happened; draw conclusions | 8 (47.1%) | 5 (29.4%) | 4 (23.5%) |
| Debate different scientific explanations | 11 (64.7%) | 3 (17.6%) | 3 (17.6%) |
| Discuss the nature of science | 8 (47.1%) | 5 (29.4%) | 4 (23.5%) |
| Prepare written science reports | 14 (82.4%) | 3 (17.6%) | 0 (0.0%) |
| Use computers for modeling and simulations | 12 (70.6%) | 4 (23.5%) | 1 (5.9%) |
| Participate in field work | 16 (94.1%) | 1 (5.9%) | 0 (0.0%) |
Participants

The elementary schools that participate in the Ice, Ice, Baby program have minority student populations that are higher than the state average. The demographics of each school are provided in the pie charts below.

Figure 3. State and National Student Demographics

Figure 4. 2008-2010 Ice, Ice, Baby School Demographics

Ice, Ice, Baby Evaluation Summary

CReSIS’ Ice, Ice, Baby K-12 Outreach Program has been extremely successful in exposing a large and diverse group of students and teachers to CReSIS-related science. Not only did participating students receive significantly more science instruction than if CReSIS had not come to their classrooms, but their teachers also received professional development in best practices in science instruction through the modeling of Ice, Ice, Baby lessons by Ms. Hamilton, the K-12 Outreach Coordinator. We will have comparative data on the effect of the program on participating teachers’ science instruction after the Science Teaching Survey is administered again at the end of the school year in May. Improving
participating teachers’ science instruction practices is an effective way to sustain the impact of the CReSIS Ice, Ice, Baby program, as those teachers will continue to teach science to students after the Ice, Ice, Baby program is phased out. Collecting longitudinal data on the students who have participated in the Ice, Ice, Baby program will tell us if the program has a lasting impact on students’ attitudes toward science, their science achievement, or the likelihood that they will pursue further education in STEM fields. Beginning in 2007, as mandated by No Child Left Behind, the Kansas Science Assessment is administered annually to 4th and 7th grade students. It may be possible to use this science assessment data to evaluate whether the Ice, Ice, Baby program has an effect on students’ science achievement.

**Other Formal Education Outreach**

During Year 4, the CReSIS Education Team presented a hands-on workshop at the National Conference of the National Science Teachers Association (NSTA) in Portland, Oregon. This presentation was overwhelmingly attended by 70+ science teachers. By far, the teachers considered the most useful aspect of the presentation to be the hands-on experience with Ice, Ice, Baby activities. Some of the participants’ quotes regarding the workshop are provided below:

“The activities are great. Exactly what we want.”

“The hands-on activities were very nice – easy to make and show and would interest the students.”

“Share more hands-on activities to support the content.”

“Excellent presentation. Good activities for classrooms that are inexpensive to prepare.”

In Year 5, the CReSIS Education Team presented seven research and professional development sessions at three national conferences. A hands-on workshop on Ice, Ice, Baby and an evaluation report of *The Heat is On* professional development workshop were presented to 32 attendees at the national conference of the North American Association for Environmental Education. Three workshops (Ice, Ice, Baby; Glacier Goo; and Making Climate Change Local Using Online Data) were presented to a total of 75 participants at the annual conference of the National Science Teachers Association. Overall, evaluation results were very positive, but the most striking finding is that 80% of participants “Strongly Agreed” that they intended to visit the CReSIS website as a result of attending a CReSIS workshop. When those who “Agreed” are included, the percentage increased to 99%. This outcome indicates the importance of maintaining a high-quality CReSIS Education website that meets the needs of teachers in the classroom. The CReSIS Education Program should maintain a presence at national education conferences as a way to continually increase the pool of teachers who are familiar with the Center, its mission, and the educational resources it provides. However, presentations and workshops at conferences are considered a gateway to the CReSIS Education website. During the recent overhaul of the Education website, an online form was implemented to gather feedback from educators using CReSIS’ online educational resources.

