OREGON CLIMATE LITERACY EDUCATION INITIATIVE
PROJECT DESCRIPTION

Oregon Climate Literacy Education Initiative (OCLEI) is an innovative partnership between the University of Oregon Physics Department, Pacific University-Oregon College of Education, and a consortium of rural Oregon school districts. OCLEI will transform climate literacy curriculum in partner middle and high schools by providing a year-long teacher professional development (PD) program consisting of extensive earth systems and climate change science coursework and training in the use of **NASA** earth observation data and earth system models. OCLEI will ensure maximum classroom impact on student learning by engaging scientists, teachers, and administrators together in *co-teaching partnerships*, in which all participants work together in rural classrooms to enact innovative content and pedagogy. Successful OCLEI climate change education models and curriculum will be disseminated statewide through the Oregon NASA Space Grants Consortium and Oregon Science Teachers Association, and nationally through NASA and the National Science Teachers Association. ON line course material as developed for this training will be delivered through PRiSm Oregon – an ON line statewide network devoted to improving math and science education in K8-12 classrooms. In the context of the Call for Proposals, **OCLEI targets NASA Goals 1 and 2 directly** by vastly increasing the core knowledge of participant teachers in basic climate science and working directly with teachers to create curriculum that utilizes data driven exercises related to NASA earth observation data and earth system models. As described below, OCLEI project leaders have already developed a simulation based approach to learning climate science and have successfully deployed it in some previous teacher PD workshops. In the operational pursuit of Goals 1 and 2, OCLEI explicitly addresses NASA Education Outcome Objective 2.2: *Provide long duration and/or sustained professional development training opportunities to educators that result in deeper content understanding and/or confidence in teaching STEM disciplines*.

OCLEI will offer a program that corresponds directly to **Funding Category D** through a data intensive approach to strengthen teaching and learning about earth system science, climate science, and global climate change science. OCLEI will directly serve 48 teachers in three rural secondary schools and three associated middle schools, which will impact approximately 4800 students. Increased teacher climate and earth systems science literacy will be achieved by providing district-based teams of middle school math and/or science teachers 12 quarter-hours of challenging coursework on current topics and research in climate change and earth systems science, which will make extensive use of NASA Earth observing data and Earth system models. Operationally, this will entail detailed hands-on workshops in various computer labs involving exercises derived from various ON line data sets and resources. We envision these workshops as **mini-research camps** where we provide easy to use data analysis and visualization tools (described later on in this proposal). This portion of the project therefore has some elements of Funding Category R in that **we are engaging In-Service teachers with climate and climate change research experiences.** Indeed, this is a key component of our innovative PD workshops. Our partnership has had a long history of providing teachers with innovative tools to assist them with data organization and analysis and we generally teach science content via data driven pathways as opposed to just "lecturing about the facts".

In addition, to improve the sustainability and delivery of the curriculum and curriculum products developed by OCLEI we will transform educational practices by co-teaching alongside participant teachers in their classrooms. This will facilitate developing and enacting climate/earth systems science lessons and units, and evaluating the impact on student learning. This approach has a large multiplicative affect and will significantly increase the number of middle and high school students using NASA Earth observation data/NASA Earth system models to investigate and analyze global climate change issues (which directly relates to Goal 2).

OBJECTIVES AND SIGNIFICANCE

A Pew Research Survey released July 9, 2009 estimates that while 84% of AAAS member scientists "think that the earth is getting warmer due to human activity," only 49% of the public agrees. While changes in public opinion about issues often lag behind advancing science, the consequences of continued climate change illiteracy are especially dire. We are now faced with alarming fact that public opinion about climate change is much more strongly correlated with political and ideological affiliation than level of education (Pew Research Center for People and the Press, 2009). Similar results were also found in the 2009 report by the Yale University project (http://www.americanprogress.org/issues/2009/05/6americas.html) who found a general complacency among the US population on both issues of climate change and energy generation. Moreover, the recent "ClimateGate" scandal, now heavily used in anti global warming blogs has, at a colloquial level, caused public mistrust in climate science. Our intent would be to use "ClimateGate" as a teaching moment for how scientists discuss the statistically difficulty of digging signal out of noise.

The next few years frame a critical window for climate literacy education and subsequent change of consumer behavior. In 2009, President Obama made the transformation of the nation's energy infrastructure as linked to global climate change a central policy goal for his administration (OFA, 2009). The economic and political nature of these issues demands that the public be able to *critically evaluate information* about climate change from an objective point of view that can be supported by data. **Public climate literacy starts at the K-12 school level, where teacher knowledge of earth system science is seriously lacking**. OCLEI leverages the scientific expertise and resources of NASA to deliver a systematic and sustained course of PD for middle and high school science and math teachers, focusing on the highly coupled fields of global climate change and choices in global energy production and new forms of transportation. The primary objectives of OCLEI are to a) increase the content knowledge of teachers in basic climate literacy (which they seriously lack), b) engage teachers in a robust exploration of the various data sets that have been used to show that climate change is occurring, c) develop teacher expertise in understanding the overall scale of the world's energy generation problem, and d) develop a suite of data/project-based exercises used by teachers to introduce their students to the **coupled** issues of energy generation and climate change. In meeting these objectives, OCLEI will both directly impact the climate change literacy of over **4800** students in several rural Oregon communities and will have constructed a unique and engaging curriculum that synthesizes our 4 objectives.

Defining Climate Change Literacy

When we speak of literacy, science literacy or climate change literacy, what do we mean? While we agree with standard definitions of science literacy like that given by James, et al: "*…familiarity with science in the wider context of human affairs…*" (James, Robinson, & Powell, 1994) it remains quite unclear how literacy thus defined would be implemented in the K12 classroom. To facilitate this implementation OCLEI has adopted the following heuristic in understanding science literacy in terms of the needed skills and experiences of students:

a) Students are exposed to a reliable and consistent knowledge base of scientific concepts
b) Students will develop scientific process skills (the process of inquiry) and critical thinking skills in terms of being able to think about the possible implications of ambiguous and incomplete data.
c) Students will be rigorously instructed on how to analyze scientific information and understand its limitations in order to make informed decisions and participate in local community-level actions that yield positive outcomes.

