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LINKING CLIMATE CHANGE EDUCATION THROUGH THE INTEGRATION OF A KITE-BORNE REMOTE SENSING SYSTEM: LINKING CLIMATE CHANGE EDUCATION AND REMOTE SENSING

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Abstract

A majority of secondary science teachers are found to include the topic of climate change in their courses. However, teachers informally and sporadically discuss climate change and students rarely understand the underlying scientific concepts. The project team developed an innovative pedagogical approach, in which teachers and students learn climate change concepts by analyzing National Aeronautics and Space Administration (NASA) global data collected through satellites and by imitating the NASA data collection process through NASA Airborne Earth Research Observation Kites And Tethered Systems (AEROKATS), a kite-borne remote sensing system. Besides AEROKATS, other major components of this system include a web-collection of NASA and remote sensing data and related educational resources, project-based learning for teacher professional development, teacher and student field trips, iOS devices, smart field data collector apps, portable weather stations, probeware, and a virtual teacher collaboratory supported with a GIS-enabled mapping portal. Three sets of research instruments, the NASA Long-Term Experience –Educator End of Event Survey, the Teacher End of Project Survey, and the pre-and-post-Investigating Climate Change and Remote Sensing (ICCARS) project student exams, are adapted to study the pedagogical impacts of the NASA AEROKATS remote sensing system. These findings confirm that climate change education is more effective when both teachers and students actively participate in authentic scientific inquiry by collecting and analyzing remote sensing data, developing hypotheses, designing experiments, sharing findings, and discussing results.

Keywords – Authentic scientific inquiry, Climate change education, NASA sources, AEROKATS, Kite-borne remote sensing system.

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1 INTRODUCTION

"Climate change is occurring and is very likely caused by human activities" (National Research Council [NRC], 2012a, pp. 1). A strong possible consequence of climate change is to negatively shape many aspects of life in the foreseeable future (NRC, 2011a). Therefore it is very important to engage formal and informal education to educate the public about those challenges climate change will bring, and to prepare current and future generations to intelligently respond to those challenges (NRC, 2011b). In fact, a good number of science teachers (earth science and environmental science in particular) are found to include discussions of climate change in their courses (Wise, 2010). However, the majority of them only informally and sporadically introduce the phenomena, causes and consequences of climate change. Science teachers are facing many challenges to integrate this emerging scientific and societal theme – global climate change- into secondary school curricula.

At first, climate change education requires that teachers have a good understanding of complex interactions between climate and people, which is usually difficult to grasp without diving deep into this interdisciplinary subject (Hansen, 2010; Wise, 2010). Secondly, a majority of science teachers regard that climate change education, beyond the scientific studies of earth science, ecology, and environmental science, is a study of nature with a specialized requirement of field research skills, and, therefore, will take a longer professional development effort (Steele, 2011). Thirdly, climate change education is viewed by science teachers involving many political, economic and social viewpoints just like environmental education, such as, religious belief (Adelekan & Gradegesin, 2005), perceived self-efficacy (Devine-Wright, Devine-Wright & Flemming, 2004), cultural traditions (Aytülkasapoğlu & Ecevit, 2002), and social norms (Corraliza & Berenguer, 2000). As a result, many science teachers do not feel comfortable addressing climate change and its societal consequences in classrooms (Kilinc, 2010). Fourthly, the instruction of climate change is falling into the disciplinary silo of earth science in secondary schools. Unfortunately earth science courses are only taken by 14% – 23% of high school students in US secondary schools (Gonzales & Keane, 2011). Therefore, there is little pressure for formally embedding climate change education into secondary school curricula.

There is an increasing volume of literature on how to broadly integrate climate change education in secondary schools. From the curriculum adoption viewpoint, the inclusion of climate change education in curricula is just as embedding any emerging subject in school education (NRC, 2011b; NRC 2012a). Six provisions that were identified by Layton (1973) and Goodson (1985, 1987) should be included in school time-tables in order to successfully embed an emerging subject in school curricula: teacher professional development, external examinations, university partnerships, teacher material interests, subject characteristics, and external constituency. Five additional themes have been proposed recently for accepting environmental education in schools: "syllabi and teaching resources, central government leadership, informal curriculum, non-formal education, and emergent process" (Yueh, Cowie, Barker & Jones, 2010, pp. 267). These traditional provisions and new additions are very relevant to promoting climate change education in schools.

