Challenges of a Multi-Disciplinary K12 Summer Content Institute

Noah Salzman, Wayne Burleson, Sandra Cruz Pol, Omnia El-Hakim, Christopher Emery, Kevin Kloesel, Kathleen Rubin

University of Massachusetts Amherst/University of Massachusetts Amherst/University of Puerto Rico, Mayagüez/Colorado State University/University of Massachusetts Amherst/ University of Oklahoma/University of Massachusetts Amherst

Abstract

During the summer of 2004, twenty-two science teachers from four states and Puerto Rico came to the University of Massachusetts Amherst for a weeklong content institute to learn about an innovative new approach to severe weather tracking and prediction. Over the course of the week, the teachers learned about electronics, networking, radar, meteorology, and complex engineered systems. They also learned about diversity and grant writing, and gained familiarity with the Massachusetts science frameworks, one of the first state frameworks in the country to include engineering as a core focus. The summer content institute was sponsored by CASA, the National Science Foundation Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere. CASA is developing a distributed network of small, low-cost radars and other sensors designed to observe weather phenomena in the lower part of the atmosphere. This new sensing system will allow for better observation, tracking, and prediction of severe weather events than current weather radar systems. CASA is a complex, multidisciplinary project involving engineering, meteorology, computer science, and sociology. This complexity was reflected in the challenges of teaching content from all of these disciplines in a weeklong summer workshop designed for middle school science teachers. Participants in CASA include four core academic institutions along with dozens of educational and industry partners. Nine people from the four core universities taught the course, which presented another set of challenges. Pre/Post tests and course evaluations indicated that despite the breadth of the course, the participating teachers were able to understand the content and had many ideas how to use the knowledge that they acquired in the content institute in their elementary, middle, and high school classrooms. Collaboration among teachers from different states was encouraged during the week that the teachers were together, and the end of the course saw several exciting plans for cooperative projects in the future. Follow-up activities included developing a CD and web-based archive of the course, and the teachers returning to the University of Massachusetts to present on the projects they developed.

1. Introduction and Context

This paper begins with a brief overview of the CASA project, an overview of summer content institutes, and why we chose to incorporate a content institute into our education and outreach efforts. This is followed by brief descriptions of the daily activities of the content institute and November follow-up session. We summarize the demographics of the participants in the course, and present our assessment techniques and results. We describe the exciting future work that grew out of the institute, and conclude with our observations and lessons learned.

In 2003, the University of Massachusetts Amherst, University of Oklahoma, University of Puerto Rico Mayagüez, and Colorado State University established the Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere (CASA)[1]. The goal of CASA is to develop next-generation technologies for tracking and predicting severe weather events. The current NEXRAD system is suitable for measuring large-scale weather data, but the distance between radar stations makes it unusable for collecting data from the lower atmosphere (<1 km) where the majority of severe weather events like tornadoes and severe thunderstorms that can result in mudslides or flash flooding occur. Each year, these types of storms can cause billions of dollars in damage and take scores of lives. To address this compelling problem, CASA is developing a dense network of small, low-cost radars that can be placed on cell phone towers and rooftops. By increasing our observation and understanding of weather events in the lower atmosphere, CASA will provide more timely and accurate warnings for severe weather events and allow for more efficient responses to weather-related natural disasters.

CASA is funded by a grant from the National Science Foundation (NSF) through their Engineering Research Center (ERC) program. One of NSF's requirements for ERCs is to improve K-12, undergraduate, and graduate engineering education. To improve K-12 teachers' understanding of engineering, CASA decided to offer a summer K-12 Content Institute (KCI).

In 2001, the Massachusetts Department of Education (DOE) published the first state science curriculum framework in the country that requires technology and engineering to be taught at the K-12 level[2]. To help develop in-service teachers' ability to teach engineering, the DOE encouraged the creation of one to two weeklong institutes by universities to teach engineering content to teachers. The teachers could then adapt the content using their own knowledge of age-appropriate pedagogy to lessons that they would teach in their own classroom. Teachers participating in summer content institutes receive professional development points for maintaining their teaching certification. In addition to professional development, CASA and the College of Engineering worked with the School of Education to offer the option (with some additional work on the part of the teachers) to receive three graduate credits through the University of Massachusetts Division of Continuing Education.

