Project Summary: Through this project, an interdisciplinary group of faculty from across the University of Toledo including social and physical scientists will develop five stand-alone, online modules for 7-12 students to improve student (and teacher) learning of climate change topics by addressing common misconceptions. Constructivist theory says that misconceptions are a barrier to student learning and need to be addressed before students can move on. This project addresses funding category D/M and goal 1 as specified in the Cooperative Agreement Notice. The highly politicized topic of climate change has many misconceptions held by students (and teachers alike). One particularly pernicious misconception that haunts many teacher and college professor is "The ozone hole is responsible for global warming." Each module will address a misconception and have a driving question related to the misconception. The modules will span topics from the impact of greenhouse gases on terrestrial planets, impacts of climate change on local populations and ecosystems, short-term weather versus long-term climate change, economic risk: what are the consequences to doing nothing and reducing individual carbon footprints. Due to the interdisciplinary nature of the misconceptions and modules that we proposal, we expect teachers from subjects beyond science such as social studies to utilize these modules. This three year project will include development of the module using inquiry-based and critical thinking pedagogy, refinement with teacher involvement, piloting of the modules with Toledo area students focusing on economically disadvantaged and underrepresented groups and dissemination to the broader educational community. Through the modules, we will promote critical thinking by students using a Milne-type grid and counterfactuals to encourage students to use their creativity to conceptualize key concepts in climate change science. We will engage students in inquiry lessons utilizing NASA data, models and simulations including but not limited to EdGCM, My NASA Data, GLOBE observation protocols, planetary data sets from the NASA Space Science Data Center and satellite remote sensing data. The satellite data has been processed by our research for research projects and includes MODIS, Landsat, TRMM, and GRACE. The university's Center for Curriculum Instruction (CCI), an award winning facility dedicated to incorporating innovative technology into the educational process, will design the web implementation of the modules. Formative assessment will be performed throughout the development process and summative assessment will be used to study the effectiveness of the program.

Climate Change Education: Engaging Teachers and Students and Correcting Misconceptions Using NASA Data

The subject of global climate change is one of the most engaging yet difficult topics to teach in schools. Political decisions are increasingly being made based on the threat of Global Warming. Teachers and students need to be prepared with a strong science background to understand the complexities of this very politicized problem. Our goal is to help teachers and students understand the science behind global climate change and how it affects their community as well as their lives. This project will equip the teachers with tools to help their students learn how to do science that facilitates the understanding of global climate change through addressing common misconceptions and teaching critical thinking.

Global climate change is arguably the most significant societal problem facing humans in the modern era. It is becoming more apparent that the next generation will face challenges balancing protection of the environment while maintaining economic growth. The Intergovernmental Panel on Climate Change (IPCC) has said that there is significant evidence that global warming is a result of human activities through the enhancement of greenhouse gases (IPCC 2007). This is a very politically charged topic and parents have been known to confront teachers when they teach students about climate change or show Al Gore's movie, *An Inconvenient Truth*. Teachers struggle to find accurate and politically unbiased classroom activities and lessons on global climate change. Often, textbooks and published teacher materials are not up to date with current global climate change resources (Cavanah 2007). Presenting teachers accurate, current information about global climate change and providing them the resources to convey the science to their students will help them approach this sensitive topic. Pruneau et al. (2003) suggests that specific global climate change teacher training should be provided as many teachers present erroneous concepts about the greenhouse effect and global climate change in their classrooms. Our personal experiences in Ohio agree with this assessment. Some of the misconceptions that students have about climate change are the same.

Misconceptions about Global climate change: Misconceptions about global climate change are one of the biggest barriers to the public's understanding of the topic. Misconceptions are often born out of a partial knowledge of scientific processes and they are promoted by climate change skeptics. Students come to class with a myriad of misconceptions and teachers have to address these misconceptions in order for learning on the topic to proceed.

Often, parents become very active in the educational process when global climate change is the topic of study. In addition, there are teachers who hold these misconceptions.

1. The percentage of carbon dioxide in our atmosphere, and the amount of carbon dioxide produced by emissions due to human activity, is too small to affect the climate.
2. The "ozone hole" is responsible for global warming.
3. Weather events such as snowstorms and cold spells disprove global climate change.

4. Global climate change will have no significant impact on people or nature.
5. Won't reducing greenhouse gases harm the economy and cost jobs?
6. Individuals cannot make a difference.

This list of misconceptions is not exhaustive and may be modified depending on the needs of the teachers. There are many webpages on the Internet that address misconceptions about global climate change. However, they are all text-based and have a "trust me" approach. Our approach will be different in that we will use NASA data, images and model output and inquiry pedagogy with critical thinking skills to improve student (and teacher) understanding of climate change science.

