2006-2612: TRANSFORMING K-12 EDUCATION VIA THE COLLABORATIVE LARGE-SCALE ENGINEERING ANALYSIS NETWORK FOR ENVIRONMENTAL RESEARCH (CLEANER) PROJECT

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Transforming K-12 Education via the Collaborative Large-scale Engineering Analysis Network for Environmental Research (CLEANER) Project

Abstract

The Collaborative Large-scale Engineering Analysis Network for Environmental Research (CL*EAN*ER) Project Office has been established with funding from the National Science Foundation (NSF) to the University of Illinois Urbana-Champaign (UIUC) and a coalition of 11 other institutions. The project office is coordinating the creation of a strategic plan consisting of research, cyberinfrastructure, and education plans that set forth a roadmap for the collaborative engineering analysis network for the study of environmental problems. This report will be completed by July 2007 and requires input from K-12 educators, administrators and other stakeholders in K-12 education. This paper describes the CLEANER project, provides an example of the CLEANER Education Committee's vision for the K-12 area and lists contacts for further information. The intention of this paper is to elicit input from the K-12 engineering education community, including K-12 educators, on how the CLEANER Education Plan could better meet the future needs of K-12 students and educators

1.0. CLEANER Overview

As its full name implies, the CLEANER project aims to transform and advance the scientific and engineering knowledge base for addressing the challenges of large-scale, complex, human-stressed environmental systems through collaborative modeling and knowledge networks. This will be accomplished through the creation of WATERS (WATer and Environmental Research Systems) Network, which will allow scientists and other professionals to advance the understanding of human impacts on environmental systems and improve and informed the management of environmental issues.

During the years 2005- 2007, the CLEANER Project Office will work with its constituencies to develop a plan for the WATERS Network. The following six committees are currently developing a roadmap for critical components of the project:

- Cyberinfrastructure
- Education
- Environmental Engineering and Science
- Organization
- Sensors
- Social Science and Economics

A list of committee members for each working group is available at http://cleaner.ncsa.uiuc.edu/people/ .

The CLEANER Project office coordinates and assists with activities leading to establishing the WATERS Network. This oversight entity will refine key environmental science and engineering questions and develop a unified community vision for addressing needs and building

infrastructure. Additional information on the CLEANER project may be found at project's website: http://cleaner.ncsa.uiuc.edu.

The following brief extract from the website summarizes the "what," "who," and "why" of CLEANER.

> The CLEANER Project Office involves a coalition of more than a dozen institutions who are leading a national planning effort to define CLEANER, funded by the National Science Foundation. CLEANER is collaborating with the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI) which represents more than a hundred U.S. universities developing infrastructure and services for the advancement of hydrologic science and education in the United States[1]. CLEANER and CUAHSI will define a joint field network, currently called the WATERS (WATer and Environmental Research Systems) Network.
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> The WATERS Network will allow scientists and other professionals to engage in better understanding how human-stressed environmental systems work and how to improve management of environmental issues. The four main components are:
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> 1. A **network** of highly instrumented field facilities for acquisition and analysis of environmental data.
> 2. An environmental **cyberinfrastructure** virtual repository of data and information technology for engineering modeling, analysis and visualization of data.
> 3. A **multidisciplinary integration** of research and education to exploit instrumented sites and networked information; formulate engineering and policy options to protect, remediate, and restore stressed environments and promote sustainable environmental resources.
> 4. A **collaboration** among engineers, natural and social scientists, educators, policy makers, industry, NGOs, the public, and other stakeholders.

2.0. Critical Role of Education within WATERS Network

Education and outreach components are critical for the success of the CLEANER Project Office and the WATERS Network as they address significant workforce issues and have the potential to transform environmental education at all levels. They will have the broadest impact and possibly the most long-lasting influence of all elements of the WATERS Network. Educational plans merit attention and resources at a level commensurate with their broad and long-lasting benefits to society.