Abundant recommendations have also been made from the perspectives of learning strategies, such as, project-based learning, authentic scientific inquiry, place-based learning, and action-oriented education. The concept of project-based learning (PBL) emerged more than half a century ago as a pedagogy, which proclaims that students could learn much better through solving real-world problems (Thomas, 2000; Barron, 2003). PBL improves their problem-solving and collaboration skills and increases students' motivation to learn as well. As a result, PBL helps students achieve better performance even with traditional academic tests (Strobel & van Barneveld, 2009; Walker & Leary, 2009). The core of PBL is the integration of real-world experience into school learning environments and, thus, is closely related to the concept of authentic scientific inquiry (ASI). ASI promotes engaging students in a full range of scientific practices as scientists in the real world do. ASI helps students understand how knowledge develops, and gives them an appreciation of the wide range of approaches that are used to investigate, model, and explain the world (Westerlund, Garcia & Koke, 2002; NRC, 2012b). Moreover, project-based scientific inquiries could be made more effective if they were conducted or implemented within existing power structures or social contexts (Wiener & Rivera, 2010). The consideration of place-based approaches into project-based or inquiry-based instructions can improve students' achievement (Carleton-Hug & Hug, 2010; Wyner & Desalle, 2010; Gautreau & Binns, 2012).

The necessity for students' involvement in practices for climate change education or environmental education has been elevated to a higher level, action-oriented education, in recent years. Climate change education as well as environmental education at schools has traditionally focused on conveying knowledge to students but not on transforming the knowledge into actions or activities valuable to alleviating the stresses caused by environmental pollution or climate change (Kilinc, Boyes & Stanisstreet 2011). Therefore, a project-based learning environment needs to have an action-oriented approach in order to develop pro-environmental behaviors for both students and teachers (Kilinc, 2010; Dalelo, 2012). An action in the context of environmental education firstly indicates a decision to do something good either alone or as a group (Dalelo, 2012). "It is a question of a change in behavior or an attempt to influence the conditions of life" (Jensen & Schnack, 2006, pp. 476). An action, secondly, must have a targeted goal aiming at discovering feasible solutions to a problem that is being explored (Jensen & Schnack, 2006; Mogensen & Schnack, 2010; Dalelo, 2012). Since climate change and its ecological and environmental consequences have significant impacts on human life, action-oriented education is a very important element of climate change education.

Furthermore, current educational research literature strongly recommends that building bridges through networks is an innovative educational approach to break barriers for accepting an emerging subject like climate change education and environmental education in schools and for sustaining the momentum (Khalifa & Sandholz, 2012). Promoting virtual cooperation between governmental agencies, universities, schools and non-governmental organizations around the world is a sustainable approach to mitigate the negative stresses caused by climate change and subsequent environmental impacts. One great example is the Global Learning and Observations to Benefit the Environment (GLOBE®) program (n.d.), which is a worldwide hands-on, primary and secondary school-based science and education program (http://www.globe.gov/). GLOBE promotes and supports students, teachers and scientists to collaborate on inquiry-based investigations of the environment and the Earth system working in close partnership with NASA, National Oceanic and Atmospheric Administration (NOAA) and National Science Foundation (NSF). The educational networking for climate change or environmental education could be local and regional (Glowinski & Bayrhuber, 2011). For example, the goal of school-based sustainability education programs in schools could align well with the sustainability awareness of student's parents and with the sustainability agendas of the communities where schools locate (Eilam & Trop, 2013). It is much more effective to build local school-community networks to coordinate the sustainability efforts than each partner trying separately.

2 DESIGN/METHODOLOGY/APPROACH

NASA's AEROKATS (Airborne Earth Research Observation Kites And Tethered Systems), developed by NASA Aero-engineer, Geoff Bland at Goddard Space Flight Center (GFSC) Wallops Flight Facility has been successfully used in an educational setting since 2004 by the University of Maryland Eastern Shore (Nagchaudhuri et al., 2005). The NASA funded Investigating Climate Change and Remote Sensing (ICCARS) project began implementing the use of AEROKATS in 2010. This project represents the first adoption of AEROKATS technology into a K-12 environment. In addition to adopting remote sensing in K-12 settings, the ICCARS project is defined by inclusion of action-oriented education, authentic scientific inquiry, project-based learning, place-based learning, and building learning communities through networks.

The ICCARS project design has four unique characteristics:

- A scalable remote sensing system,
- Data-driven learning and visualization,
- Integration of technology and fun into project-based learning,
- Engagement of a large number of students in place-based authentic inquiry.

2.1 A Scalable Remote Sensing System

Large and growing archives of orbital imagery of the earth's surface have been collected over the past 40 years (Xie, Sha & Bai, 2010). Remotely-sensed images have proven valuable for a wide variety of applications involving both historical and contemporary conditions of the earth surface, including ecological systems, land uses, and land covers (Shrivastava & Gebelein, 2007; French, Schmugge, Ritchie, Hsu, Jacob & Ogawa, 2008; Xie, Sha, Yu, Bai & Zhang, 2009a). Moreover, remote sensing data portray the earth from a local to global scale (Filchev & Stamenov, 2010). Therefore, satellite imagery is a valuable medium for children to learn about the non-sustainable uses of natural resources at different places and over different times on earth (Jahn, Haspel & Siegmund, 2010). For example, the pace, magnitude, and spatial reach of human alterations of the Earth's land surface are unprecedented (Lambin et al., 2001). Changes in land-cover (i.e., biophysical attributes of the earth's surface) and land-use (i.e., human purpose or intent applied to these attributes) are among the most important (Turner, Clark, Kates, Richards, Mathews & Meyer, 1990; Lambin et al., 1999). Land-use and land-cover changes are so pervasive that, when aggregated globally, they significantly affect key aspects of the functions of the Earth's systems. Land-use and land-cover changes directly impact biotic diversity worldwide (Sala et al., 2000); contribute to local and regional climate change (Chase, Pielke, Kittel, Nemani & Running, 1999) as well as to global climate warming (Houghton, Hackler & Lawrence, 1999); are the primary source of soil degradation (Tolba & El-Kholy, 1992); and, by altering ecosystem services, affect the ability of biological systems to support human needs (Vitousek, Mooney, Lubchenco & Melillo, 1997). Such changes also determine, in part, the vulnerability of places and people to climatic, economic or socio-political perturbations (Kasperson, Kasperson & Turner, 1995).