Intrinsic Merit
Objectives and Expected Significance:

We have brought together an interdisciplinary team of scientists that include both the natural and social sciences. We expect that this will allow us to investigate misconceptions from different perspectives and will allow us to reach a broader audience than is normally addressed by global climate change lessons.

Objectives

1. Improve secondary school teacher and student content knowledge of global climate change by addressing common misconceptions and using NASA data, models and simulations
2. Increase the amount of NASA data, models and simulations used in secondary school classrooms by teachers and students
3. Increase the use of global climate change curriculum beyond science courses
4. Improve university faculty awareness of pedagogy in teaching

Addressing the goals of this Cooperative Agreement Notice (CAN) NNL10ZB1011C, we are focused on funding category D/M and goal 1. Specifically, we will be "using NASA Earth system data, interactive models and/or simulations to Strengthen Teaching and Learning about Global Climate Change."

Approach and Methodology:

To address misconceptions that teachers and students possess about global climate change, we will develop and test 5 online modules. Each module will be designed to match a specific template. This will ensure continuity throughout the modules and enhance ease with which teachers adopt multiple modules. The modules will focus on activities students can do and include a comprehensive teachers guide. Each module will contain the following:

- Content specific pre and post tests
- Links to The National Academic Content Standards specially in Earth Science, Physics, Biology, Chemistry, Social Studies and Math
- Assessment of students' prior knowledge and misconceptions
- A driving question
- Expert instruction and credible resources to answer the driving question
- Guidance on critical and creative thinking

- Inquiry activity using NASA data, models or simulations

The modules will be specifically aimed for students in grades 7-12 with particular emphasis on grades 7-9 and take between 4 and 6 class periods (assuming a 45 minute class) to complete. To acquire a module, teachers will need to register online and will receive the information for free. Each module will be stand-alone so that a teacher may complete the module and implementation guide and prepare to teach that module in the classroom. Given the demands on teachers, allowing flexibility when they go through the module is paramount. Teachers will take a multiple choice assessment test to receive a certificate of completion for the module.

Pedagogy: Each module will use constructivist and inquiry-based pedagogy and critical and creative thinking will be encouraged. Research indicates that inquiry-based learning promotes student motivation, fosters personal and situational interest, and connects curricula to issues that interest students or affect them directly (Blumenfeld et al., 1991), especially for minority urban students (Patrick et al. 2000). Student attitudes toward mathematics and science were shown to be predictive of academic performance in mathematics and science (Simpson & Oliver, 1990; Singh et al., 2002), and their attitudes toward learning science tend to decline sharply during the middle school years (Simpson & Oliver, 1985; Yager & Penick, 1986).

In classrooms that utilize inquiry-based teaching methods, teachers are facilitators posing a range of questions that lead to deeper understanding about science skills and concepts while utilizing on-going assessment throughout the inquiry process. Research has shown that this inquiry-based environment, coupled with an interdisciplinary science curriculum that links unifying concepts and processes such as systems, order and organization (Krajcik et al., 1999) enhances student learning. Although national science curriculum goals (American Association for the Advancement of Science, 1989) state that inquiry-based teaching methods should be the primary way in which science is taught, implementation of these methods is a challenge to teachers.

Critical and Creative Thinking

Current teacher and student misconceptions about climate change present major obstacles to the progress of their education of the topic. Teachers should aggressively strive to reduce and eliminate these misconceptions so their students can proceed to reach higher-level cognitive abilities necessary to better comprehend complex climate change issues.

At present discussions about climate "change" involve people in all walks of life elaborating diverse perceptions of existing environmental conditions into myriad stories with indeterminate outcomes. These discussions involve storytelling and storytellers. Teaching students systematically and efficiently about climate change can involve a simple pedagogy that compares and contrasts selected climate change stories, whatever their provenance or politics. For example: "The anthropogenic origins of global warming" is an example of a popular climate change story can be supported by the authority and validity of NASA data. This simple pedagogy could teach the sort of critical thinking that exercises the minds of students to achieve clarity, and thereby empowers them to judge with measurable confidence which stories are more truthful than others.

We will include a two-step procedure for teaching students the systematic skills to judge among climate change stories in search for more truthful stories, and to do so with measurable confidence. The first step is teaching general critical thinking skills about conflicting climate change stories and their relative truths. The second is teaching the power of counterfactual thinking (Bunzl, 2004) to enable students to create their own convincing student-generated stories about climate change that involve NASA data.

The first step involves the introduction of the importance of both "authority" and "validity" to establishing the relative veracity (truthfulness) of a story. Teachers can introduce to their students a "de Mille"-type grid (de Mille, 1980) with four quadrants, to illustrate a lesson (accompanied by selected examples) about climate change stories that generate misconceptions:

	High validity	Low validity
High authority	+ +	+ -
Low authority	- +	- -

Figure 1. Categories of truthfulness.