2.1 Increasing the Pipeline

Multiple reports point to the decline in students studying science, technology, engineering and mathematics (STEM) at colleges and universities as well as the increase in the rate of those leaving STEM[2]. For example, the Task Force on American Innovation reports that the number of job openings in STEM areas is five times the number of U.S. students graduating in STEM. More specifically, in the area of environmental engineering, the US Bureau of Labor Statistics[3] anticipates that the number of environmental engineering jobs will increase by more than 38% in

the next 10 years and Fortune Magazine puts environmental engineering in the top 20 careers. However, nationally, the number of students studying environmental engineering has not been increasing to meet the coming demand. NSF has noted that the available workforce looms as a limiting factor to the development and deployment of sensor networks required for large environmental observatory systems[4].

Addressing the demand for qualified STEM instructors represents a major national challenge. Several professional organizations have collected data indicating disturbing trends in the nation's STEM teacher workforce. The Committee for Economic Development (CED) finds that almost a third of high school math classes are taught by teachers who did not major or minor in mathematics. According to the National Center for Educational Statistics[5], in 1999-2000 (the most recent year for nation-wide data), 70 percent of the U.S.'s largest urban school districts had vacancies in mathematics, 61 percent had vacancies in biology/life sciences, and 51 percent had vacancies in the physical sciences. Observations collected by the National Council on Teacher Quality indicate that it is extremely unlikely that every state will meet the new federal requirement that there be a "highly qualified teacher" in every classroom in the nation by the end of academic year 2006[6]. .

WATERS Network holds the potential to increase STEM student recruitment and retention by transforming education through research experiences and engaging curricula delivered with effective pedagogies. These experiences and curricula could reach a diverse audience, especially populations that are underrepresented in STEM. WATERS Network will provide professional development for K-12 teachers as well as university faculty. WATERS Network will also play a role in developing strategies for supporting highly qualified instructors who are well-versed both in their content areas and in modern methods for effective teaching.

2.2 What Does WATERS Network Offer K-12 Education?

WATERS Network provides the opportunity for integrating research and education in environmental science and engineering. By providing access to professional communities that are focused on important aspects of environmental quality, students can share and participate in the development of the outputs of these communities. Collaborative networks will provide students (and their instructors) with shared knowledge, real data, and recent research findings. Students will have more effective and more efficient learning because of this access and, over time, many will become full-fledged members of these communities as leading researchers and educators in colleges and universities, K-12 education, government, and industry.

The benefits of WATERS Network to K-12 education are numerous. The following is a partial list of benefits to education that can accrue from WATERS Network:

- Providing real life data for exploration and demonstration by students from K-12 through graduate.
- Training K-12 teachers in environmental science and engineering education.
- Enhancing the relevance and quality of instructional materials.
- Linking educators (and their students) with scientists.
- Providing a basis for learning about environmental policy through simulations.

3.0 WATERS Network Education Goals

The Education Committee held a two-day working session in mid-September 2005 to define strategic goals, identify target populations for environmental education, and select constructs for transforming education.

The Education Committee elected to focus on four strategic goals:

- Bring together educators, scientists, engineers, administrators, and citizens to form a powerful collaborative that will transform the current state of formal and informal education in environmental engineering and hydrologic science.
- Propagate "best practices" in education that are informed by rigorous cognitive and pedagogical research in order to create a diverse, internationally competitive workforce.
- Enable synergistic interactions among scientists and pre-collegiate/collegiate/graduate educators in setting research agendas and distributing results for the benefit of society.
- Provide broadly accessible, state-of-the-art information bases and shared research and education tools.

From these goals, a range of educational reform objectives evolved – covering delivery of instruction, learning outcomes, teacher/instructor training and professional development, and social impacts. The Education Committee selected five target populations that include K-12, Undergraduates, Graduate Students, Industry representatives, and citizens.