Improved scientific and technical literacy will empower students to become responsible citizens in a rapidly changing world and will better prepare students for effective participation in the decisions and actions that take place in their homes, their communities, and their world. Moreover, climate change literacy will better prepare students for interpreting and acting on issues related to environmental sustainability. We are now living in the most globally unsustainable period in history with the emergence of the energy and consumption footprints of India and China. As a result, we have emerged into a new global paradigm that must be explicitly understood if sustainability is to be achieved:

> ***Climate and energy resources are the two fundamental shared resources of the world and no one country or individual can claim ownership to them.***

K-12 education will play a crucial role in creating a more climate change literate society. Yet, when today's middle and high school science teachers were trained in science content, much of the science behind climate change simply did not exist. OCLEI will meet this need not only by bringing teachers "up to speed" on climate change, but will transform educational practice around climate literacy by developing inquiry/project based activities to engage students in climate change learning to ultimately become more climate literate citizens.

<u>Climate Literacy for Middle and High School Teachers</u>

Climate literacy for middle and high school teachers begins with an awareness of climate basics, i.e., the clear relationship between atmospheric greenhouse gas concentrations (primarily water vapor) and average global temperature. OCLEI will fully educate teachers on a) the energy-use-related factors that determine the evolution of atmospheric CO_2 concentration, b) the fundamental "greenhouse-effect" science that potentially cause changes in average global temperature, c) the complex and influential "feedback" mechanisms inherent in events such as melting icecaps and glaciers, changing precipitation patterns, shifting vegetation cover and aerosol pollution acting as a source of global diming and d) the extremely important role of methane emissions that serve to enhance any warming signal. Our view of climate literacy closely aligns with the NOAA guidelines and includes understanding a) the major environmental factors that affect climate, and b) how those factors are coupled with each other to produce climate change. As an example outcome of climate literacy obtained through OCLEI training, the climate literate teacher would understand potential surface warming as a result of a) the water vapor feedback loop, b) increased atmospheric CO_2 concentration, c) increased atmospheric CH_4 concentration and d) "pipeline" warming due to the oceans acting as an enormous heat buffer.

The overall theme of OCLEI courses is effectively summarized by a graphic presented in The Intergovernmental Panel on Climate Change (IPCC) *Fourth Assessment Report: Climate Change 2007* (see Fig. 1). The graphic describes the coupling between global average temperature and energy generation, illustrating the significant range of uncertainty (see Fig 1). The X-axis represents CO_2 concentration in the atmosphere, driven by the rate at which we burn

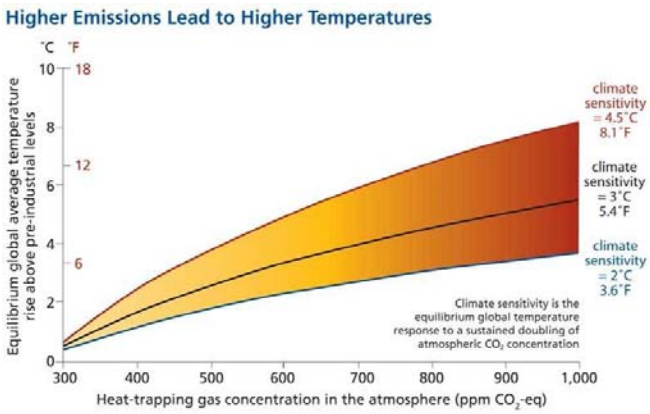

Figure 1: Higher Emissions Lead to Higher Temperatures.

fossil fuels. The Y-axis represents the modeled response of average global temperature under different assumptions of "climate sensitivity (the response of the atmosphere to a sustained doubling of CO_2 concentration). Without any feedback processes (e.g. clouds) that sensitivity is 2 C. However, models that incorporate various feedback mechanisms yield sensitivity as high as 4.5 C. The difference between these two scenarios is large in terms of overall impact on the Earth. Because annual CO_2 concentration increases have accelerated since 2003 from a historical rate of ~1.25 ppm/year to ~2.5 ppm/year (due to the emergence of China and India into the global economy and the corresponding increase in fossil fuel use), we are now faced with both serious global climate change, and substantial uncertainty in the magnitude of the long term change.

Understanding the science underlying the above claims is central to OCLEI professional development and the attainment of climate literacy by the participants.

Classroom Pedagogy for Climate Change Literacy

Improving overall public climate literacy requires that teacher content knowledge be joined with effective, inquiry-based pedagogy emphasizing data analysis. Our past work in science teacher PD indicates that many K-12 teachers equate inquiry-based pedagogy with teaching the "scientific method" (Carr, et al, 2009). This is especially true in middle and high school, where students often apply the steps of the scientific method in simplistic, artificially contrived contexts, usually disconnected from vital science concepts. It is therefore critical that innovative pedagogy be modeled, taught, and supported in content-focused professional development, coupling content knowledge with content pedagogy. To blend content and pedagogy in PD, OCLEI incorporates research-based *data-centered inquiry* in its courses and activities, modeling pedagogy in which *student learning is driven by the investigation and analysis of authentic observations and data* (Bothun, 2003). Data-centered inquiry differs from the "scientific method" in that the student will articulate, test, and reconstruct their flawed conceptual models using real data and observations. OCLEI will use data-driven inquiry to target central yet difficult concepts necessary for understanding climate change. For example, most teachers (and hence there students) think of the atmosphere as a simple "blanket," and they apply this model when considering the effect of greenhouse gases. The "blanket" model, while somewhat useful, is insufficient to properly understand the physical interaction of solar radiation, atmospheric constituents, and terrestrial albedo in driving average global temperatures. From previous PD workshops we know that a pretest question on the origin of the greenhouse effect often produces this kind of teacher response: "*The CO_2 in the atmosphere reflects back heat emitted by the ground, like a blanket reflects back heat from my body*." One of the key science misconceptions in this statement is the word "reflect". To then counter this misconception, the teachers are supplied wavelength-dependent transmission data of atmospheric gases such as H_2O, CO_2, and CH_4 which they represent using graphical software. In turn, this leads to understanding that atmospheric gases, at certain wavelengths, absorb the infrared flux from the blackbody radiation of the Earth and then re-emit a portion of that absorbed flux back to the surface, thus elevating surface temperatures. By testing initial conceptions (e.g. the blanket concept) against data, participant teachers learn not only an improved model for understanding the “greenhouse-effect” but gain critical experience in analyzing and portraying real data.