In contrast, the principle of remote sensing and the techniques of image interpretation and processing are very abstract. Therefore, in order to provide a more authentic learning experience where students have fun while learning the complex concepts and techniques of remote sensing, the ICCARS project adopted AEROKATS technologies. The NASA AEROKATS program designs and develops custom airborne sensor systems (Aeropods), fitted to a wide variety of scientific and agricultural applications. Three of these systems were adapted to the ICCARS project:

- a single visible-light camera system, or MonoCam Aeropod, for training and basic aerial photo interpretation;
- a two-camera imaging system, or TwinCam Aeropod, for collecting four-band (red, green, blue and near-infrared) images; and
- an airborne portable weather station, the Air-Column Profiler, for collecting atmospheric data.

The primary instrument of concern in this paper is the TwinCam Aeropod, though classrooms made good use of the MonoCam and Air-Column Profiler systems as well. A NASA Space-Act Agreement enabled students from two schools to design custom systems for specific research projects.

Students fly an AEROKATS "mission" in the field at an identified site that is suitable for flying a large kite and instrument package safely (Figure 1). A mission consists of a planning phase, flight and safety protocols, in-situ data collection, the launch, flight and retrieval of an Aeropod, and the onboard data. After the mission, students analyze the data they collect. In the case of the TwinCam, students collect four-band, (R, G, B, NIR) imagery, and use a simplified image processing application, MultiSpec (Purdue Research Foundation, 2013), to interpret and process the AEROKATS imagery. This hands-on, authentic data collection experience, models satellite-based remote sensing, which helps students gain a better understanding of this process, as well as the application of satellite imagery in the study of global climate change.

Figure 1. A composite photo of flying the Aeropods: Panel A – the kite; Panel B – the Aeropods; Panel C – the flying crew of students

The ICCARS eCollaboratory website includes links to many types of NASA data products and tools that are relevant to studying the effects of climate change. Examples include the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper (ETM), Moderate-resolution Imaging Spectroradiometer (MODIS), Advanced Very High Resolution Radiometer - AVHRR, and SPOT-Vegetation. Papers and web-resources on the background information as well as hands-on worksheets are collected on the ICCARS website to support students in conducting image processing and analysis.

2.2 Data-Driven Learning and Visualization

The NASA data and remote sensing images are geo-spatial in nature and are best viewed and analyzed in geographic information systems (GIS). GIS has long been recognized as an interdisciplinary technology supporting high-level thinking and spatial reasoning (Bednarz & Audet, 1999; Drennon, 2005; NRC, 2006). "GIS is envisioned as an invaluable resource for use in extending a learner's understanding of geography as it allows for the visual illustration and manipulation of central concepts of the discipline" (Breetzke, Eksteen & Pretorius, 2011, pp. 148). GIS is well suited to conducting open-ended investigations, visualizing complex real-world problems, and supporting multiple modes of learning (Henry & Semple, 2012). From the data analysis point of view, GIS has five salient features:

- integrating data from multiple sources into large data sets (Xie et al., 2009b);
- serving as data mining visual and spatial aids (Hunter & Xie, 2001);
- analyzing spatial patterns in data (Batty & Xie, 1994);
- analyzing data from multidisciplinary perspectives (Hunter & Xie, 2001); and
- easily connecting with the Internet and sharing data and related analyses with colleagues (Hunter & Xie, 2001; Xie et al., 2009b).

Therefore, a GIS-enabled ICCARS resource website linked with an ICCARS online collaboratory is an important portal.

2.3 Integration of Technology and Fun into Project-Based Learning

Remote sensing, GIS, and global positioning system (GPS) are the three primary pillars of geospatial technology. Because the uses of geospatial technology are so widespread and diverse, the market is growing at an annual rate of almost 35%, with the commercial subsection of the market expanding at the rate of 100% each year (U.S. Department of Labor – Employment & Training Administration, 2010). Moreover, almost all enterprises are using the Internet to disseminate location-related (geographic) data in map forms using Web GIS (Green, 1997; Rohrer & Swing, 1997; Peng & Tsou, 2003). With the increasing popularity of global on-line mapping web applications (e.g. Google Maps, Microsoft Virtual Earth, Yahoo Maps, ArcGIS Online), Web GIS is part of "business exchange" and there is an ever-growing volume of literature and public participation (Carver, 2001; Clark, Monk & Yool, 2007; Kulo & Bodzin, 2013).