For example, stories that include NASA data will hold more authority and validity, i.e. credibility is seen as more true than others (thus a quadrant #1 – type story). Teachers introduce students to examples of climate change stories lacking NASA data to represent quadrants 2, 3, 4.

The second step involves introducing the concept of counterfactuals (What-if … then, what? thinking) followed by providing examples of counterfactual climate change stories (What if there was no such thing as petroleum? What if humans ate kangaroos instead of cattle?). Briefly, counterfactual thinking is a term used in the humanities and social sciences to describe the tendency people have to imagine alternatives to reality (Nemeth, 2005; Stanovich, 1994; Warf, 2001, 2009). They are known to have value as heuristic models to improve critical thinking. Teachers can be made aware that counterfactual thoughts can lead to stories that result in misperceptions *and* affect causal judgments. They can teach students how to articulate -- in speaking and writing -- their own counterfactual stories involving climate change.

NASA Data: NASA has many resources available to assist in finding the best data, model output and simulations for these modules. Dr. Czajkowski will assist the Co-I's in finding appropriate NASA data, models and simulations. We will utilize NASA's Global Change Master Directory. http://gcmd.nasa.gov/index.html. We will look to GLOBE and S'cool for engaging students in data collection and inquiry-based projects. We will look at My NASA Data lessons as there are many on renewable energy and the effects of greenhouse gases on the climate. NASA's Educational Global Climate Model (EdGCM) is a good way for students to experiment on their own on ways that the climate system works and we will use satellite data (MODIS in particular).

Module Development

Below are a group of proposed modules including the misconception(s) and driving question that they address. Through this project, we will collaborate across disciplines to identify, develop and refine the modules. The modules suggested cover the following themes:

1. Global climate change due to increases in greenhouse gases.
2. Short-term weather versus long-term climate
3. Expected impacts of global climate change
4. Benefit-cost analysis of global climate change
5. Mitigation strategy: reducing individuals carbon footprint

These are only suggested modules and we will work to refine them through the first year of the grant.

Module: Comparative planetology: using our Solar System as a laboratory for understanding the impact of greenhouse gases (Bjorkman & Megeath)

Misconception 1: The percentage of carbon dioxide in the atmosphere, and the amount of carbon dioxide produced by emissions due to human activity, is too small to affect the climate.

Misconception 2: The "ozone hole" is responsible for global warming.

Driving Question: What factors determine the temperatures at the surfaces of rocky terrestrial planets like Earth?

Studies have shown that students and the general public have significant misconceptions about the role and nature of greenhouse gases (e.g., Kempton 1997), the nature of the Earth's atmosphere, and the connection with the "ozone hole" (e.g., Jeffries et al 2001). We propose to address these misconceptions through a comparative study of the terrestrial planets, using NASA datasets. This module is designed to adapt an astronomy/planetary science approach to help students understand how and why carbon dioxide plays a major role in determining the surface temperatures of not just the Earth, but all the terrestrial planets with atmospheres. Comparisons between the terrestrial planets in our solar system will be used to address such issues as how variations in incident sunlight, greenhouse gas concentrations, and albedo can affect surface temperatures, and what this comparison can tell us about possible future possibilities for climate change on Earth.

Students will use data from the NASA Planetary Data System (NASA PDS) through the NASA Space Science Data Center (NSDDC), including fundamental measurements of physical properties, images (albedo), and spectral information from space probes such as Messenger, Galileo, multiple Mars orbiter and rover missions, Magellan, and Venus Express, to compare the surface temperatures of Mercury, Venus, Earth, Moon and Mars, and to explore how these temperatures depend on measured values of incident sunlight (solar insolation), planetary rotation, reflection of sunlight (albedo), and the concentration of greenhouse gases in the atmospheres (if any). The goal is to understand how temperatures are determined by a balance between absorbed solar radiation and re-radiated infrared radiation, and how atmospheres can heat up the surface by trapping infrared radiation. Data will also be presented to show how infrared radiation is absorbed primarily by the carbon dioxide, water vapor and methane in the Earth's atmosphere, and by carbon dioxide in the atmospheres of Venus and Mars. The main point is to demonstrate that strong greenhouse warming is present on planets with atmospheres, and carbon dioxide is the primary driver of the greenhouse effect on other planets. Further discussion will focus on the role of ozone in the Earth's atmosphere, and on understanding the nature of the "ozone hole", and why it is not connected with global warming.

NASA Data, Model, Simulation: This module will utilize planetary data sets outlined above. NASA's Educational Global Climate Model (EdGCM) will be evaluated for potential use in the module.

Module: Great Lakes water resources (Lawrence & Weintraub)

Misconception: Weather events such as snowstorms and cold spells disprove global climate change.