CASA is a complex, multi-disciplinary project divided into three research thrusts: sensing, distributing, and predicting. To help the teachers understand how a complex engineered system is comprised of multiple parts, we decided to present the content of the KCI in modules reflecting each of the CASA research thrusts. We presented modules on radar and electronics to help teachers to understand the sensing thrust research, modules on computer networking and interfacing sensors for the distributing thrust, and weather and using weather data for the predicting thrust. Two modules dealt with complex engineering systems, and in addition to the technical modules the teachers also learned about grant writing, diversity issues, and the Massachusetts Science and Technology/Engineering Frameworks to help them learn how to implement the engineering content in their own classrooms.

2. Daily Activities

With the exception of a field trip on Thursday and one evening session, the KCI ran from 8:30 AM to approximately 5 PM and consisted of several modules ranging in length from one-half to three hours. Each day was comprised of modules from the different content areas, to help teachers understand the interconnections between the different disciplines and develop a progressively more complex understanding of CASA.

Sunday Night

<u>Welcome</u>

- Introductions
- Dinner
- Keynote Address by Director of CASA Professor David McLaughlin giving an overview of engineering, the CASA project, and CASA's unique potential for education and outreach

Monday

<u>Pre-test and Syllabus overview</u> (75 minutes) *Chris Emery, Adjunct Lecturer at the University of Massachusetts Amherst and High School Physics Teacher Emeritus*

- Administered a pre-test as required by the Massachusetts Department of Education for all summer institutes to demonstrate learning gains made as a result of the KCI
- Introduced instructors
- Presented an overview of the course including schedule and work expectations

<u>Frameworks</u> (30 minutes) *Chris Emery*

- Introduced teachers to the Massachusetts Science and Technology/Engineering Curriculum Frameworks
- Presented a brief overview of the Engineering Design Process and encouraged the teachers to use this model for understanding the engineering concepts they would learn over the next week

<u>Diversity Case Studies</u> (45 minutes) *Omnia El-Hakim, Professor of Civil Engineering and Assistant Dean for Diversity in the College of Engineering, Colorado State University*

- Presented theoretical case of issues surrounding diversity that may occur in the science classroom

- The teachers were divided into small groups to discuss each of the cases, and then reconvened to discuss how they would handle the cases

<u>Pixels and Voxels</u> (60 minutes) *Kevin Kloesel, Professor of Meteorlogy and Assistant Dean of Academic Affairs, University of Oklahoma*

- Introduced teachers to the importance of resolution in measuring data
- The teachers looked at various pictures, beginning with a very low resolution version of the picture and increasing the resolution until they were able to determine the content of the image
- Illustrated that different resolutions are required for making different measurements. Recognizing that an image was a person required relatively low resolution, but determining the specific person pictured required considerably higher resolution
- Introduced volume pixels, or voxels, a three-dimensional element related to the resolution of a radar

<u>Bits and Bytes</u> (120 minutes) *Chris Emery*

- Presented the binary number system and converting from decimal to binary
- Introduced electronics prototyping using a breadboard (Figure 1)
- The teachers learned about electronics components, circuit assembly, and reading schematics by building a 4 bit counter connected to a 555 timer IC used as a pulse generator driving four LEDs to display the count.

<u>Electronics</u> (120 minutes) *Sandra Cruz Pol, Professor of Electrical Engineering, University of Puerto Rico, Mayagüez*

- Introduced the teachers to analog electronics
- Constructed a variety of circuits, including lighting a light bulb, a simple electromagnet, and a "synthesizer" capable of producing eight different tones

Figure 1: Learning electronics and breadboarding

Figure 2: Scopes and multimeters

Tuesday

<u>Scope</u> (180 minutes) *Chris Emery*

- Learning to use electronics test equipment (Figure 2)
- Using a multimeter to measure voltage and resistance
- Using a scope to measure voltage, period, and frequency
- The teachers performed measurements on the circuits that they had built during the previous day