**Informal Education Outreach**

During the summers of Years 3, 4, and 5, CReSIS also contributed to a two-week workshop for fifteen middle-school students through Elizabeth City State University (ECSU). The CReSIS K-12 Outreach Coordinator presented the Ice, Ice, Baby activities to these students as part of the workshop. Students completed a 10-item multiple-choice pre-test before the workshop to assess their level of understanding regarding the science content covered in IIB. The same assessment was administered following the workshop as a post-test. Overall, students showed a 7% increase in understanding after participating in the workshop; not a resounding success. It may be that the IIB curriculum is more appropriate for formal, classroom-based lessons and that it is less engaging for older students participating in a summertime learning experience. CReSIS has other resources that may hold greater interest for older students, and these can be incorporated into the ECSU middle school program. The Climate Pathfinders program
described in the next section was specifically designed as an after-school program for middle school students, and could be used in the ECSU program in the future.

Climate Pathfinders is a weekly after-school program for 6th-8th grade students developed by the CReSIS Education Team. During Year 4, Climate Pathfinders was offered at several schools in Lawrence, Topeka, and Kansas City that serve primarily low-income students. As part of the program, students learn about issues such as recycling, carbon emission from cars, and the effects of leaving a large carbon footprint. Climate Pathfinders’ program resources will be available soon for free download from the CReSIS website.

In addition to conference presentations, after-school programs, and summer workshops, CReSIS’ K-12 Educational Outreach efforts included participation in many Family Science Nights, Science Fairs, and a Regional Science Olympiad.

Table 8.

<table>
<thead>
<tr>
<th>Phase 1</th>
<th># of Informal Events</th>
<th>Total # of Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 2</td>
<td>14</td>
<td>2708</td>
</tr>
<tr>
<td>Year 3</td>
<td>19</td>
<td>8570</td>
</tr>
<tr>
<td>Year 4</td>
<td>15</td>
<td>1207</td>
</tr>
<tr>
<td>Year 5</td>
<td>10</td>
<td>1560</td>
</tr>
</tbody>
</table>

IV. Overall Summary of CReSIS Education Program Evaluation

Both the REU and K-12 outreach programs at CReSIS have been successful in realizing the Center’s stated Education objectives. Ice, Ice, Baby is a strong K-12 outreach program that is focused on schools with a significant number of underrepresented minority students in Topeka and Kansas City. The Ice, Ice, Baby program is designed to reinforce and enhance K-12 foundational skills necessary to pursue undergraduate and graduate education in STEM fields. Student science notebooks have provided qualitative evidence that this program has been very successful. Quantitative data on the impact of IIB on participating teachers’ science instruction is being collected during Year 5 to confirm this conclusion. Additionally, The Heat is On: Confronting Climate Change in the Classroom professional development workshop for K-12 teachers was very successful in increasing participating teachers’ polar and climate science content knowledge as well as their self-efficacy beliefs toward teaching climate science. Previous research suggests that when teachers increase their content knowledge and self-efficacy beliefs, it results in higher achievement for their students.

The Research Experience for Undergraduates program is also a critical and successful component of CReSIS’ overall Education program. The REU program has attracted a highly diverse and increasingly well-qualified cohort of participants each summer. Participants in this program not only increase their interdisciplinary knowledge in CReSIS-related fields, but they also produce a technical paper and presentation based on their supervised summer research project.

It is worth noting that the CReSIS website plays an important role in the Center’s education program, and it underwent a complete overhaul during 2009. These changes to the website are expected to greatly increase the effectiveness of the CReSIS Education program.

Strengths

The CReSIS REU and K-12 outreach activities are well-aligned with the Center’s stated educational objectives. CReSIS’ Education program has been particularly successful engaging students at all levels who come from groups typically underrepresented in STEM fields. On average, 21% of the students who
participated in the Ice, Ice, Baby program were African American and 46% were Hispanic. Likewise, the REU program was successful in creating highly diverse cohorts; on average 56% of the REUs were female and 76% were from groups typically underrepresented in STEM fields (including female.)

**Weaknesses and Future Efforts**

The most notable weakness in the Center’s education program is the unfulfilled need for more follow-up, longitudinal data on all the students the Center seeks to impact (i.e. graduate, undergraduate, REU, and K-12 students). In order to assess the impact of CReSIS on the development of “the next generation of scientists and engineers for the nation in Center related disciplines,” additional longitudinal data is needed. How does participation in the Center impact the future STEM education and career choice of a student? Future evaluation efforts of the CReSIS Education Program will include the collection of such data.