<u>OCLEI Professional Development Model</u>
OCCEI builds on *North Coast Teachers Touching the Sky* (NCTTS), a successful three-year ESEA Title IIB Math/Science Partnership project delivered by the PI and Co-I to six rural, high-poverty Oregon coast school districts from 2005-2008 (Carr, et al, 2009). NCTTS trained school-based teams of K-12 teachers to better utilize inquiry-based science instruction models within a comprehensive earth and space science curriculum. NCTTS activities included two week-long summer fieldwork institutes, a series of on-site Friday-Saturday mini-institutes during the school year, and hands-on mentoring and observation of participant teachers in their classrooms. NCTTS enabled the development of a robust and abiding partnership between PI Bothun and Co-PI Carr, their respective institutions, and the teaching and administrative staff of a number of rural, high-needs, partner school districts. The communication and trust built over several years in comprehensive partnership serves as a strong foundation for OCLEI and most of the NCTTS participant teachers are eager to engage in a similar experience. The primary reason for the success of NCTTS was that each cadre of teachers was involved with the project for 12 months instead of just attending “one-off” workshops. Like NCTTS, OCLEI seeks to enhance teacher core content knowledge, build the capacity for inquiry-based science teaching, and develop teacher leadership for sustainable and meaningful action in schools. This articulated approach between content knowledge, content pedagogy, and a focus on teacher leadership leads to powerful and coherent teacher PD (Penuel, et al, 2007). OCLEI will extend and build on what has been learned in previous work, with content focus on earth systems science and climate change, and modeling data-driven classroom inquiry using NASA and other earth observation data resources. Critically, OCLEI will rethink the way teachers are supported in their classrooms, engaging scientists, master teachers, novice teachers, pre-service teachers, science educators, administrators, and others, in *classroom co-teaching partnerships* as further described below.

<u>Partner School Districts</u>: Nowhere in Oregon is the need for PD in science teaching more acute than in high-poverty, rural school districts. OCLEI is partnering with five small, rural districts of the Oregon North Coast, including Tillamook SD 9, Nestucca Valley SD and Neahkanie SD in Tillamook County, Seaside SD and Astoria SD in Clatsop County. These districts were selected based on a combination of higher than average community poverty, the presence of diverse, underserved student populations, and a student underachievement in science based on 2008 Oregon Department of Education achievement test data. Oregon’s North Coast is largely agricultural, with many families involved directly in agribusinesses such as farming, milk production, fisheries, and forestry, industries directly impacted by climate change. Past experience has shown that teachers in the rural districts we serve prefer intensive, face-to-face summer PD, followed during the busy school year by a more flexible, hybrid delivery format blending face-to-face and online activities. OCCEI delivers an interlocking set of PD activities designed to sustain learning through a full school year and provide hands-on support in classrooms. Figure 2 presents a schematic visualization of this process.

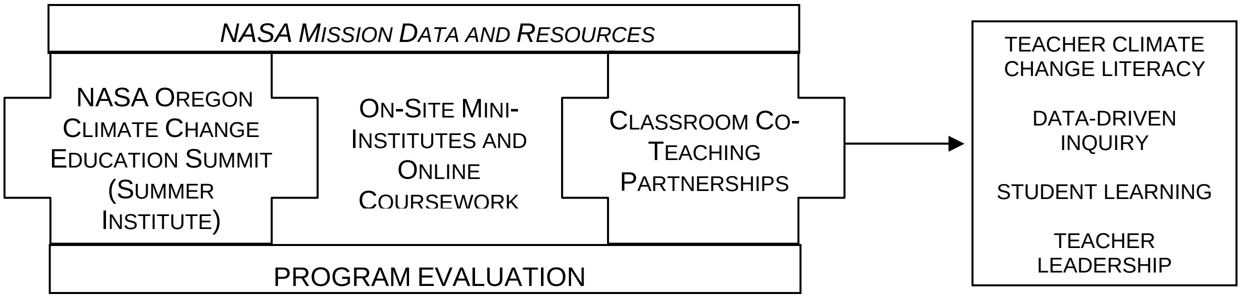

Figure 2: OCCEI Professional Development Model

Classroom Co-Teaching Partnerships: The ultimate goal of PD is to increase teacher core knowledge resulting in improved student learning. In the past, such development for science teachers often consisted of short, "one-shot" workshops without post-activity support; this approach to transmitting educational innovation was largely ineffective (Desimone, Smith & Ueno, 2006). More recently, researchers have emphasized the "sustained" PD, in which support continues in schools and classrooms for at least 100 hours throughout the school year (Meyer & Barufaldi, 2003). NCTTS sustained its summer institute work with periodic short workshops during the school year, classroom observation visits by staff scientists, and the support of release planning time for teachers. However, even with these sustained efforts, the measured impact on teacher practices in NCTTS classrooms varied widely between individual teachers and schools. While the PD "transmitted" by NCTTS resulted in clear gains in teacher content and pedagogical knowledge, too many teachers and their students experienced little discernable impact in the classroom (Carr, et al, 2009). This provided us strong evidence that we can and need to do better. Those lessons learned from NCTTS have empowered us to adopt an additional strategy for OCLEI through the creation of *classroom co-teaching partnerships*. In this approach, scientists and researchers work alongside classroom teacher's *in situ* (Henderson, Beach & Famaino, 2006). OCLEI will facilitate a co-teaching partnership in each participating school, engaging staff scientists and science educators, master, novice, and pre-service teachers, and school administrators in the joint task of working with students in real time, "learning at each others elbows" (Roth & Tobin, 2002). Significantly, to handle more teachers, OCLEI will include in classroom co-teaching partnerships pre-service teachers from Pacific University's *National Science Foundation Robert Noyce Scholar* program.

OCLEI Climate Change Education Model

OCLEI uses earth systems science as the foundation for understanding climate change (see below). In addition, we emphasize **energy production** as part of the climate change process, leading to a more comprehensive content package than similar efforts, which likely focus just on climate change. OCLEI strongly integrates energy generation and use and climate change in order to demonstrate a) the scale at which conventional fossil fuel facilities need to be replaced by non-greenhouse gas emitting sources of energy production, b) the kinds of technologies that need to be developed and deployed, and c) the timescale over which real implementation of significant sources of alternative energy can be brought on line. Both recent studies (Carnegie IAS Commission on Mathematics and Science Education, 2009) and our own experience shows that undergraduate students are becoming increasingly concerned, interested and passionate about climate change and alternative energy**, but their passion is not well informed**. As climate literacy begins to emerge as a pre-requisite to being an educated citizen, science teachers need to be well trained on how to deliver this complex subject in an understandable and physically truthful manner to K8-12 students.

OCLEI will create a multifaceted web-based suite of climate visualization and data analysis tools that will enable a data-driven learning approach to better engage teachers and students on the issue of climate change as it relates to our choices of energy production. The study of energy production (and use) encompasses a broad range of interconnected themes, providing an excellent opportunity to integrate not only math/science/technology subjects but also social, political, economic and environmental aspects. Effective science and environmental education may be particularly important in light of strong evidence suggesting that American students – in fact, the U.S. public in general – are lacking in awareness of environmental and energy-related issues (BAMS, 2005; NEETF, 2002). Education programs that promote scientific literacy will help prepare students to interpret scientific, environmental, and energy-related issues and make sound choices and actions as voters, consumers, and professionals.