Driving Question: What is the relationship between short-term weather and long-term climate change?

One challenge associated with education initiatives for global climate change is to explain and justify the issue of short term versus long term changes in the environment associated with climate, in particular the respective roles of local weather and global climate impacts. Students often have challenges with understanding the temporal and spatial aspects of climate and the respective roles of annual, seasonal and other changes in comparison to decadal or century long trends in climate conditions. An aim of global climate change education needs to provide an opportunity for students to be exposed to the concept of long term and short term changes or cycles apparent in climate driven natural processes and consider the evidence for the increasing impact of changes to these processes that are unique and separate from underlying short term forces.

This module will provide an opportunity to examine the issue of short term versus long term trends of the impacts on climate on water resources in the Great Lakes basin. The fluctuations in water supply through natural processes to the basin and resulting water levels as a result of the long term regional water balance in the Great Lakes are well documented and understood. Short term weather conditions have been shown to drive the system through input (precipitation) and output (evaporation, discharge, outflows), whereas longer term climate conditions are superimposed on these factors resulting in cycles or periods of changes to stream flow conditions and water levels. Studying these drivers and trends of water resources within the Great Lakes basin will provide all students an opportunity to consider how weather and climate interact at differing scales to create environmental conditions that support such a critical natural resource – water.

Using existing data sets from NASA, NOAA, NWS, and USGS, the task will be to examine three important aspects of Great Lakes water supply and storage: winter season basin snow pack and lake ice; annual lake water levels; and watershed runoff and river discharges. Students will be provided a basic introductory reader on Great Lakes water resources focusing on understanding the long term and annual water balance equation. Students will be able to examine how short term weather and long term climate factors drive the supply of water resources and impact trends in increasing and decreasing river flows and resulting water levels.

NASA Data, Model, Simulation: We will use MODIS datasets of snow and ice cover that we have previously downloaded. Students can take part in the GLOBE lake/stream ice observation protocol that is part of the Seasons and Biomes investigation.

Module: Response of the Sahel region of Africa to global climate change (Becker)
Misconception: Climate change will have no significant impact on people or nature.
Driving Question: Will global climate change have significant impacts on people and/or nature?

One common misconception that students have is that there is and will be no significant impact from global climate change, or if there is, it is limited to low-lying coastal areas inundated by sea level rise. This module will directly address that misconception, showing how a system has responded to global climate change in the past, and investigating what predictions are made for the future of the region. Over the past century the climate of the Sahel region, the transition region between the Sahara desert of Northern Africa and the rainforests of Central Africa, has undergone significant changes. Ahmad et al. (2000) showed that there has been a drastic decrease in mean rainfall throughout the 20^{th} century, and precipitation has been reduced from the middle of the century to the end of the century by 29-49% (IPCC, 2001). The region, which covers roughly $4x10^6$ km^2, is home to more than 30 million people.

The effects of predicted global climate change on the Sahel region vary between climate models, but GCM models predict warming of between .2 and .5°C/decade, with increases most in the interior of the Sahel and couth central Africa (Hulme, 2001). Students will investigate the range of effects that may occur in the Sahel, based on current climate models (i.e. Held, 2005; Biasutti and Giannini, 2006), which predict an overall warming and drying trend in the Sahel.

In order to help students understand the ongoing and potential significant future effects of climate change throughout the globe, students will study impacts in the region as an example to show effects of global climate change on human populations, vegetation density, and economic health, and what changes are predicted in the future. To do this, they will use the Pathfinder 8km NDVI dataset to investigate the effects of this climate change on vegetation health in the Sahel. Students will first complete an introductory exercise in how NDVI information is generated from satellite images. Following this, students will complete an exercise examining both the overall vegetation health of the region, and of smaller targeted areas, in which they will quantify the areas which are undergoing change. Landsat TM data will show the combined effect of the change in rainfall and land use on Lake Chad. TRMM data will be used to investigate current rainfall patterns, and Grace data will be used to observe how this rainfall shows up as variability in water storage in watersheds in the Sahel region.
NASA Data, Model, Simulation: These datasets have been developed by Dr. Becker and can be used in this module: MODIS EVI, NDVI; NOAA/NASA Pathfinder NDVI, Landsat TM, Landsat MSS, TRMM, GRACE, NASA GISS GCM output

Module: Benefit-cost analysis of global climate change (Egan)
Misconception: Won't reducing greenhouse gases harm the economy and cost jobs?
Driving Question: Is the uncertainty related to the exact current and future global climate change damages an excuse for inaction?

The social economic benefit-cost analysis of global climate change can be complex due to uncertainty in regards to the damages and also the long time frame (Pindyck, 2007). However, simple to understand examples can be devised highlighting the potential range of net benefits to society from undertaking reductions in greenhouse gas emissions, showing that beginning reductions immediately is necessary as "cheap insurance" against the worst-case scenario outcomes (Dietz and Stern, 2008).