Networking (60 minutes) *Jim Kurose, Professor of Computer Science, University of Massachusetts Amherst*

- Lecture providing a general introduction to networking
- The Internet
- Communications Protocols
- Pieces of a computer network
- Challenges face by CASA networking radars
- History of computer networks

Interfacing (30 minutes) *Noah Salzman, Research Assistant and Graduate Student in the School of Education, University of Massachusetts Amherst*

- Making measurements using sensors
- Analog to Digital conversion
- Interfacing sensors to a computer

Hydrology (150 Minutes) *Kevin Kloesel*

- The phases of water
- The hydrologic cycle
- Methods of looking at water in the atmosphere (radar, visible satellite imagery, infrared satellite imagery)
- Using ice cream and "Magic Shell" topping to model weather patterns on earth

Complex Engineered Systems (90 Minutes) *Theodore Djaferis, Professor of Electrical and Computer Engineering and Associate Dean of the College of Engineering, University of Massachusetts Amherst*

- Engineers as problem solvers
- Describing engineering problems as systems comprised of inputs, processes, outputs, and feedbacks
- Modeling complex systems
- Illustrating the development of a control system for a toy car and demonstrating how they affect the behavior of the car (Figure 3)

Tuesday Night

Engineering Analysis and Design (120 minutes) *Wayne Burleson, Professor of Electrical and Computer Engineering and Co-director of CASA Education and Outreach*

- Learning about design and engineered systems by "dissecting" technology
- Teachers took apart cell phones, VCRs, computer peripherals, and cordless phone (Figure 4)
- Identified common elements in each of these items (power source, inputs, outputs, feedback)
- Learned to apply theoretical knowledge of engineering to real-world objects

Wednesday

Grant Writing (90 minutes) *Omnia El-Hakim*

- Learning how to write grants
- Types of grants available for K-12 science and technology education

- Teachers assigned to small groups and given the task of writing a simple grant proposal as homework

Radar (120 minutes) *Sandra Cruz Pol*

- What is radar?
- Theory behind radars
- How are radars used in weather prediction and detection
- Shortcoming of modern radar systems
- How CASA will allow for better tracking of severe weather events

Radar Kit (30 minutes) *Noah Salzman*

- Radar applications (air traffic control, police radar, satellite mapping of other planets)
- The Doppler effect
- Demonstration of a speed radar assembled from a kit

MIRSL Tour (30 Minutes)

- Teachers toured the Radar laboratories at the University of Massachusetts
- Spoke with undergraduate and graduate students about the projects that they are working on
- Demonstration of a radar
- Learned about and saw a truck with radar developed by the university used for chasing tornadoes in Oklahoma

Curriculum Project Session (120 minutes)

- Time to work on grant proposals and brainstorm ideas for final projects
- Complete circuit projects from previous modules
- General access to course instructors

Figure 3: Control systems demonstration using a model car

Figure 4: "Dissecting" electronics in the laboratory

Thursday

To give teachers a look at the design, testing, and manufacturing of radar systems in an industry setting, teachers were hosted for a day at Raytheon's radar facility in Tewksbury, MA. They went on tours of the facility, learned about the manufacture and testing of radar equipment, spoke with practicing engineers, and heard two technical presentations from University of Massachusetts alumni working for Raytheon. On the bus trip back to Amherst, the teachers watched the NOVA documentary *Hunt for the Supertwister* on chasing tornadoes in Oklahoma featuring CASA researchers and technology.

Friday

End Users and Distributed Collaborative Adaptive Sensing (DCAS) (30 minutes) *Brenda Philips, CASA Director of Industry, Government, and End-User Partnerships, University of Massachusetts Amherst*

- The importance of addressing the needs of end-users in systems design
- The CASA project's unique approach to providing appropriate data to the people that need it when they need it

Weather Stations (30 minutes) *Kevin Kloesel and Noah Salzman*

- How do personal weather stations work?
- Weather sensors
- Choosing a weather station
- Installation concerns
- Limitations

Using Radar and Weather Data (120 minutes) *Kevin Kloesel*

- How meteorologists use radar data to predict the weather
- Deciphering weather radar imagery (Figure 5)
- Using the Oklahoma Climatological Survey radar visualization software

Revisiting Frameworks (30 minutes) *Chris Emery*

- Adapting the knowledge that teachers have learned to create lessons for their students
- Final project expectations
- Administer Post-test

Project presentations (120 minutes)

- Each of the teachers presented their ideas for their curriculum project
- Received feedback from instructors and peers

Wrap up and goodbye (Figure 6).