The focus of this paper is the K-12 target population (students and teachers). In addition, input on how best to construct a plan so that WATERS Network can transform all aspects of teaching and learning within this context is being sought from the audience. More specifically, the following questions are posed:

- **Curriculum Content –** What types of K-12 curricula will be developed or already exist that could be part of the WATERS Network?
- **Pedagogy –** What K-12 pedagogical approaches will be used, enhanced or transformed in the WATERS Network?
- **Education and Research Inform Each Other –**In what ways can K-12 educators and students work with researchers to develop new knowledge and to disseminate that knowledge?
- **Vertical Collaboration Among Researchers, Educators, and Learners –** How can the WATERS Network increase collaboration between researchers and K-12 students and their teachers**?**
- **Sustainable Professional Development –** What avenues can the WATERS Network provide for the continuous refreshing of the knowledge base of K-12 educators?
- **Leveraging and Networking with Existing Programs –** What are the existing K-12 related programs that can partner with WATERS Network?
- **Technological Support and Enhancement of Learning –** How will the WATERS Network support and enhance learning via technology?

We invite the audience to respond to these questions, which are expanded upon in the following section that elaborates on each of the seven constructs by (1) giving a goal statement, (2) including some of the processes to achieve the goal, and (3) describing some of the expected

outcomes. To further engage the audience and elicit comments, we include two scenarios that encapsulate how the WATERS Network could transform K-12 Education.

4.0 Constructs for Transforming Education

The seven constructs for transforming environmental education are outlined below by describing related goals, the processes for achieving that goals, and example outcomes to illustrate the benefits of pursuing those goals.

4.1 Modernizing Curricula Content

The WATERS Network will be accessible for educators to develop curriculum at all levels including K-12, undergraduate, and graduate. At the K-12 level, WATERS Network curricula will be aligned with primary and secondary educational standards in order to maximize efficiency and effectiveness. For primary and secondary students, heavily used texts (e.g. Prentice Hall - Science Explorer; Holt – Chemistry) will be used to guide development of new curricula and establish links to exisiting curricula and concepts currently offered in classrooms. For primary and secondary students, course projects based on water quality monitoring, assessment, and management will be developed that will be easily updated using WATERS Network summary reports. The availability of summary data at regular intervals will also provide the opportunity to use longitudinal data as a context-based teaching tool.

4.2 Transforming Pedagogy

The project will transform pedagogy for environmental education via a cybercollaboratory infrastructure that allows access to data available from the WATERS Network. The cybercollaboratory will allow for interaction with researchers, educators and students, thus stimulating interest in science, technology, engineering and mathematics (STEM). At the K-12 level, students will use WATERS Network data in problem based learning scenarios that require high level thinking skills, including synthesis and analysis of data. The WATERS Network database will allow examination and comparison of state or regional environmental parameters. Students will use the data to examine and propose solutions to environmental problems. Students will investigate issues that affect them directly, thereby increasing the relevance of their education and research. WATERS Network will create sample environmental problems and issues that students will use for research projects. Tutorials and animations will guide students through the WATERS Network data in their investigations. Depending on student age, ability level, and depth of investigation, they will be encouraged to collect samples in their local area, connecting abstract data obtained from WATERS Network to concrete samples extracted from their local environment.

4.3 Education and Research Inform Each Other

A multidisciplinary integration of research and education will exploit sites with environmental instruments and network information in order to formulate engineering policy options to protect, remediate, and restore stressed environments, and promote sustainable environmental resources, creating a two-way flow of knowledge between research and education. K-12 students and

teachers will be introduced to real-time data for use in classroom research projects. Students will identify local and regional water issues and report this information to WATERS Network researchers. K-12, undergraduate, and graduate students will work in extensive collaborative research teams allowing information flow to and from researchers, educators, and students within WATERS Network. Teams of researchers, students and educators will present workshops on the availability of WATERS Network data for K-graduate research opportunities at regional and national conferences. At the K-12 level, modular curricula will be developed that specifically focus on communicating the scientific and engineering processes used by WATERS Network researchers. Animations or lessons will show how sensors are revolutionizing scientific and engineering research as well as how the data collected by the sensors apply to everyday life and can be used in policy and decision making, emergency management and time critical interagency operations.