Earth Systems Science: Gateway Knowledge for Climate Change Literacy: One important finding of NCTTS that strongly informs OCLEI was the identification of considerable deficiency in teacher knowledge in the general area of Earth Systems Science (ESS). This is hardly a surprise; much of the necessary foundational material in ESS didn't even exist in college 10 years ago when most participant teachers were trained. As ESS becomes increasingly important as a conduit for understanding global climate change, it becomes imperative that teachers be well trained in ESS and be well exposed to the wealth of data resources that are now available (mostly online) that are currently contributing to our understanding of ESS.

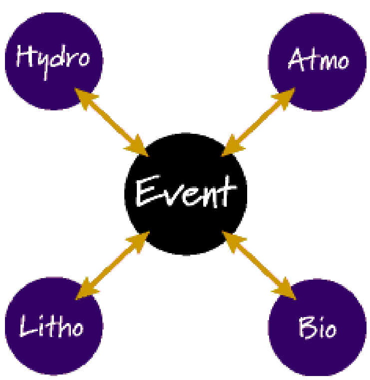

Figure 3: Simple Event-System Interactions

Knowledge of the various pathways in which the Earth systems are all connected is critical to understanding climate change. The existence of feedback channels (positive and negative) within the overall climate system are some of climate change's most important physical drivers, but **teacher knowledge of the role of these feedback systems has proved to be virtually non-existent.** The lack of recognition of the connectivity of ESS processes became evident during the previous NCTTS project when teacher teams were assigned an earth systems analysis project. The purpose of the analysis is to sketch some of the ways "events" both natural (e.g. forest fire, flood, windstorm, volcanic activity, tsunamis, etc) or man made (e.g. Columbia River Dredging; construction of LNG import facilities, etc) have upon the various earth system spheres (e.g. atmosphere, lithosphere, hydrosphere, and biosphere). The analyses done by teachers tended to show only the simple, direct causal connections between the given event and the four spheres, treating earth systems in isolation from each other (see Fig 3).

Clearly, in a complex system such as the Earth, multiple pathways exist. Figure 4 represents a more complete set of connections that the event ultimately triggers. Our experience, however, is that K-12 teachers have great difficulty conceptualizing these pathways, let alone identifying the physical drivers behind the

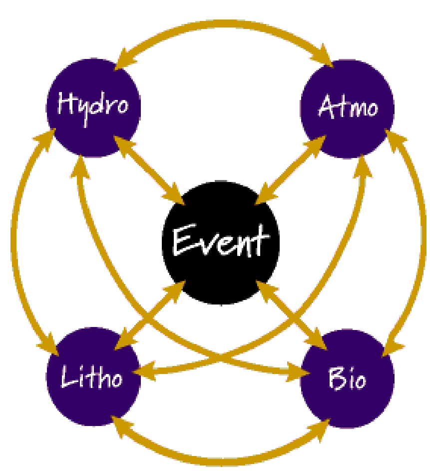

Figure 4: Complex interactions between and among systems

pathways**. In a similar way, the linkage between industrial processes and global climate change also follows many routes; a central goal of our approach to this subject is to reveal some of these routes**. In particular, it becomes important to discuss the role of **methane** in global climate change in terms of these various routes and feedback channels. Increased literacy in climate change, therefore, can be represented by helping teachers transition their concept of linkage away from Figure 3 and towards Figure 4.

<u>Climate Change Curriculum Framework</u>
Much of OCLEI course content originates with the wealth of undergraduate curriculum material on both global climate change and global energy production that the PI has produced over the last 5 years. OCLEI course content is consistent with the Climate Literacy Framework set out by the National Oceanic and Atmospheric Administration and the National Science Foundation. It is also intended to introduce the science that underlies much of the policy recommendations of the fourth assessment of the Intergovernmental Panel on Climate Change (IPCC, 2007).

<u>Essential Questions</u>: OCLEI courses are anchored in four *essential questions* of climate change:

1. *What are the physical drivers of the climate system and the dynamics by which they are maintained or altered?* Teachers will learn about jet streams, ocean currents and the various known interaction mechanisms. Short-term fluctuations such as El Nino and La Nina will play a major role in this discussion, as they are well-documented agents of change in altering major climate patterns.

2. *How is data used to measure regional climate and to detect regional climate variations*? Participant teachers will learn how to retrieve extant climate data, how to visualize it, and how to use it to define a given climate in a physically defensible manner. Presently, most teachers (and other policy makers) simply teach the “fact” that climate change is occurring. In order to make physical sense of climate change, teachers will learn to define a regional climate, and use extant NASA and other data resources to show that the defined climate has actually changed. Since climate data is generally noisy, it is ultimately ambiguous and the same data set may be used to support multiple points of view. One of the main indicators of climate change literacy is the ability to recognize what conclusions the relevant data can and cannot support. **The intrinsic nature of climate data offers an excellent opportunity to improve teacher’s understanding of science as an uncertain process**.

3. *How are climate and climate shifts often driven by processes that operate for decades*? Decadal changes (e.g. the PDO or the AMO) are now well defined by data, but their origins remain a significant puzzle. However, the existence of these climate cycles is very important in terms of choosing a baseline climate if one wishes to assess whether or not climate change has occurred. Indeed, the very existence of these long term fluctuations suggests that there is no representative time period in which one can define an “average climate”.

4. *What are the exchange processes between the atmosphere and the ocean, the ocean and the land, and the land and the atmosphere*? The rates of exchange of these processes are determined by planetary energy balance considerations. The basic effect of human activities on climate is to alter these rates of exchange thus taking the system out of a state of equilibrium to a more unstable state or volatile state. A fair argument can be made that this leads to increasing climate and weather volatility. The amplitude of our exchange rate alterations is directly correlated with the rate at which we use fossil fuels as our primary energy source relative to the rate that natural processes mix them out of the atmosphere.