- Surveys

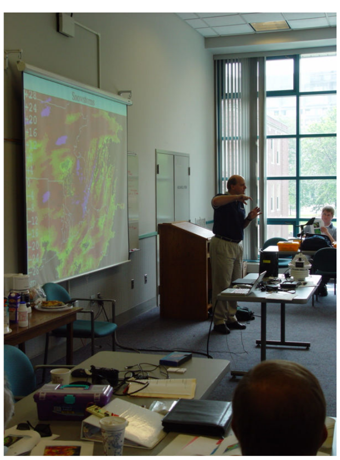

Figure 5: Lecturing on interpreting radar images

Figure 6: Participants in the 2004 KCI

3. Callback

Local teachers returned the University of Massachusetts Amherst campus in November of 2004 to present the curriculum projects that they had developed based on what they had learned during the week they spent at the KCI. Curriculum projects included integrating electronics into science or technology classes, building simple weather instruments, exploring the engineering designing process by designing a space probe, and the Weather RATS project detailed later in the "Future Work" section of this paper. There was a great deal of variation in the projects that the teachers developed in response to what they learned at the KCI. They developed lessons for students from elementary through high school. Some teachers developed lesson plans for one or two days of instruction, others developed projects for their students spanning several weeks or months. Several of their teachers used the knowledge they had gained from the KCI to develop curriculum that addressed weather topics from the Massachusetts curriculum frameworks for Earth Science, and other teachers developed lessons that focused on the engineering design process and aligned with the standards established in the Technology/Engineering curriculum frameworks. In addition to designing projects for their classrooms, teachers taking the class for graduate credit also each read and reviewed a book of their choosing related to weather, electronics, engineering, or other subjects covered during the KCI.

To encourage further dissemination of the content learned during the KCI, a CD-ROM[3] and web-based archive of the course[4] were developed. These include presentations, curriculum materials, and photos from the course, useful links, and videos of some of the lectures given during the KCI.

4. Demographics

Along with encouraging education and outreach innovations, the NSF recognizes the need to promote diversity in engineering, and encourage increased representation of women and minorities in engineering[5]. The NSF requires ERCs to address these issues, and working with teachers can be a very effective and efficient means of encouraging more students to pursue engineering. Several of the teachers that participated in the content institute teach in inner-city school districts and have the potential to reach students that might not otherwise consider engineering as a career.

The participants in the content institute are themselves a very diverse group. The KCI was developed with middle school teachers in mind, and of the twenty-two participants in the KCI, ten teach middle school, six teach high school, four teach elementary school, and two work in other capacities with K-12 students. Sixteen of the teachers are female and six are male. Fifteen participants identify themselves as white/Caucasian, five as Hispanic/Latino, one as Asian, and one as Native American. In addition to gender and racial diversity, the participants also came from four states and Puerto Rico. K-12 teachers are not often presented with the opportunity to meet and interact with their colleagues from other states. The ability to work with teachers from other parts of the country and learn about other states' educational practices and curriculum frameworks proved to be one of the most valuable aspects of the KCI.

5. Assessment

To assess the teachers' learning, comply with assessment requirement for the University of Massachusetts and the Massachusetts Department of Education, and provide us with useful feedback, we administered a pre/post test to the Massachusetts teachers and numerous surveys to the entire group. The results of the pre/post-test, including the results of a Paired t-test, are shown in Table 1. The teachers showed moderate to strong content gain in all of the areas tested, with greater and more statistically significant gains in some areas than in others. This reflects the difficulties in teaching about complex systems like radar. Due to logistical requirements, the pre/post test was written before the content of the KCI was finalized, so some areas that received significant instructional time like weather were not well represented on the test, and some questions on the test received less instructional time than originally intended.