Specifically, NASA's climate change data base, in conjunction with estimates of the benefits and costs of various temperature change scenarios, will be used to estimate present value net benefit calculations. The module will be interactive, with the participants having the ability to change many input variables and see the resulting change in the present value net benefit calculations. The module will also educate the participants on the foundations of benefit-cost analysis and several interactive examples to demonstrate its ability as a policy tool.

A common misperception is that the uncertainty surrounding global climate change, meaning the inability to exactly predict the future climate change damages, is a reason for inaction. However, the module will clearly demonstrate that uncertainty can be incorporated into the benefit-cost analysis and highlight that the only remaining debate amongst environmental economists is how much reduction how soon?

Another common misperception is that reducing greenhouse gases will significantly harm our economy and reduce overall employment. While a credible source of information can rightly claim job reductions in certain sectors of the economy that emit a relatively high amount of greenhouse gases, such as jobs related to the production of coal, the complete picture is that jobs are not lost, but transferred. For every "dirty job" that is lost, there is a "clean job" created somewhere else in a low greenhouse gas emitting sector of the economy.

In terms of "harming the economy", the gross domestic product (GDP) is the most widely utilized measure for our national economy. It is possible climate change policy will lower the growth rate of GDP. However, the decline is expected to be small, e.g., in Krugman (2010), the author quotes the Congressional Budget Office's estimate of the decline due to the currently debated climate change policy, "would reduce the projected average annual rate of growth of gross domestic product between 2010 and 2050 by 0.03 to 0.09 percentage points." Moreover, a small decline in GDP growth represents the costs of the policy, but one has to compare this to the benefits. The problem is that GDP is NOT a "quality of life" index. GDP only includes newly produced goods and services, and it ignores completely the pollution caused from the production of the goods and services. Citizens have a willingness to pay for the plethora of goods and services our economy produces for them, but they also have a willingness to pay, in general, for clean air and water, and for reducing greenhouse gas emissions. A balanced "quality-of-life" index, which included newly produced goods and services AND the value of reduced greenhouse gases would certainly *increase* after an efficient greenhouse gas reduction policy was implemented.

NASA Data, Model, Simulation: This module may look at Hazards assessment from NASA through the Global Change Master Directory or it could utilize GCM model output to show potential impacts of global climate change.

Module: Calculating your carbon footprint (Apul and Khare)
Misconception: individuals cannot make a difference.
Driving Question: How can I reduce my greenhouse gas emissions?

"Individuals cannot make a difference" is a misconception often held by students. This misconception can largely impede our society's ability to reduce emissions. If individuals assume there is nothing they can do, they might not think about any solutions or ways they can help reduce greenhouse gas emissions.

To be able to answer this question, students and teachers will have to first investigate how their actions and lifestyles may or may not contribute to global climate change. Students and teachers will use online personal carbon footprint calculators to estimate their individual emissions. Many calculators are available and a user friendly popular one will be selected for this purpose. Understanding the calculators will require discussion of fossil fuels, their availability and the climate change implications of not only carbon dioxide but other greenhouse gases such as nitrous oxides, methane and chloroflorocarbons.

Students will use NASA Earth observation data to connect effects of personal choices on greenhouse gas concentrations (GHGC) in the atmosphere and hence global climate change. Specific comparison with IPCC reference scenarios for future evolution of GHGC and personal consumption activities will be demonstrated. Users would be able to select sources of energy and view the results through interactive data manipulation. A comparison of the positive effects of replacing fossil fuels with renewable energy sources would be described through this interface.

Students will also learn about direct versus indirect emissions. For example, when they drive a car, they are directly emitting greenhouse gases to the atmosphere. Yet, when they use electricity, the emissions are not happening right at the same site but at another location; thus these would be indirect emissions. Similarly, students will learn about upstream and downstream emissions. For example, an upstream emission would be the purchase of a sweater or food. Manufacturing of the sweater or farming and transportation of the produce would require emissions and thus the sweater and the food each have 'embedded carbon' in them. An example of downstream emissions would be a student's trash. Once the students throw their waste into trash, the trash may be landfilled and methane emissions would occur from the landfill.

Once students understand their carbon footprint, they will then be asked to develop strategies to reduce it. They will also be asked to make estimates of how much emissions could possible be reduced from their own school. Such questions will require students to analyze the problem more deeply.

NASA Data, Model, Simulation: This module might look at scenario generation for GCM's such as the NASA Goddard Institute for Space Sciences (GISS) GCM or we may choose the My NASA Data lesson "Think Green: Utilizing Renewable Solar Energy".