OCLEI Curriculum Framework:

Our historical understanding of atmospheric processes and climate progressed from the simple to the complex, creating a natural pedagogical pathway around which to orient OCLEI curricula. This is clearly seen in the evolution of the IPCC process and its outcomes. The evolutionary steps involved in climate modeling are the following:

- In the mid 1970's climate models were very crude and consisted of incoming solar radiation, the principal driver of climate, coupled with precipitation patterns. Direct CO_2 injection into the atmosphere from fossil fuel burning was the only feedback channel considered.
- By the mid 1980's the role of clouds was introduced to the model, either as high altitude highly reflective ice crystal clouds that serve as cooling agents (negative feedback), or as low altitude water vapor clouds that provide additional warming (positive feedback). In addition, the changing albedo of the Earth were being considered due to a) changing land use patterns (e.g. paving over green space) and b) changing character of ice masses (either through melting or becoming dirtier due to particulate pollutants settling out at the poles).
- At the time of the IPCC First Assessment Report (FAR) in 1990, climate models had grown to also consider the effects of the oceans as a simple "swamp" for CO_2 storage. The FAR issued presented this overall consensus statement:

  The unequivocal detection of the enhanced greenhouse gas effect from observations is not likely for a decade or more.

- By 1995, the Second Assessment Report (SAR) climate model had become considerably more sophisticated than the earlier models by incorporating two new features, a) sulphate particles in the atmosphere either from volcanic events or from industrial processes (mostly coal burning), and b) the recognition that the ocean is a transport and storage system for CO_2 through the action of deep ocean current transport mechanisms. Not surprisingly, The SAR reached a somewhat different consensus:

  The balance of the evidence suggests a discernible human influence on the behavior of the global climate.

  The findings of SAR in 1995 represent a crucial "pedagogical moment" in climate change education. On one hand, sufficient data existed in 1995 to support the case for anthropogenic climate change. On the other hand, the intrinsic ambiguity and uncertainty of climate data challenged the public and policy makers to make a scientifically literate assessment of the facts**.** Lacking such literacy, the public expected instead unambiguous "smoking guns" to establish sound public policy. A **central pedagogical goal in OCLEI courses is to train teachers to effectively understand how to manage the inherent uncertainty in climate data in order to reach a trustworthy scientific conclusion**.

- The third assessment report (TAR) issued in 2001 used essentially the same climate model parameters as the SAR with just small refinements in how atmospheric aerosols were incorporated into the models. That TAR consensus statement was a bit stronger than the SAR statement:

  There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities.

- The fourth assessment (AT4) was released in February 2007. Additional refinements in AT4 model include a) changing vegetation patterns that alter the overall exchange rates within the carbon and sulphur cycles between the land and the atmosphere and b) the recognition that atmospheric chemistry (particularly the 12 year cycle associated with the breakdown of methane) can produce decadal changes in the overall microchemistry of the atmosphere. AT4 included the strongest consensus statement to date:

  Most of the observed increase in globally averaged temperature since the mid 20th century is very likely due to the increase in anthropogenic greenhouse gas concentrations.

  This statement became much more visible to the public because a) AT4 asserts the global average temperature has indeed increased and b) the likely reason is human activities. Yet, as noted earlier, a significant portion of the public remains convinced that there is "no real evidence for anthropogenic climate change" (Pew Research, 2009).

Data-Driven, Project-Based Pedagogy: Participant teachers will learn how climate change models have evolved by engaging in a series of data-driven projects and activities. Studies have suggested or directly shown that data-driven learning is an effective pedagogy that requires the application of scientific thinking to authentic, ambiguous data (Blumenfield, Krajcik, & Tal, 2006; Baker & White, 2003; Bednarz, 2000). Such exercises also lend themselves readily to collaborative, active work and a high perceived relevance of content, improving the learning and retention of science concepts (Kucharski, et al, 2005). OCLEI's data-driven pedagogical approach is consistent with recent developments in curriculum reform, aimed at the integration of science, technology, and mathematics as they relate to the real world (Yager, 2004). The **coupled** issues of climate change and energy generation is highly relevant and thus allows for an effective teaching of scientific methods within a societal context that is meaningful to today's student. Environmental and energy-related issues provide a convenient platform for problem or project assignments in an integrated math/science/technology project-based curriculum; OCLEI courses will expose the participant teachers to range of possible projects that, in turn, they can co-teach alongside project staff to their own students.

Data Visualization Tools and Climate Data Sets: An important aspect of our PD approach is to provide tool to participant teachers to allow them to visualize and analyze data. Through the training of the use of those tools, teachers in turn can design data exercises for their students.

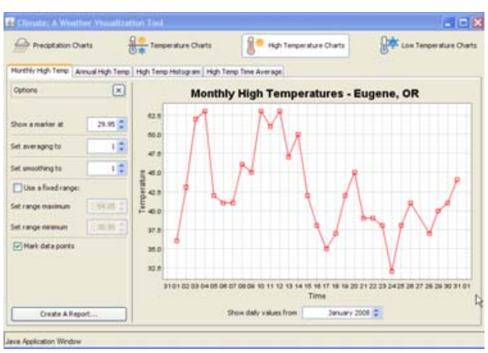

Figure 5: Monthly Climate Visualizer

Here we provide examples of some tools: "Monthly Climate Visualizer" (see Fig 5), which incorporates any data set that contains the high/low temperature and precipitation data for individual days. This interface allows teachers to interrogate the data either on a monthly or annual basis. Smoothing and averaging algorithms are built in so that students can construct smooth decadal averages to search for signatures of climate change. A second tool we have designed and implemented is "The Global Greenhouse," a climate change simulator. The simulator allows for the

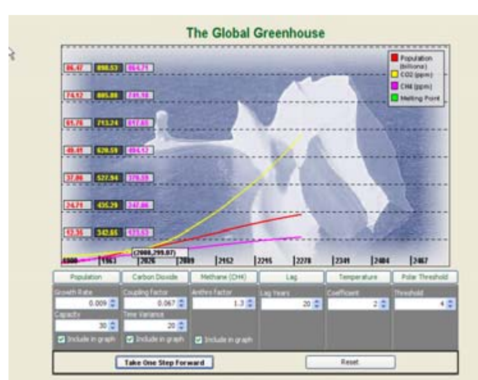

Figure 6: The Global Greenhouse

manipulation of a very comprehensive set of adjustable parameters that fully define, in an operational way, the potential behavior of the Earth's climate system to human activities and involves a metaphorical melting of the polar caps (see Fig 6) as the end result to avoid. This climate change simulation begins in 1900 with initial conditions of 1.5 billion human population, 280 ppm of atmospheric CO_2, and 20 ppm of atmospheric methane CO_2 equivalent. The graphs show the behavior of these three outputs as a function of time based a set of adjustable input parameters. Within the simulator, users can run many different combinations of input models and test various scenarios against favorable and unfavorable climate models. A standard exercise is to given different teams different climate models and then run the simulation to compose a press release on the potential impacts of global climate change. In this way teachers (and students) can begin to understand and appreciate the strong relation between predicted societal impact and climate model uncertainty which then aids in them understanding Figure 1. Course material and exercises will also make heavy use of Google Earth (to study the potential impacts of rising sea level) as well as the rich image data sets such as those available at NASA's *Earth Observatory***.** Our previous experience with NCTTS has clearly shown that in the PD format, teachers do not want to be lectured to but rather they want to learn how to develop data exercises for their students which will facilitate their obtaining mastery of the subject material. A consistent theme in all of our PD workshops is the use of computer based tools to facilitate data operations and analysis on relatively large data sets. **That theme of data driven inquiry will be the foundation of the OCLEI program.**