Key Concepts	Questions and Points	Class Average Pre-test Score		Class Average Post-test Score		Class Average Content Gain		t(11)	P
		Points	%	Points	%	Points	%		
Systems	20 Pts	7.8	39%	10.1	50.4%	2.3	11.4%	1.533	0.153
Radar	#1 20 Pts	10.3	51.3%	11.3	56.5%	1.0	5.2%	1.114	0.289
	#2 20 Pts	7.1	35.4%	11.7	58.3%	4.6	22.9%	2.561	0.026
Electronics	#1 10 Pts	4.4	44%	8.0	80%	3.6	36%	5.457	<0.001
	#2 10 Pts	3.3	33%	7.6	76%	4.3	43%	6.888	<0.001
Interfacing	20 Pts	3.8	19%	8.3	41.6%	4.5	22.6%	4.005	0.002

Table 1: Summary of Pre/Post test results and Paired t-Test analysis

Results of the surveys indicated that the teachers felt that the KCI was a good learning experience and would enthusiastically recommend attendance of future institutes to their colleagues. While there were several comments on the volume of material and diversity of content being overwhelming, most teachers did not find this to be a barrier to their learning and appreciated the exposure to a variety of fields. Teachers frequently cited the ability to work with teachers from different states as their most valuable aspect of the KCI. The teachers also appreciate connecting with faculty and staff at the university and having access to these people as a resource.

6. Future Work

One of the most exciting outcomes of the KCI was the inception of the Weather RATS (Research And Tracking Systems) project. During the grant writing module, a randomly assigned group of teachers from across the country came up with a grant proposal to purchase individual weather stations for each of their schools. Students would then compare the data collected at their own school with those collected from other schools to help them understand the interconnectedness of weather patterns and foster relationships with students from a different part of the country. Instead of leaving this as simply an exercise for a module of the KCI, the teachers chose to pursue this concept and write a full-fledged grant proposal to make this project happen. As of the writing of this paper, the grant application has been submitted to the National Science Foundation, and appears likely to be funded as part of the NSF's Research Experience for Teachers program. The operations director of CASA has also agreed to coordinate the project. We are very impressed with the teachers' initiative in pursuing this project, and hope that this initial group of seven teachers will become the basis for a much larger outreach effort.

Planning is underway for future KCIs as well. The next CASA KCI will be held in the summer of 2005 at the University of Puerto Rico, Mayagüez campus. Rotating the campus that hosts the KCI from year to year will enable CASA education and outreach efforts to have a larger, more geographically diverse impact. By involving participants from this past KCI in the 2005 institute, we hope to strengthen and expand the relationships that were established during the 2004 KCI. In addition to the CASA-sponsored KCI, the University of Massachusetts College of Engineering will also offer future summer institutes sponsored by the Massachusetts Department of Education.

7. Conclusions

The summer 2004 KCI was a valuable experience for the participants, and we learned several useful lessons. Nine instructors from four different universities made planning the KCI extremely challenging, but enabled the recruitment of a geographically diverse group of teachers. This ultimately proved to be one of the best aspects of the KCI. The teachers valued the interactions with their peers from other places, which contributed to bonding during the workshop and the formation of long lasting relationships. The WeatherRATS project will continue to foster these relationships among the teachers, and develop new relationships among their students. Developing collaborations and direct communications among geographically diverse groups of students remains rare despite the internet, and fostering these types of interactions is novel and valuable. The travel expenses involved with bringing the teachers from other areas to the campus added significantly to the budget for the workshop, but clearly was a worthwhile expenditure and worth repeating for future content institutes.

Despite planning the course early on to focus on the needs of middle school teachers, we received very positive feedback from the elementary, middle, and high school teachers. By focusing primarily on content and leaving age-appropriate pedagogical decisions mostly to the teacher to work out on their own, we were able to work effectively with a broader group of teachers. Being able to recruit from a larger teacher pool also made finding a sufficient number of participants for the course significantly easier.