In addition, the assembling and operation of the AEROKATS remote sensing system involves the knowledge of aerodynamics, engineering and hands-on mechanical skill. The AEROKATS system also includes handheld field data collection software installed on an iPhone or iPad for entering "mission" related data such as launch site features, location data, launch team information, and atmospheric conditions (recorded by Kestrel weather station). The iPhone or iPad enabled data collector also communicates with the ICCARS data server for downloading data to mobile device or uploading field data to the server for sharing with teacher collaborators. It is worth pointing out that the flying of AEROKATS missions is a fun activity, encouraging students to conduct field observations and engineering-like experiments. For many youths, a draw to science inquiry and engineering experiment could be simply a project that looks like fun (Boss, 2013). Flying a kite with a twin-camera sensor for collecting color and infrared composite imagery with their peers is particularly appealing to them. Not to mention that they can later use a software package to interpret the images they collect and to match with the images collected by satellites.

2.4 Engagement of a Large Number of Students in Place-Based Authentic Inquiry

A good portion of the NASA data collected for the ICCARS project, the learning materials provided to students and teachers, and the lesson units developed by teachers are focused on local communities. In particular MODIS and AVHRR data products across the Great Lakes Basin from 1990 to present are compiled to support the studies of climate change on a regional scale. Landsat at 30-m spatial resolution annually from 2000 to 2010 are processed to study Land-Use-Land-Cover changes along the Detroit River. Participating teachers and students can use these image products with MutiSpec to perform basic image analysis such as Normalized Difference Vegetation Indices (NDVI) and classification of dominant land uses or covers. The NDVI data can be used to compute biomass and predict yield (Xie et al., 2009a). Crop yields are affected by temperatures and thus by climate changes (Parry, Rosenzweig, Iglesias, Livermore & Fischer, 2004). Teachers and students can use the data collected through AEROKATS to investigate the relationship between crop productivity, temperature changes and other variables along the Detroit River or in Michigan.

In brief, the ICCARS project, implemented jointly by Wayne County Regional Educational Service Agency (RESA) and Eastern Michigan University (EMU) with a grant from NASA Office of Science Education, focused on experiences and activities that support high school level instruction/learning in NASA-related STEM content and engage teachers and students in dialogue with NASA scientists and peers in order to gain deeper insight into NASA STEM content. The ICCARS project was formally started in July, 2010 and successfully completed in April, 2013. The first cohort (September, 2010-June, 2011), included 16 teacher participants and focused on development of the ICCARS model. In July, 2011, the full implementation phase began and 42 additional teacher participants were added. Teachers participated in ICCARS summer institutes, field AEROKATS flying missions, monthly webinars, and they actively shared ideas in an ICCARS eLearning Collaboratory. Together, they created 26 instructional modules with 66 fully developed lesson units using the ICCARS materials and NASA data in the context of climate change education (Table 1).

Content area[a]	***# of units***
Biology	*16*
Chemistry	*5*
Earth Science	*17*
Environmental Science	*2*
General Science	*10*
Mathematics	*7*
Physics	*1*
Scientific Literacy	*2*
Social Studies	*5*
Technology	*1*
Total number of units	*66*

[a]The content area of a lesson unit is declared by its developer. Many of the units are interdisciplinary and refer to secondary content areas as well.

Table 1. Summary of ICCARS climate change lesson units by content areas

Thirty-four teachers embedded the ICCARS materials and climate change education into their school curricula. They taught a total of 2496 students with an average 75 contact hours per academic year. The survey results indicated that teachers delivered their instructional units in a variety of formats based on the structure of their units and the curriculum calendars at their schools, with 36.7% delivering the unit in a single block, and 63.3% embedding their units in their instruction throughout the school year. Unit duration (number of class periods dedicated to ICCARS activities) varied widely as well.

3 CONCLUSIONS

3.1 The ICCARS Project Outcome Analysis

The ICCARS project had a broad scope as was mentioned earlier. Therefore, this paper focuses attention to the outcomes that were directly related to the ICCARS' unique features and the AEROKATS remote sensing system in particular. The outcome assessment involved three types of evaluation research approaches:

- the NASA Educator End of Event Survey;
- the ICCARS' Teacher End of Project Survey (the exit survey); and

- the impact analysis of ICCARS curriculum integration on students' performance.

The NASA Educator End of Event Surveys distinguish between long-term experience (> 2 days), and short-term experience (< 2 days) events, and are otherwise identical.