4.4 Vertical Collaboration Among Researchers, Educators, and Learners

The CLEANER Project Office and WATERS Network can transform K-12 education by facilitating the vertical collaboration of K-12 educators, undergraduate students, graduate students, faculty, and stakeholders in the community, government, and industry. The goals of vertical collaboration are to (a) enhance environmental science education at all levels, (b) accelerate the exchange of information and ideas between educators and students from K-12 through post-graduate education, and (c) promote the development of relationships between individual educators that will be mutually beneficial. The goals of vertical collaboration will be met by (a) providing forums for interaction among educational groups that currently have minimal contact, (b) creating hands-on and virtual educational activities for multi-level groups, and (c) establishing multi-level collaboration as core components of WATERS Network projects. Further, the cyberinfrastructure of WATERS Network can provide channels of communication among K-12 schools, colleges and universities, research institutions, government agencies, professional societies, and the general public. The WATERS Network will be used for virtual or remote collaboration among universities, K-12 schools, industry, and other community stakeholders. The cyberinfrastructure is uniquely suited to providing a distributed environment for collaboration. Researchers will identify opportunities for K-12 students and other interested stakeholders to participate in research efforts by monitoring a particular dataset. Direct hands-on collaborations between faculty and students at universities will be established with local K-12 students. These collaborations as well as organized activities such as science fairs or career days will expose K-12 students to careers in environmental science and engineering. Conversely, undergraduate and graduate students in science and engineering disciplines can consider careers as K-12 educators.

4.5 Sustainable Professional Development

The WATERS Network seeks to promote continued professional development for students, educators, and researchers all along the educational pipeline. WATERS Network will offer summer research opportunities at WATERS Network facilities for K-12 educators (may be credit-bearing), where they will receive instruction on current environmental research methodologies and state-of-the-art monitoring technologies that emphasize the critical, global role of water research. With support available through WATERS Network, participants will then

develop environmental science and engineering modules for use in their K-12 classrooms. Each year that WATERS Network offers summer research opportunities for K-12 educators, a new cohort of teachers with upgraded research skills, better understanding of current environmental issues, and knowledge of WATERS Network will be back in the classroom. Each teacher's newfound knowledge and enthusiasm will serve as a catalyst for increasing student interest and retention in science and math classes. Additionally, if each summer participant develops one teaching module based on his/her interaction with WATERS Network researchers, the modules could be pilot tested in the originator's classroom, further developed utilizing the expertise of WATERS Network education professionals, cataloged and housed in a WATERS Network web-based resource library, and made available for wide-spread dissemination. In just a few years, this program will develop a significant cadre of teachers who will in turn reach a significant number of K-12 students.

4.6 Leveraging and Networking with Existing Programs

The WATERS Network will lead partnerships to build unique, state-of-the-art educational programs and will join existing programs to transform environmental education within our schools, universities and communities. Forming strong partnerships with other environmental sensor networks will allow the sharing and exchange of data as well as build upon these organizations' successful education and outreach efforts. Such partnerships will lead to the development and dissemination of multi-institutional curricular and teaching approaches that use the resources of the WATERS Network and other modern research tools. WATERS Network will have staff positions that are solely responsible for organizing and linking related resources (e.g. observatories, tools, funding, databases etc.). By identifying and networking with existing funding programs that can be used in education and research, WATERS Network influence will be leveraged.

WATERS Network liaisons will develop partnerships with other environmental observatories, government agencies, and industry members to integrate information from WATERS Network with other available data sources. Governmental agencies such as the National Oceanic and Atmospheric Administration (NOAA), National Aeronautics and Space Administration (NASA), United States Geological Survey (USGS), National Science Foundation (NSF), and Center for Disease Control (CDC), have considerable interest in funding observing networks such as WATERS Network, Integrated Ocean Observing System (IOOS), and National Ecological Observatory Network (NEON). WATERS Network liaison staff would maintain strong communication ties with appropriate organizations so that dissemination of specific information is sent to appropriate audiences including K-12 Educators and students.

4.7 Technological Support and Enhancement of Learning

The Internet has revolutionized the use of and access to real-time data. The effective display of real-time data for non-expert audiences including K-12 students is of critical importance. WATERS Network will create a user friendly interface that will effectively deliver available data in a manner that will be usable by K-12 students. The design of the interface will be an iterative process, incorporating user feedback to increase usability.