Examples of some ON line data sets, models and simulations that will be used as part of the curriculum foundation for OCLEI coursework are summarized in Table 1:

Table 1: OCLEI ON Line Course Resources

Resource URL	Material relative to Planned Course Work
http://gcmd.nasa.gov/	• General Resource Data base – RIMFROST data base will be used for various climate data exercises
http://earthobservatory.nasa.gov/	• Various white papers; satellite data bases on ice loss and deforestation
http://www.climatescience.gov	• Repository of white papers that deal with methane and the general issue of methane hydrates
http://www.ncdc.noaa.gov/	• Best resource for US state, regional and national climate data
http://www.purdue.edu/eas/carbon/vulcan/	• Project VULCAN: monitoring and visualizations of National output of carbon dioxide – very informative
http://visibleearth.nasa.gov/	• Repository of water vapor measurements in our Atmosphere-relevant to the water vapor feedback lop
http://flood.firetree.net/	• Sea Level rise simulator interface to Google Maps ; elevation overlays from NASA data

<u>OCCEI Work Plan and Timeline</u>

The timeline below assumes a funding cycle beginning 1 Nov 2010; work will begin as soon as project is approved, giving ample time to plan and deliver the initial summer institute, the *NASA Oregon Global Climate Change Education Summit*. We will use a generative process in developing further project components; informed by continual ongoing analysis of formative assessment data collected at all OCLEI activities (see Table 2).

<u>Table 2</u>: OCLEI Work Plan and Timeline

Timeframe	Activities
Nov 1-Apr 1	• Hold planning meeting and finalize institute design structure and content • Hold information meetings at district sites • Recruit initial cohort of 24 participants in school-based teams including a minimum of 3 teachers and 1 building or district-level administrator. • Develop and deliver pre-institute ON line course material
June 2011	• Hold *NASA Global Climate Change Education Summit* at Pacific University Campus in Forest Grove, OR. 40 hour face-to-face course held in intensive 5-day format. • Collect and analyze pre-assessment data.
Oct-Dec 2011	• Deliver second 3 quarter-hour hybrid course (online plus two Friday/Saturday mini-institutes) focusing on energy generation and the integration of climate science and energy production. • Initiate classroom co-teaching teams in participant schools.
Jan-Mar 2012	• Deliver third 3 quarter-hour hybrid course (online plus two Friday/Saturday mini-institutes) focusing on the analysis and representation of climate data, computer related data analysis and the construction of data sets and exercises for students • Continue to develop classroom co-teaching teams in participant schools.
Apr – May 2012	• Classroom co-teaching teams implement climate change lessons in schools • Presentation of concept map capstone projects • Summative assessment • Analysis of assessment data reflection, revision of practices • Submit annual report to NSPIRES
June 2012	• Select/recruit master teachers from OCCEI program completers for participation in new yearly cycle. • Start next cycle with similar calendar as above but start next summer institute in August 2012

<u>OCLEI Activities</u>: The OCLEI program will begin with the *NASA Oregon Global Climate Change Education Summit* (GCCES) a five-day intense summer institute held at Pacific University in Forest Grove, OR, located 1-2 hours drive from partner districts. NASA GCCES will be publicized as a significant campus and community event including public demonstrations and talks related to climate change aimed at Pre-service teachers and undergraduate students. Each day will consist of a morning and afternoon session of instruction and activities using university classroom, lab, and computer resources. Participants will be provided food and refreshments, and will have the option of lodging on campus. Activity will continue during the school year in a series of four *Climate Change Mini-Institutes*, held as Friday evening dinner meetings/Saturday workshops in school district facilities. The mini-institutes will be publicized locally and the work of teachers featured in local press outlets (which always improves morale). Learning will be sustained flexibly with online activities and exercises between the mini-institutes. This model was the operational cornerstone of the previous NCTTS effort and it proved to be highly effective.

Classroom impact will be ensured by creating at each school site a *Co-Teaching Partnership* (CTP), consisting of participant teachers, the building principal, an OCCEI scientist (PI and/or co-PI), and a NSF Pacific Noyce Scholar pre-service science teacher. It is important to emphasize that these Noyce Scholars will participate along with the teachers in the summer workshop to improve their core knowledge of climate and energy systems. The partnerships will develop and co-teach OCLEI lessons and units. The goal is that all partners will be significantly involved in "live" teaching of climate literacy curriculum and in post-lesson dialogue and analysis of student learning. Through a variety of co-teaching situations, all stakeholders will learn first hand how professional development must be adapted, modified, or even radically rethought in order to be successfully carried out in unique school and classroom contexts. OCLEI scientists will engage in a minimum of three co-teaching sessions at participant schools. Co-teaching teams will be provided with modest funds to support class release time for planning and dialogue.

Participant Teacher Compensation: Teachers respond positively to being treated as professionals, and adequate compensation for out-of-contract time spent in PD. Our prior experience in NCTTS revealed the critical role of this compensation in producing results as well as enthusiasm for process participation. OCLEI will compensate participant teachers $1500, divided into three $500 payments tied to completion of program requirements. This sum compares well with other high-quality professional development programs in our state, some of which compensate teachers at up to $3000 per year. Participants will also earn UO graduate level credit for each completed workshop through the UO's continuing education program. Each mini-workshop and associated ON line content will count for 3 credits of continuing education at the "masters" level.

Partnership Experience & Sustainability

OCLEI partners have substantial experience delivering sustained, collaborative professional development over the past several years, sustaining work even in the absence of a funded project. Examples of prior professional development projects involving OCLEI partners include *North Coast Highly Qualified Science Teacher Initiative (NHQSTI)* an ESEA Title IIB MSP Grant, serving 48 K-12 teachers along Oregon's North Coast from Nestucca to Astoria. During the three-year project, NCHQSTI developed a robust and valid evaluation model for assessing teacher content knowledge, classroom implementation of inquiry-based teaching, and student learning outcomes. NCHQSTI was noted by external evaluators for its high coherency and impact on participating teachers (Northwest Regional Education Lab, 2008). Partners are currently active with Tillamook SD and other school districts around the state as consultants on infusing service learning projects with STEM literacy development.