The learning outcome was assessed by employing a repeated-measures design. A repeated-measures design is used when a pre-test and post-test is administered to the same group of learners over a defined period. According to Gravetter and Wallnau (2004), the repeated-measures design is "especially well-suited for studying learning, development, or other changes that take place over time" (pp. 355). All of the data was entered into IBM SPSS Statistics version 21. The pre-test and post-test results were analyzed using the paired-samples t-test. All testing was two-tailed, with nominal alpha set at 0.05. In addition, an electronic survey was developed using the SurveyMonkey software (SurveyMonkey Inc., 2013). SurveyMonkey is a user-friendly software that permits one to analyze survey responses. Basic frequencies and percentages were generated for each completed survey.

The NASA Long-term and Short-term Experience- Educator End of Event Surveys, are required for all NASA-funded educational projects, and are monitored by the NASA Office of Education. The survey instruments were administered at various times throughout the course of the ICCARS project, which was funded for two-years, with a one-year no-cost extension. A total of 324 entries were retrieved from both surveys. Additionally, 30 teachers completed a Long-term Experience-Educator End of Event Survey at the end of the implementation phase of the project. The combined survey results were reported in Table 2 and Table 3.

Survey questions	***SA***	***A***	***N***	***D***	***SD***	***RC***	***RR***
This ICCARS/NASA experience has inspired me to bring NASA content into my classroom.	*172*	*143*	*9*	*0*	*0*	*324*	*96%*
These ICCARS/NASA resources will be effective in increasing my students' interest in STEM topics.	*132*	*170*	*13*	*0*	*0*	*315*	*93%*
Based on my ICCARS/NASA experience, I will make changes to my teaching activities.	*142*	*141*	*23*	*1*	*1*	*308*	*91%*
This ICCARS/NASA experience provided ideas for encouraging student exploration, discussion and participation.	*148*	*143*	*19*	*1*	*1*	*312*	*93%*
I can immediately apply what I learned from this ICCARS/NASA experience to my teaching about science, technology, engineering or mathematics (STEM).	*150*	*145*	*18*	*5*	*0*	*318*	*94%*
The ICCARS/NASA materials used in this experience align well with what I teach.	*111*	*159*	*33*	*4*	*1*	*308*	*91%*
I will be more effective in teaching STEM concepts introduced in this ICCARS/NASA experience.	*140*	*148*	*29*	*2*	*1*	*320*	*95%*

Note: General participant's reflection on the usefulness of NASA experience and materials
(SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Disagree; RC = Response Count; RR = Response Rate)

Table 2. Cumulative results from participants in ICCARS activities from the NASA Educator End of Event Surveys

Survey questions	*SA*	*A*	*N*	*D*	*SD*	*RC*	*RR*
ICCARS/NASA experience has inspired me to bring NASA content into my classroom	*16*	*14*	*0*	*0*	*0*	*30*	*100%*
ICCARS/NASA resources will be effective in increasing my students' interest in STEM topics	*15*	*15*	*0*	*0*	*0*	*30*	*100%*
Based on my ICCARS/NASA experience, I will make changes to my teaching activities	*14*	*16*	*0*	*0*	*0*	*30*	*100%*
ICCARS/NASA experience provided ideas for encouraging student exploration, discussion and participation.	*12*	*16*	*1*	*0*	*0*	*29*	*97%*
I can immediately apply what I learned from ICCARS/NASA experience to my teaching about science, technology, engineering or mathematics (STEM)	*15*	*12*	*3*	*0*	*0*	*30*	*100%*
The NASA materials used in ICCARS experience align well with what I teach	*6*	*17*	*6*	*0*	*0*	*29*	*97%*
I will be more effective in teaching STEM concepts introduced in ICCARS/NASA experience	*12*	*16*	*2*	*0*	*0*	*30*	*100%*

Note: General participant's reflection on the usefulness of NASA experience and materials
(SA = Strongly Agree; A = Agree; N = Neutral; D = Disagree; SD = Strongly Disagree; RC = Response Count; RR = Response Rate)

Table 3. Results from participants completing survey at the end of the ICCARS project

Table 4 revealed the content areas of the ICCARS participating teachers. It was very clear that the majority (nearly 70%) of ICCARS participants were science teachers. Additional subject areas represented by ICCARS teachers included Mathematics, English, Social Studies, Library Sciences, and Technology. Moreover, the NASA long-term experience survey asked general reflection of teachers concerning the usefulness of the NASA experience and materials provided by from the NASA-funded project of ICCARS (Table 2 and Table 3). For the questions regarding the educational values of NASA content, resources, and experience (the first five questions), a majority of teachers (over 90%) either strongly agreed or agreed with the positive responses.

Subject	*Count*	*% of total*
Science	*40*	*69*
Mathematics	*10*	*17*
Library Science	*1*	*2*
Social Studies	*5*	*9*
Technology	*2*	*3*
Total	*58*	*100*

Table 4. Content areas of the ICCARS participating teachers

Furthermore, a majority of teachers were positive about the alignment of climate change education with what they were teaching and the possible improvement of their teaching effectiveness because of their NASA experience (Table 2 and Table 3: the sixth and seventh questions). Another multiple-option question in the NASA educator experience survey asked what specific activities teachers planned to change or add to their teaching practices (Table 5). Clearly, a majority of respondents (70%) planned to use NASA/ICCARS web resources; a majority wanted to use the NASA/ICCARS subject matters (68%), technology resources (68%), and nearly half (48%), wanted printed materials, respectively. Teachers completing the entire project responded even more favorably as shown in Table 6.