We were initially worried that the breadth of content covered in the course would be overwhelming and not result in significant learning from the teachers. Seeing their final projects clearly disproved this theory. The teachers drew their inspiration from many different content areas. Some chose to focus on weather and weather instruments, other teachers more comfortable with teaching about engineering and technology developed new electronics exercises, and the Weather RATS undertook the development of a complex engineered system of their own.

We believe that the KCI was ultimately a success, and will continue to use and build on this model for future education and outreach activities. We look forward to continuing relationships established during the summer, and using these as the foundation for a stronger relationship between CASA and the K-12 community.

References

[1] Engineering Research Center for Collaborative Adaptive Sensing of the Atmosphere. http://www.casa.umass.edu

[2] *Massachusetts Science and Technology/Engineering Frameworks.* (May 2001) http://www.doe.mass.edu/frameworks/current.html

[3] Course CD-ROM development project. http://ripples.cs.umass.edu/casa/

[4] 2004 Summer K-12 Content Institute Web Page. http://www.casa.umass.edu/educationandoutreach/k-12/kci.html

[5] The Congressional Commission on the Advancement of Women and Minorities in Science, Engineering and Technology Development. (September, 2000). *Land of Plenty: Diversity as America's Competitive Edge in Science, Engineering and Technology*. National Science Foundation, Arlington, VA.

Acknowledgement of Support

This work was supported primarily by the Engineering Research Centers Program of the National Science Foundation under NSF Award Number 0313747. Any Opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Science Foundation.

Biographical Information

NOAH SALZMAN

Noah Salzman is a M.Ed. candidate in the School of Education at the University of Massachusetts Amherst. He is a Research Assistant in Education and Outreach for the CASA Engineering Research Center. Prior to pursuing a career in education, he received his B.S. in Engineering from Swarthmore College and worked as an engineer for several years.

WAYNE BURLESON

Wayne Burleson is Associate Professor of Electrical and Computer Engineering at the University of Massachusetts Amherst where he has been since 1990. He is co-director of Education and Outreach for the CASA Engineering Research Center and directs research in several areas of engineering education. He also develops new microelectronic circuits, architectures and design tools in collaboration with the semiconductor industry. He is a member of ACM, ASEE, Sigma Xi, and a senior member of IEEE.

SANDRA CRUZ-POL

Dr. Sandra Cruz-Pol is an Associate Professor in the Electrical and Computer Engineering at the University of Puerto Rico, Mayagüez. Her research interests include Microwave Remote Sensing of the atmosphere and the development of K-12 outreach programs. Dr. Cruz-Pol is involved in two NSF Engineering Research Centers, the NASA Tropical Center for Earth Studies, and recently received the NASA Faculty Award for Research. She is a senior member of the IEEE.

OMNIA EL-HAKIM
Dr. Omnia El-Hakim is the Assistant Dean for Diversity in the College of Engineering, Colorado State University. She is also a Professor of Civil Engineering and the Principal Investigator/Director of several programs: Colorado Alliance for Minority Participation, Women and Minorities in Engineering Program (WMEP), and Colorado PEAKS Alliance for Graduate Education and the Professoriate.

CHRIS EMERY
Chris Emery taught high school physics and electronics for 30 years, and retired in 2002. For the past ten years he has developed and taught a number of physical science courses for both pre- and inservice elementary and middle school teachers at the University of Massachusetts Amherst.

KEVIN KLOESEL
Dr Kevin Kloesel is the Assistant Dean of the College of Geosciences at the University of Oklahoma, and serves at the Director of Outreach for the Oklahoma Climatological Survey. Dr. Kloesel is responsible for providing training and education to K-12 schools and emergency management agencies in Oklahoma for use in decision-making and safety planning.

KATHLEEN RUBIN
Kathleen Rubin, Assistant Dean for Outreach in the College of Engineering at UMass Amherst, has had over fifteen years experience working to develop programs that serve students in engineering. In addition to her role as Assistant Dean, she serves as the Director of Education and Outreach Programs for the engineering research center – CASA (The Center for Collaborative Adaptive Sensing of the Environment), established in September 2003.