Management Team: Dr. Greg Bothun (PI) will assume lead responsibility for developing and delivering OCLEI climate change curricula and digital tools. Dr. Bothun has been involved in K-12 teacher professional development since 1990. He is the director of the Pine Mountain Observatory and oversees a large in-state K12 visitation program that is done in conjunction with the *Friends of Pine Mountain Observatory* – a group of local amateurs that help to support the educational outreach mission of the observatory. Dr. Bothun has also developed an extensive series of physics/astronomy/earth system science JAVA/FLASH based visualizations, simulations and virtual experiments to serve as important aids in both data- and inquiry-driven curriculum (see http://homework.uoregon.edu/demo/). Dr. Bothun recently chaired a national conference on how improving computing infrastructure can lead to breakthroughs in various forms of renewable energy – (see http://www.sc.doe.gov/ascr/WorkshopsConferences/CRNARE.html) and has recently begun a large scale investigation into regional climate change in the Pacific Northwest and well as the Northeastern United States using a new statistical method of climate indexing.

Dr. Kevin Carr (Co-PI) will assume lead responsibility for developing and delivering instruction in data-driven pedagogy, and in developing co-teaching partnerships. Dr. Carr has been actively involved since 1998 in professional development of both pre-service and in-service science teachers. He is an expert on educational action research, collaborative and inquiry-based learning, and program evaluation and assessment. He was Co-PI with Dr. Bothun of *North Coast Highly Qualified Science Teacher Initiative*, NCLB Title IIB Grant, Oregon Department of Education, 2005-2008 ($554,000) and in 2003 was awarded a NASA IDEAS grant, in conjunction with Dr. Bothun, to better train Oregon high school teachers in astronomy. He currently serves as PI for a NSF Noyce Scholarship Grant for supporting new STEM teachers serving in high-needs schools.

<u>Sustainability</u>: Our past projects have been sustained by adhering to two specific principles: First, we include district superintendents as active partners, not only assisting in teacher recruitment and support, but as participants in selected activities alongside teachers. Second, we select school-based teacher teams who will mutually support each another in enacting innovative content, tools, and pedagogy into their own curriculum. OCLEI will create co-teaching partnerships, which will bring OCLEI scientists and researchers into the classroom with participants, working together for student learning. We anticipate that the relationships formed during the development of co-teaching partnerships will result in deep and transformative change for all partners in a similar manner as occurred in the previous NCTTS program. In addition, video and other resources that define the ON line courses can continue to be offered throughout the State of Oregon via PriSM Oregon: A statewide collaboration of public and private colleges and universities to build the capacity of Oregon's K-8 teachers in math & science instruction (see http://www.prismoregon.org/)

<u>Dissemination</u>: The Oregon Department of Education and NASA Oregon Space Grants Consortium will be provided with much-needed teacher-developed and field-tested models of climate change curricula, place-based projects, and assessments. Presentations will be made at the *Oregon Science Teacher Association* (OSTA), along with publication of articles in *The Oregon Science Teacher* (TOST), and other national science education and practitioner journals.

Evaluation

OCLEI will carry out a rigorous and comprehensive program evaluation with assistance from project partner Education Northwest (Formerly Northwest Regional Education Laboratory). Education Northwest (EN) provides research and development assistance to education, government, business, and labor as part of a national network of 10 educational laboratories funded by the U.S. Department of Education, Institute of Education Sciences (IES). EN Evaluation Specialist Edith Gummer has participated in all phases of project design as a member of the OCLEI writing team.

<u>Instruments and Design</u>

OCLEI will perform a rigorous analysis of project impact on teacher content knowledge, classroom practices and student learning. OCLEI has selected instruments and analysis procedures appropriate to a mixed-methods experimental design (see Table 3). OCLEI will implement a pre- post-test design to evaluate changes in teacher climate change literacy, and to better understand participant knowledge and misconceptions on the general topic the greenhouse effect, global climate change, and world energy use. Impact on classroom practice will be assessed during the project using the Reformed Teaching Observation Protocol (Piburn et al, 2000). The *RTOP* details for each participant a composite measure of multiple aspects of lesson design and implementation, content taught and classroom culture. Careful training of evaluators is required for effective implementation of *RTOP*. OCLEI partners have used the RTOP for several years and have established staff inter-rater reliability.

Deliverables

EN will coordinate the compilation of annual project reports to NASA. In addition, project investigators will work with project data to disseminate project learning and outcomes to the broader climate science education community via a web site dedicated to this project.

Table 3: OCLEI Evaluation Plan Aligns to NASA Education Outcomes and Project Goals

NASA Education Outcome Objective	OCLEI Goal	Instrument(s)	Analysis Method
2.2 Provide long duration and/or sustained professional development opportunities to educators that results in deeper content understanding and/or confidence in teaching STEM disciplines	1(a). Increase teacher climate change and earth systems science literacy	Climate Change Literacy Instrument (OCLEI-developed)	Pre-Post Comparison
	1(b). Improve teacher access to NASA climate change and NASA earth systems science resources	Fieldnotes Interviews	Open-coded for category access to resources
2.4 Provide K-12 students with authentic first-hand opportunities to participate in NASA mission activities, thus inspiring interest in STEM disciplines and careers.	1(c). Encourage pedagogical innovation and (d) transform classroom practice	Fieldnotes Interviews RTOP Video Taping	Formative comparisons as project progresses
	2. Increase the number of middle and high school students using NASA Earth observation data/NASA Earth system models to investigate and analyze global climate change issues	Fieldnotes Interviews RTOP	Formative comparisons as project progresses

In sum, OCLEI will offer a comprehensive, interdisciplinary, PD program consisting of an *intensive one-week summer institute* followed up with *school year mini-institutes* delivered in a hybrid format, along with *classroom co-teaching partnerships*, an innovative strategy in which scientists and teachers work side-by-side in the classroom. Training and pedagogy will center on several different data-driven exercises involving climate data analysis which will make heavy use of NASA climate data resources. This analysis will be folded into our current patterns of energy generation and use, and potential forms of alternative energy, to fully link energy generation and climate change as the two biggest economic and social problems of this century which must find effective policy to solve. The fundamental goal of OCLEI is to therefore instill both energy and climate literacy into the participant teachers so that they can better educate their students on these fundamental issues.