Response	***Total***	***Response rate***
Use printed materials presented at my NASA experience	*157*	*48%*
Use subject matter covered at my NASA experience	*224*	*68%*
Use teaching techniques presented at my NASA experience	*95*	*30%*
Use technology resources introduced at my NASA experience	*218*	*68%*
Use web resources presented at my NASA experience	*231*	*70%*
Other	*10*	*3%*
Response Count	*319*	*95%*
Number of surveys returned (N)	*337*	*100%*

Note: The responses concerning the question: Which activities do you plan to change or add to your teaching practices (Check all that apply)

Table 5. Cumulative results from participants in ICCARS activities from the NASA Educator End of Event Surveys

Response	***Total***	***Response rate***
Use printed materials presented at my NASA experience	*18*	*60%*
Use subject matter covered at my NASA experience	*25*	*83%*
Use teaching techniques presented at my NASA experience	*12*	*40%*
Use technology resources introduced at my NASA experience	*25*	*83%*
Use web resources presented at my NASA experience	*24*	*80%*
Other	*0*	*0%*
Response Count	*30*	*100%*
Number of surveys returned (N)	*30*	*100%*

Note: The responses concerning the question: Which activities do you plan to change or add to your teaching practices (Check all that apply)

Table 6. Results from participants completing the end of the project survey

The second outcome assessment instrument was the ICCARS' Teacher End of Project Survey (exit survey). The exit survey was designed to ask specific questions concerning the unique features of the ICCARS project and to obtain the information needed to complete the project final report. In total, 40 questions were included in the exit survey and 30 teachers completed the survey. Two of the questions were closely tied with the research theme of this paper. The first one is, "Which NASA resources, made known to you through the ICCARS project, have helped you better understand the issues of global climate change (check all that apply)?" (Table 7). The resources most commonly cited by teachers (83.3%), were data analysis and visualization tools. Abundant evidences from NASA resources and the remote sensing images were equally important (76.7%) to help them understand the climate change issues. Social networking approaches (including the peer groups – 70.0% and other mass-media, such as, podcasts, blogs or webinars – 46.7%) were also noticeable helpers. Furthermore, the field data collection and the understanding of scientific concepts underlying climate change were identified as useful helpers.

Answer options	*Response count*	*Response percent*
Data analysis and visualization tools (e.g., My NASA Data, NEO, ICE, etc.)	*25*	*83.3%*
Abundant general evidences (e.g., articles, key indicators and data based evidence from NASA websites, etc.)	*23*	*76.7%*
Satellite or airborne Remote Sensing images (e.g., Landsat images, NASA Earth Observatory, etc.)	*23*	*76.7%*
Participation in peer groups (PLCs, etc.), that share the same concern about climate change	*21*	*70.0%*
Participation in field data collection concerning climate change (e.g., Globe Student Climate Research Campaign, etc.)	*16*	*53.3%*
Access to scientific concepts underpinning global warming or sea level rising	*15*	*50.0%*
Podcasts, blogs, or webinars	*14*	*46.7%*
Detailed case studies and reports	*8*	*26.7%*
Other (please specify)	*0*	*0.0%*
The total number of teachers answered	*30*	

Table 7. Which NASA resources have helped you better understand the issues of global climate change?

The other question was about the NASA AEROKATS remote sensing system, "How has flying NASA AEROKATS missions helped increase your students' interest in STEM learning (choose all that apply)?" (Table 7). This was also a multiple-option question, which teachers could select as many options as they deemed meaningful. In fact, five schools could not organize students to fly the AEROKATS remote sensing system because of different reasons. As a result, the teachers from these schools chose the answer, N/A (not applicable). Nevertheless, the remaining teachers positively responded to this question (Table 8). The meaningful contributions of the AEROKATS remote sensing system to the increase of students' STEM interest included, 'out-door activity', 'fun', 'hands-on science project', and 'collecting their own real world data'.

Answer options	*Response count*	*Response percent*
It is an out-door activity	*24*	*80.0%*
It is fun to fly AEROKATS missions	*22*	*73.3%*
It is a hands-on science project	*21*	*70.0%*
Students enjoy collecting their own real world data	*18*	*60.0%*
It is an experiment in physics	*9*	*30.0%*
It is an engineering project	*7*	*23.3%*
Students are interested in aerial imaging	*7*	*23.3%*
N/A	*5*	*16.7%*
Other (please specify) [a]	*1*	*3.3%*
Did not increase	*0*	*0.0%*
The total number of teachers answered	*30*	

[a] Teamwork experience in science.