Link to Educational Standards (Hedley, Toledo Diocese Teachers): The modules being developed for this grant will all be aligned with the national standards in Science, Mathematics, Technology and Social Studies. By aligning the modules to the national standards, the modules will be useable to students and teachers across the United States.

State standards are based on national standards so it will not be difficult for the teachers in each state to then interpret them in the language of their own state standards.

In order to facilitate the scientists' development of these standards based modules, a master teacher, with a Ph.D. in Curriculum and Instruction, will be working with each of them to align the activities of the module to the standards. This teacher will be responsible for working with each scientist throughout the development of the modules so that they meet not only content standards but effective pedagogy as well.

Web Design and Hosting: The Center for Creative Instruction (CCI) at the University of Toledo is a world-class research and development technology center dedicated to incorporating innovative technology into the educational process and will develop the web modules for this grant. Formed in 1993, the Center has extensive experience in developing tools and applications to enhance education and training. The CCI specializes in the evaluation, development, and dissemination of information technology with specific emphasis on multimedia development. The specialty areas in CCI include medical and digital illustration, web development, software engineering, and technology and multimedia development.

The CCI has developed numerous educational modules, software products, online training applications, and websites to support education. Anatomy & Physiology Revealed (APR) was produced by the CCI and UT faculty for the McGraw-Hill publishing company in 2004 and revisions continue. Initially a CD series and now an online product engineered in Flash, APR is currently being used in over 400 schools and in 25 countries for teaching Anatomy and Physiology. This web based educational tool incorporates high end digital photographs, 2D and 3D animations, images, medical illustration, and advanced software engineering techniques that create an extremely powerful online experience (http://www.aprevealed.com). The product has won numerous awards including the McGraw-Hill Corporate Achievement Award in the innovation category.

The CCI has also collaborated with numerous UT constituents on research grants and other educational initiatives to develop modules for courses as well as to produce and implement training tools. New technologies and techniques are continually evaluated and incorporated into projects when appropriate such as handheld applications, streaming video, animations, Quicktime VR, social media, and many more. Online training modules with integrated databases have been developed for the university such as Search Committee Training, Online Diversity Training, and online event registration systems. An automated online Continuing Medical Education system with tracking and commerce was also developed and is maintained by the CCI that includes the capability to provide online education to non degree offering courses. Pre and post quizzes can be tracked and analyzed through a system developed by CCI for the research study.

The CCI also manages the institutional website from a strategic perspective using a centralized content management system. Strategic use of Facebook, YouTube, Blogs, RSS feeds, and other social media tools have been integrated into the website as well as the UT intranet by the CCI when applicable http://myut.utoledo.edu. Many of these same technologies can also be effectively used to enhance online courses and virtual classroom environments.

Impact: This proposal builds from work carried out under a NASA International Polar Year (IPY) grant, NNX07AR31G, with Dr. Czajkowski as principal investigator. Under this grant, Dr. Czakjowski and Dr. Hedley took a program developed in Ohio, SATELLITES, and trained trainers and teachers in West Virginia, Maryland and Pennsylvania and will train teachers in Maryland this summer. Through this project students study the polar regions using inquiry-based techniques, field observations and development of a project. After the end of IPY, we changed the theme of SATELLITES to global climate change and have had considerable response. Teachers are very eager to learn more about climate change. Through the NASA IPY grant it became clear that although a summer professional development training of one week is a good approach to affect a teachers' teaching technique, shorter content driven professional development can be very useful to a teacher on specific topics.

Project Timeline of Activities

Date	Event
	YEAR 1 October 2010 to September 2011
Oct 2010	Faculty develop student inquiry-based activities for each module using NASA data, models or simulations.
Feb 2011	Obtain feedback from educators about module designs and revise modules. This is an iterative process.
	Link in critical thinking component to each module.
Spring 2011	Present in-development modules at national conference – seek feedback from the broader community. – possibly Association of American Geographers (AAG) annual meeting.
Summer 2011	Begin web development
	YEAR 2 October 2011 to September 2012
Fall 2011	Significant web development by CCI
Spring 2012	Initial testing of modules within educators' classrooms and revise modules in continued interactions.
	Evaluation of test teacher and student – revision of the modules based on evaluation.
Late spring 2012	Presentation of modules to the Toledo Diocese principals at one of their monthly meetings to recruit more teachers to test the modules within their classrooms.
March 2012	Presentation of modules at a national teachers' conference such as NSTA. Generate interest among a broad range of teachers. Make changes to modules and dissemination plan based on feedback.
	YEAR 3 October 2012 to September 2013
Fall 2012	Implement modules across Toledo Diocese classrooms
	Broad evaluation of implementation – continue to refine modules based on evaluation.
March 2013	Presentation of modules at a national teachers' conference such as NSTA. Generate interest among a broad range of teachers. Make changes to modules and dissemination plan based on feedback.
Summer 2013	Role out program to teachers across the United States.