To support the use of WATERS Network data in education, the web site will have a user friendly interface, searchable databases, online support, timely updates of data and information, links to the WATERS Network data examples with local and regional interest, a national focus, and concise educational materials that can be customized for specific stakeholder needs. Students and educators will be trained on how to use the CLEANER cyberinfrastructure, utilizing its benefits while incorporating technology in formal and informal educational experiences. The communication tools will be used by students to collaborate with peers and to enhance student-teacher interactions.

The publicly accessible and friendly website will be created to serve various stakeholders including K-12 education. The website format will be the result of an iterative design process, involving research as how best to display data and information. The web site architecture will offer several features including: concise navigation, standardized material, technical support, glossary, search engine, informative tutorials and scenarios, and a virtual teaching assistant.

5.0 A Scenario of WATERS Network Application in K-12 Education

The example Middle School Science Project scenario below provides an illustrative example of ways in which CLEANER and WATERS Network can be used by multiple constituencies to transform education.

> Using a Problem Based Learning approach, 6th grade students work on a regional water quality problem. Students have access to real-time data. They also collect data and add it to the WATERS Network via an interface that 6th grade students can navigate. The students' instructor Ms. Jones has a summer WATERS Network research position with Professor Wilson at the local University. Ms. Jones uses the WATERS Network to communicate with Wilson's research group year round. She keeps up with the most recent findings of the research group as well as discusses her students' data with the research group. At the end of the academic year, the 6th grade students participate in a meeting where they present their data gathering and analyzed results. Also attending the meeting are undergraduates and graduate students from the local university, who present their research as well. Ms. Jones uses part of her summer research position to develop WATERS Network curriculum that is standards based and she publishes it on appropriate sites for easy access by similar instructors. After two summer research positions, she works with other K-12 instructors and Professor Wilson to develop an environmental science and engineering short course for other K-12 educators. This credited short course would provide basic environmental engineering and science knowledge to K-12 instructors as well as develop skills for navigating the WATERS Network so they could learn to access and analyze data, as well as collaborate with others on the WATERS Network.

6.0 Input from K-12 Engineering Education Community

During our interactive poster session, the authors will describe CLEANER and ask for input on these questions:

- How can CLEANER transform K-12 engineering education?
- What funding mechanisms can be used to fund innovative collaborations?

- How can K-12 students and educators be directly involved in CLEANER research?
- What are example projects that can be used as models for educational components of CLEANER?
- What are possible educational experiences K-12 students could have with CLEANER that they do not have now?

The CLEANER Education Committee requires constituent participation in the development of this plan. All K-12 students need to understand the science and engineering issues related to the environment in which they live. Below are a number of methods to contribute to the development of the CLEANER Education Plan.

- To involve the broader community, CLEANER is placing documents and working papers on its web site and in the CLEANER CyberCollaboratory at: http://cleaner.ncsa.uiuc.edu. The CLEANER Education Draft Plan should be available by June 1, 2006 if not sooner.

- To keep apprised of developments related to CLEANER or the CyberCollaboratory, subscribe to the ***CLEANER Quarterly Update***, an electronic newsletter. To **subscribe**, please send an email to majordomo@ncsa.uiuc.edu with the following in the email body: subscribe cleaner Your Name < youremail@somewhere >
(subscribe cleaner John Doe < johndoe@home.com >)

- To provide feedback, consider signing up for the CyberCollaboratory at http://cleaner.ncsa.uiuc.edu. There you will find under COLLABORATION, a Forum for providing feedback on the Education Plan. Or, send an email to eae1@humboldt.edu. By June 1, there will other methods available to provide feedback listed at the CLEANER website[7]. Should you join the CyberCollaboratory, users are invited to provide feedback on the tools and the environment of the CyberCollaboratory. Feedback can be given in the CyberCollaboratory or in CLEANER Town Hall Meetings listed on the CLEANER Project web site[7].

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