Table 8. The responses concerning the question about the NASA AEROKATS remote sensing system

The third survey instrument was the pre- and post-ICCARS student exams of the same 22 questions. The exam questions were adapted from 'A Matter of Degree', created by KQED Public Broadcasting, (2013) and based on a 2009 analysis of a nationally representative study of 2,164 American adults conducted in the fall of 2008, called

Global Warming's Six Americas. The climate profiling questions of 'A Matter of Degree,' were developed by the Yale Project on Climate Change and the George Mason University Center for Climate Change Communication (2013). These survey questions covered general attitudes and knowledge about global climate change. Pre-and-post ICCARS exam results were reported for sixteen schools, and included results for 526 students (Table 9). The post-ICCARS exam gains in four schools (164 students), exceeded 52%. (The t-test of one school and 11 students was > 0.05 and thus the change was not statistically significant). The score changes in other six schools and for 171 students showed gains between 33% and 50%. Another way of looking at the post-ICCARS exam results was that the test scores in thirteen out of sixteen schools, and for 440 of 526 students, showed improvements that were statistically significant.

# students[a]	*Pre-test mean*	*Post-test mean*	*% change*	*p value[b]*
116	*11.63*	*20.02*	*72.14*	*0.000 *****
26	*10.50*	*17.35*	*65.25*	*0.000 *****
11	*6.73*	*10.36*	*53.93*	*0.072*
11	*7.00*	*10.64*	*52.00*	*0.014 **
63	*4.98*	*7.43*	*49.20*	*0.000 *****
9	*6.89*	*9.67*	*40.35*	*0.003 *****
43	*11.37*	*15.84*	*39.31*	*0.000 *****
5	*9.80*	*13.60*	*38.78*	*0.060*
8	*9.13*	*12.38*	*35.64*	*0.010 **
43	*13.95*	*18.67*	*33.84*	*0.000 *****
29	*11.14*	*13.17*	*18.22*	*0.000 *****
18	*11.06*	*13.06*	*18.08*	*0.002 *****
16	*11.25*	*13.13*	*16.62*	*0.009 *****
44	*15.14*	*16.43*	*8.52*	*0.010 **
70	*8.69*	*9.33*	*7.36*	*0.066*
14	*7.29*	*11.00*	*3.71*	*0.001 *****

[a] A total of 526 students from sixteen schools participated in the pre-and-post-ICCARS Yale-based climate change knowledge tests. The pre-and-post comparisons were conducted by each school.

*[b] Statistical Significance: * < 0.05, ** < 0.01.*

Table 9. Comparison of the exam mean scores of the pre- and the post-ICCARS experience from students

3.2 Discussion

Embedding climate change education in school curricula is analogous to integrating an emerging subject into schools. Among the numerous provisions identified by Layton (1973), Goodson (1985) and Yueh et al. (2010), teacher professional development, syllabi and teaching resources, university partnership, external constituency, and emergent processes are the most important factors that should be placed in school time-tables. A unique contribution made by the intermediate school district: Wayne RESA to the success of the ICCARS project was the long-term commitment of the Science Office, the Instructional Technology Office, and the Instructional Services, the Administrative, and the Education departments, formally acknowledging climate change education as an emerging school curriculum subject and including the ICCARS experience as a regular component of Wayne RESA's teacher professional development program. In other words, Wayne RESA placed the climate change education onto many school agendas in Wayne County, Michigan. The ICCARS project also had a broad cooperation with Eastern Michigan University and its Institute for Geospatial Research and Education (EMU/IGRE), NASA/GFSC Wallops Flight Facility, the GLOBE®Program (Global Observations to Benefit the Environment), the Michigan Climate Coalition, UC Berkley's Lawrence Hall of Science, and the Wayne County

Math and Science Center. As a result, the ICCARS project had the ideal university partnership and external constituency.

The ICCARS project adapted many emerging processes in order to promote a broad acceptance of climate change education from teachers and students. A very important aspect of the project was integrating the kite-borne NASA AEROKATS remote sensing system at a local scale, with the satellite-based remote sensing at global and regional scales. These NASA data sources and experiences at multiple scales enabled teachers and students to investigate climate change and its impacts from global issues to their backyard community concerns. The AEROKATS system also enabled teachers and students to implement "authentic science inquiry" to look into causes and consequences of climate change, and "place-based learning" to establish natural linkages between technologies and neighborhood stresses caused by climate change. In other words, the studies of climate change could occur in students' milieu (Hunter & Xie, 2001). As students participated in project activities (i.e., learning remote sensing, and applying them to investigate climate change and its consequences), they enhanced their STEM learning by becoming community citizens. Thus the project provided an opportunity for students to use their own community as a platform for learning. This was exactly consistent with the key idea promoted by the action-oriented learning. The action-oriented place-based learning was likely to enhance participants' self-efficacy, which may be an important ingredient in climate change literacy "through a connection to a perceived ability to reduce a threat (Value-Belief Norm theory), or through locus of control (Environmental Citizenship Behavior Model)" (Monroe, 2003, pp. 122). In short, all three assessment tools confirmed that both teachers and students were benefiting from this emergent integration of the multi-scaled remote sensing systems into climate change education. A similar effort and success was recently found in a European project, the web-based learning platform, "Planet Action – A SPOT Image Initiative: Are You Active in Fighting Climate Change," (2013) an exemplary project educating the youth for sustainable development from the viewpoint of remote sensing and the geosciences.