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Budget Justification

Project Salaries

- Professor Gregory D. Bothun, University of Oregon is the PI: We request 0.67 months of summer salary in years 1 to 3, to support the development of ON line materials for the workshops and mini-workshops. Fringe rate is 32% of this summer salary.

- Associate Professor Kevin Carr, Pacific University is the Co-I. We request 1.5 months of summer salary in each year of the grant to support workshop development for this project and to host the summer week long workshop. Fringe rate on that salary is 30%. To support this salary a **Subcontract** to Pacific University will be awarded. The overhead rate charged by Pacific University on that subcontract is 36%.

- Web programmer Josh Rogers will work on the various simulations and data exercises needed to support the ON line course work component of this project. This effort will involve 4 person months of time. Fringe rate on his salary is 55%.

- We request support for one undergraduate student at a salary averaging $500 per month to assist with curriculum development and ON site teacher workshops

- In years 2 and 3 we request support for consulting services of our external evaluator, Edith Gummer, of NWREL at the level of 4 and 8K respectively.

Participant Support Costs:

Indirect costs are not charged for this cost category. These costs come in two forms:

- By prior arrangement with the Continuing Education Program at the University of Oregon, we have negotiated a rate of $50 per credit for teacher participants. There are 4 “classes” each at 3 credits for this project. There are 16 participant teachers. Hence we request 50x12x16 = $9600 per year to cover tuition costs.

- We also plan to provide teachers with a $1500 per year stipend for participation. This amount is consistent with past practices.

Travel:

- We request $3000 per year to support the in state travel costs associated with the PI and Co-I movement to the various workshop locations along with mileage reimbursement for teachers to attend the summer workshop at Pacific University.

Equipment:

- We request $3000 in the first year to purchase a project laptop/data projector and network attached storage for backup of media files and $2000 for the purchase of Davis Weatherlink stations to be deployed at each participating schools.

- We request $200 a year in paper based materials and supplies

Publication Costs

- We request $4,000 to support the costs of publication and dissemination of the project results in year 3

Indirect Costs:

- This project qualifies for the University's 29% overhead rate that is a flat rate charged to Public Service grants. Direct costs charged as such are for everything except Participant Support Costs as described above. Only the first 25K over the three year subcontract is charged UO overhead.

Resume of G. Bothun

Education:

- B.S. Astronomy, University of Washington, Seattle WA, June 1976
- Ph.D. Astronomy, University of Washington, Seattle WA, August 1981

Professional Employment:

- Scientific Programmer: The Very Large Array Radio Telescope NRAO 1977
- The University of Washington, Astronomy Instructor 1980-1981
- Harvard-Smithsonian Center for Astrophysics, Center Research Fellow 1981--83
- California Institute of Technology, Bantrell Research Fellow 1983--86
- The University of Michigan, Assistant Professor **in Astronomy (1986--1989)**
- The University of Michigan, Associate Professor in Astronomy (1989--1990)
- The University of Oregon, Associate Professor in Physics (1990--1995)
- The University of Oregon, Professor in Physics (1995--present)
- The University of Oregon, Professor in Environmental Studies (2000—present)

Other Professional:

- UNIX System Administrator for Physics Department
- Webmaster for various educational technology curriculum projects
- Director, University of Oregon Pine Mountain Observatory (1990 – present)
- Scientific Editor, The Astrophysical Journal (1996---2002)
- National Academy of Sciences Decadal Panel (1997—2000)
- Phi Beta Kappa Visiting Scholar 2000---2001

Professional Societies:

- American Astronomical Society
- American Association for the Advancement of Science

Professional Experience:

Research Productivity

- 190 Papers in Peer Reviewed Journals (1980-2009)
- Original Member: ISI Highly Cited Researcher in Space Sciences (1980-2000 period)
- One Graduate Level Textbook: *Modern Cosmological Observations and Problems*
- One Undergraduate Textbook: *Cosmology: Mankind's Grand Investigation*
- Approximately 25 Popular Articles (Newspapers/Popular Magazines)
- Over $3.0 million in grant funding from NASA and NSF since 1986
- Chair of Numerous NASA and NSF Peer Reviews

- Approximately 2000 nights of Observing since 1980 on most of the major radio and optical telescopes in the world
- Extensive experience with Space Based instrumentation - including the Hubble Space Telescope, GALEX, and the Spitzer Space Telescope

Research Interests:

- Galaxy formation and evolution
- Dwarf Galaxies
- Galaxies of Low Surface Brightness
- Large Scale Structure
- Clusters of Galaxies
- Observational Cosmology
- Applications of Instructional Technology
- Climate Change Indicators
- Sustainable Energy Implementation and Policy

Miscellaneous:

- Initiated the *Electronic Universe Project* - a Web server dedicated to public outreach and education in space sciences, energy issues, global climate change and other matters through the delivery of real data, explanation and analysis. This has been on the air since Feb 9, 1994 - making it one of the first such servers in the entire world. Server has seen close to 35 million hits since operation commenced.
- Developed suite of Java based simulation tools for introductory classes in physics, astronomy, and environmental studies. Widely used Nationwide.
- Have given over 150 public lectures since 1984 to various groups
- Helped developed the new Environmental Studies/Sciences program at the University of Oregon
- Supervise the Friends of Pine Mountain Observatory Educational outreach program which visits 200+ K12 classrooms a year in the State of Oregon and which accommodates approximately 2500 visitors per year during the summer to the observatory.
- Have lead numerous K12 teacher professional development workshops

Kevin M. Carr, Ph.D.

EDUCATION

- Ph.D., Science Education. University of Idaho, May, 1998
  Dissertation: *Reflective judgment and cognitive interaction in an electronically distributed learning environment*
- M.S., Physics. University of Idaho, May, 1997
- B.S., Physics. University of Oregon, June, 1986

EMPLOYMENT

- August 2008-present: Associate Professor of Science Education, Pacific University, Forest Grove, OR
- August 1998-2008 : Professor of Education, George Fox University, Newberg, OR
- August 1994 -May 1998 : Graduate Teaching Assistant, University of Idaho, Moscow, ID
- August 1991 - August 1994: Science & Mathematics Teacher, Portland Adventist Academy, Portland, OR
- August 1987 - August 1991: Science Teacher, Roseburg High School, Roseburg, OR

PROFESSIONAL MEMBERSHIP

- *American Educational Research Association* (AERA)
- *National Association for Research in Science Teaching* (NARST)
- *National Science Teachers Association* (NSTA)
- *Oregon Science Teachers Association* (OSTA)
- *Oregon Space Grant Consortium* (OSGC)
- *Northwest Teacher Research Collaborative (NWTRC)*

RECENT PUBLICATIONS

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