Management: Dr. Czajkowski will lead this interdisciplinary group of faculty. The faculty range from physical sciences (Becker, Bjorkman, Khare, Megeath and Weintraub) to the social sciences (Egan, Lawrence and Nemeth), Engineering (Apul) and education (Hedley). Bringing together faculty from both the social and physical sciences will enhance the modules focus and impact. Dr. Nemeth will integrate critical thinking skills into all of the modules while Dr. Hedley will integrate inquiry-based learning. Evaluation will be carried out independently by the INSPIRE Evaluation Services group on campus headed up by Dr. Mentzer.

This group of faculty has worked together on other projects, a benefit to being at a mid-major university. In particular, Czajkowski, Egan, Lawrence and Nemeth were a core of faculty that developed the new doctoral program in Spatially Integrated Social Sciences (SISS). Khare, Lawrence, Hedley, Weintraub and Mentzer work on the NSF Math and Science Partnership grant on renewable energy and global climate change that Czajkowski is the PI for. Lawrence, Weintraub and Khare were instrumental in developing the new minor in renewable energy that is available to University of Toledo undergraduate students.

Investigator	Department	Background	Project Role
Kevin Czajkowski	Geography and Planning	Remote Sensing, Atmospheric Sciences, 12 years experience as a scientist working with teachers	PI, assist Co-I's to link modules to NASA data, models, simulations
Defne Apul	Civil Engineering	Sustainability engineering, green infrastructure	Co-I, Develop module on carbon footprint
Ricky Becker	Environmental Sciences	Geology, Remote Sensing, numerous investigations of water resources in Northeast Africa using NASA datasets	Co-I, Develop module on changes in the Sahel
Karen Bjorkman	Physics and Astronomy	Observational astronomy; 20+ years experience working with teachers and public outreach	Co-I, Develop astronomy- and planetary-science module
Kevin Egan	Economics	Environmental Economics, particularly benefit-cost analysis focusing on the benefits of environmental public goods	Co-I, Developing benefit-cost analysis module
Sanjay Khare	Physics and Astronomy	Thin films, energy sources, renewable energy	Co-Coordinating a module with Defne Apul
Patrick Lawrence	Geography and Planning	Environmental Geography, impacts of society on the environment	Co-I, Developing short-term weather versus long-term climate changes
Tom Megeath	Physics and Astronomy	Infrared and observational astronomy; significant experience working with NASA datasets	Co- Coordinating a module with Karen Bjorkman
David	Geography	Cultural Geography, and	Co-I, integrating critical

"Jim" Nemeth	and Planning	methodological issues in human geography	thinking skills across all modules
Michael Weintraub	Environmental Sciences	Soil ecology, Biogeochemistry, Ecosystem Ecology	Co-Coordinating a module with Patrick Lawrence.
Mikell Hedley	Geography and Planning	Retired teacher, Ph.D. in use of geospatial technology to enhance students learning in science.	Curriculum Designer
Gale Mentzer	INSPIRE Evaluation Services	Science Education	Project Evaluator

Partnerships/Dissemination Sustainability: For this proposal, we have partnered with the Toledo Diocese for northwest Ohio. The Toledo Diocese has 81 schools in 19 counties and many of the schools are quite removed from Toledo. It is difficult for teachers from these districts to attend face-to-face professional development. The Toledo Diocese is excited about this project because it will give its rural teachers opportunities to learn about this important topic and to receive online modules for their students. Three teachers from the Diocese will assist in developing the modules by specifically contributing to the type of things students should learn from the module as well as advise faculty on the module design. In year two of the project, Toledo Diocese teachers will test the modules and recommend changes to them. In year three, teachers across the Diocese will be able to complete the modules.

The ultimate goal is to have these modules available and implemented by teachers from across the United States. To sustain the modules after funding has ended, a modest level of funding is needed to maintain the servers delivering the modules as well as some time by faculty to update the materials as needed. It is envisioned that a small fee of possibly $20 per teacher would sustain the program indefinitely.

The modules will be broadcast to the larger user community through teacher listservs and national and local teacher listervs such as the Michigan Earth Science Teachers Association (MESTA), the National Science Teachers Association (NSTA) and the National Earth Science Teachers Association. We have given many presentations at conferences run by these organizations in the past and will use our allocated travel budget to go to their meetings and "advertise" the modules.

Another aspect of dissemination is that we have been working with the National Council for Science and the Environment (NCSE) through Dr. Jorgensen who is a Co-I on that NASA GCCE grant that was funded in the first round. Drs. Lawrence and Weintraub will be piloting one of the NCSE modules in their online Climate Change course. We will have the opportunity to adopt and adapt the materials in the NCSE module for the purposes of this project as needed.