The second emergent process was to integrate data analysis and visualization in climate change education. Geographic information based education was more effective when educators or students actively participated in solving real-world challenges by developing hypotheses, designing experiments, collecting data, analyzing real-life data in visual forms, and discussing results. As the ICCARS Teacher End of Project Survey revealed, ICCARS' analysis and visualization tools were the number one NASA resource that helped teachers better understand the issues of global climate change (Table 7). The graphic representations of climate changes and the visualized patterns of ecological and environmental consequences of climate change from local to regional or even to global scales helped fill the knowledge gaps among teachers.

The third emergent process was to integrate technology and fun with the AEROKATS remote sensing system. The flying of the AEROKATS remote sensing system involved mechanical skills to assemble the Aeropod and kite system, teamwork skills to follow protocols and operate the system safely, data collection and management skills to obtain in situ field data (ground control points and reference data), computing skills of using image analysis software, and image processing skills of interpreting the images. Moreover, the AEROKATS flying was an outdoor activity and hands-on authentic science project. Students responded well to the team projects that embedded STEM learning into fun activities. The integration of technology is very important to Wayne RESA's mission.

Wayne County is the most populous county in Michigan and includes the City of Detroit. Twenty high schools out of the 34 school districts in Wayne County did not make Adequate Yearly Progress (AYP) for the 2011-12 school year. Of those 20, 14 have more than 20% of their students from families living below poverty, with 6 exceeding a 50% poverty rate. (This is up from 2007 when (a) 19 school districts in Wayne County did not make Adequate Yearly Progress (AYP) for the school year, (b) only 10 of those 19 had more than 20% of their students from families living below poverty, and (c) only 2 of those 10 exceeded a 50% poverty rate.)

Of these fourteen districts (US Census Bureau, 2013), ten have minority student populations that exceed 35 percent (the minority population ranges from 35.3% to 99.7%). The ICCARS project took into consideration the national goals to provide the nation with a technologically sophisticated workforce and to provide opportunities for young people that would attract them to and prepare them for careers in science, mathematics, and engineering. The ICCARS experience confirmed that students from underserved communities had great potential and drive when it became clear to them that the learning materials were relevant and technological, and would increases job and career opportunities (van Eijck & Roth, 2007; Literat, 2013).

Another key effort of the ICCARS project was to provide teacher professional development and to develop syllabi and teaching resources in the context of climate change education. The content expectations of instruction, knowledge gaps, and a lack of learning experiences for teachers identified in the ICCARS project suggested that all science teachers would benefit from professional development focused on climate science, best practices in climate instruction, and peer communication. While the ICCARS project originally planned to develop 60 instructional units, the ICCARS participating teachers finally developed 66 lesson units, using PBL methodology grounded in inquiry and student led investigations, applying NASA image data and resources, and aligning with Michigan educational standards in earth science, biology, chemistry, physics, mathematics and social studies. These instructional units were published online by the Wayne RESA web site (Modules and Units, 2013) (http://www.resa.net/curriculum/curriculum/science/professionaldevelopment/climatechange/modules-and-units/) and are now serving as an important learning material for the dissemination of the ICCARS project. As indicated by the NASA Long-Term Experience – Educator End of Event Survey, the use of web resources concerning NASA data and materials in the context of climate change education was the most widely favored practice that teachers were planning to adapt in classrooms (Table 5 and Table 6). It was also clear that the peer communication advocated through the ICCARS' e-Learning Collaboratory played a meaningful role to sustain the teachers' momentum of embedding climate change education in school curricula (Table 7). The e-Learning Collaboratory (http://www.iccarsproject.net/) included eight major elements: 'Climate Change Resources', 'Remote Sensing Resources', 'NASA AEROKATS', 'iOS Resources', 'ICCARS Modules and Units', 'ICCASR PLC', 'ICCARS Observation Mapper (GIS enabled mapping toolbox)', and 'ICCARS Follow-Share-Interact (including, Facebook, Twitter, Picasser, and Blog). These elements together encouraged teachers to communicate with each other and thus facilitated the successful completion of the ICCARS project. More importantly, the e-Learning Collaboratory is still alive, disseminating the ICCARS learning materials and the NASA remote sensing experience to a broad spectrum of secondary teachers in Michigan.

A final note is that the concepts of remote sensing are comprehensive and the techniques of image processing are advanced. In addition, it usually takes a long learning curve to master basic skills of GIS-based data visualization and analysis. However, due to the scheduling constraint, the ICCARS project was not able to allocate sufficient time for providing knowledge development in remote sensing principles and for skill training in image processing and GIS-based data analysis. A good number of teachers pointed out in the ICCARS exit survey that the technology training should be enhanced in future similar professional development opportunities.

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