Relevance to NASA: The NASA materials to be used with each module will be incorporated through inquiry-based learning lessons for the students and implementation guides. This proposal addresses the third major educational goal of NASA, particularly "Through hands-on, interactive educational activities… to increase science literacy" and thus strength the nations workforce (page 29, NASA's Strategic Plan). We will be addressing Objective 2.3 of NASA's Strategic Plan: curricular support resource for NASA themes and content with the theme being climate change. These online modules fill a gap in NASA's educational outreach program.

Diversity: Diversity is a priority of the University of Toledo. The University of Toledo's mission is to serve the urban area of Toledo and in doing so caters to underrepresented groups. The university instituted a scholarship program two years ago in which any economically disadvantaged student may receive a full ride scholarship as long as their high school GPA is 3.0 or higher. The team of scientists working on this proposal are diverse in itself and are very mindful of inclusion of underrepresented groups in projects. Four of the scientists are women, two are Asia-Pacific Islander and one is Native American.

On this proposal, we are working closely with the Toledo Diocese (see attached letter of collaboration). The Toledo Diocese serves minority students and economically disadvantaged students in the Toledo urban area as well as students in rural counties surrounding Toledo that have a significant percentage of economically disadvantaged students. Our implementation of the program will have these things at the forefront so that the modules are workable in the classroom. One of the biggest difficulties is computer availability and internet conductivity in the urban as well as rural schools. The modules will be developed so they can be accessible to these urban and rural students by minimizing content file size and by have alternative hard-copy ready versions of the modules that a teacher can download and use in the classroom.

Evaluation (Mentzer): The evaluation will be conducted by INSPIRE Evaluation Services under the direction of Gale A. Mentzer, PhD who has over 12 years experience as a professional program evaluator including the evaluation of several large-scale federally funded projects. Under Mentzer's supervision, INSPIRE staff comprised of both experienced and novice program evaluators will be devoted to the project evaluation. INSPIRE also makes use of graduate assistants to develop high quality program evaluators for the future. This newly opened center, housed on the UT campus, operates independently and therefore does not pose a conflict of interest.

Baseline data will be collected during the first year and appropriate benchmarks will be developed based upon the baseline. All content tests will look for a statistically significant gain (pretest/post test; $\alpha = 0.05$) as well as a minimum medium effect size. All tallies will look for a statistically significant gain over baseline using chi square goodness of fit ($\alpha = 0.05$), and focus group interviews will be analyzed using qualitative methods that search for common themes.

A possible outcome of this project that we will test is the improvement in pedagogy as expressed by the science faculty through their teaching through interaction with the educators. While Dr. Czajkowski has worked with teachers and K-12 students for over a decade, most of the faculty on this proposal have only worked with K-12 teachers in a tangential way.

In addition, we will work with NASA's Education Office on the type of cross project evaluation that is required.

The evaluation plan is designed to provide both formative and summative evaluation of the project goals and is presented in the following logic model:

Method	Variable Measured	Time of data collection	Collected by	Purpose
1. Improve secondary school teacher and student content knowledge of global climate change by addressing common misconceptions and using NASA data, models and simulations,				
Teacher pretest/post test of content and data use and application (project developed)	Higher order teacher knowledge of content	Before and after implementation of teacher training	Electronically through project website	To determine whether training is effective. To determine whether teachers can apply the content to their classrooms.
Teacher satisfaction survey linked to each module (project developed based upon guidelines of Graham, et al. (2001)	Teacher perceived value of modules including clarity, usefulness, and salience	At completion of teacher training and at completion of use with students	Electronically through project website	To determine whether the modules effectively convey content
Student pretest/post test of content and data use and application (project developed)	Student knowledge of content	Before and after implementation of teacher training	Electronically through project website	To determine whether modules assisted in improving student content knowledge
2. Increase the amount of NASA data, models and simulations used in secondary school classrooms by teachers and students				
Tally number of times teachers and students access NASA resources	Use of NASA resources	Ongoing as resources are accessed	Electronically and through teacher feedback	To determine nature and extent of use of resources
3. Increase the use of global climate change curriculum beyond science courses				
Tally types of classes that utilize the modules (included in teacher feedback survey)	Applicability of modules to content areas beyond just science	At completion of teacher training and at completion of use with students	Electronically through project website	To determine whether the modules are applicable to other content areas beyond science
4. Improve university faculty awareness of pedagogy in teaching				
Teacher satisfaction survey linked to each module (project developed based upon guidelines of Graham, et al., 2001)	Alignment of module with sound online pedagogy	At completion of teacher training and at completion of use with students	Electronically through project website	To measure faculty awareness and application of pedagogy
Focus group interviews with faculty	Growth in understanding of pedagogy	Prior to onset of project and annually	Project evaluator	To examine extent to which faculty understand and improve pedagogy knowledge