J4.10 A PROGRESS REPORT ON THE HANDS-ON INTERDISCIPLINARY LABORATORY PROGRAM: AN APPROACH TO STRENGTHEN THE WEATHER RADAR CURRICULUM AT THE UNIVERSITY OF OKLAHOMA

Mark Yeary[1]*, **Jacqueline Dubois**[2] **Tian Yu**[1],
Robert Palmer[2], **Michael Biggerstaff**[2], **L. Dee Fink**[3], **Carolyn Ahern**[4]
[1] School of Electrical & Computer Engineering – Univ. of Okla., Norman, OK
[2] School of Meteorology – Univ. of Okla., Norman, OK
[3] Instructional Development Program – Univ. of Okla., Norman, OK
[4] Ahern & Associates, Norman, OK

1. Abstract

This paper describes the curriculum details of an on-going NSF DUE project that commenced in the fall 2004 semester at the University of Oklahoma (OU). This three-year project offers a new active-learning and hands-on laboratory program that is interdisciplinary, in which engineering, geoscience, and meteorology students are encouraged to actively participate. The program is intended to generate a unique, interdisciplinary research-oriented learning environment that will train future engineers and meteorologists in the full set of competencies needed to take raw radar data and transform it into meaningful interpretations of weather phenomena. The heart of the program is the development of a set undergraduate courses, offered by the School of Meteorology and the School of Electrical & Computer Engineering, that will provide hands-on laboratory experiences in the special knowledge and skills necessary for organizing real-time weather data, improving and preparing that data for display, and interpreting its meteorological and scientific significance. In addition, programs for middle school students have been generated for the purpose of increasing their interest in science and engineering prior to entering college.

2. Introduction

Undergraduate students are not exposed to enough real-life authentic data. This proposed program leverages on the new National Weather Radar Testbed (NWRT) to develop an interdisciplinary curriculum enhanced by hands-on laboratory exercises. The NWRT is a national resource that combines the talents of engineers and meteorologists for the study of weather. This recently engineered national facility will expose students to a cornucopia of scientific data as the atmosphere is explored.

Severe and hazardous weather such as thunderstorms, downbursts, and tornadoes can take lives in a matter of minutes. In order to improve detection and forecast of such phenomena using radar, one of the key factors is fast scan capability. Conventional weather radars, such as the ubiquitous NEXRAD (Next Generation Radar developed in the 1980's), are severely limited by mechanical scanning. Approximately 175 of these radars are in a national network to provide the bulk of our weather information.

Under the development for weather applications, the electronically steerable beams provided by the phased array radar at the NWRT can overcome these limitations of the current NEXRAD radar. For this reason, the phased array radar was listed by the National Research Council as one of the two candidate technologies to supercede the NEXRAD (NRC 2002). By definition, a phased array radar is one that relies on a two-dimensional array of small antennas. Each antenna has the ability to change its phase characteristics, thus allowing the overall system to collectively locate specific interesting regions of weather. The National Weather Radar Testbed (NWRT) is the nation's first facility dedicated to phased array radar meteorology. Figure 1 depicts the agile, electronically steerable beams, reduced scan times, and increased lead times, while Figure 2 depicts the system components of the new radar. In addition, the demand for students trained in this area will be high as new radar technologies replace the ones designed 20 years ago, and as weather radar usage extends into areas such as homeland security. From the

*Corresponding Author: M. Yeary (yeary@ieee.org), School of Electrical and Computer Engineering, University of Oklahoma, Norman, OK 73019, USA

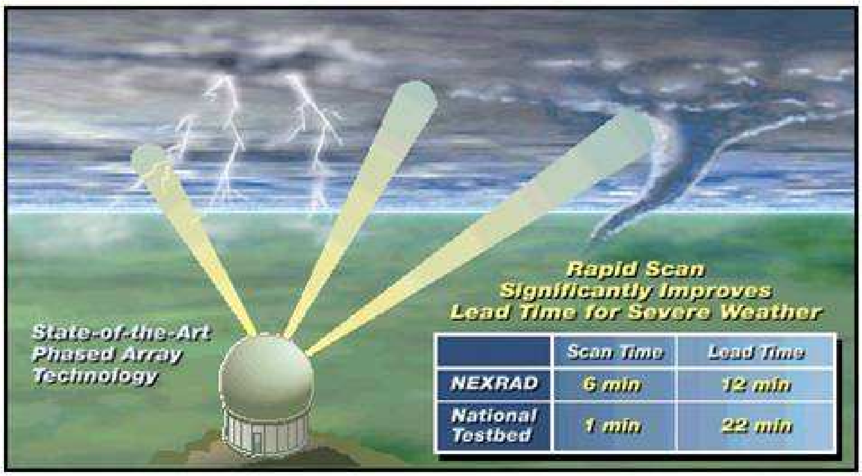

Figure 1: *New Radar – Adaptive Beam Scanning for Improved Detection.*

Federal Aviation Administration's (FAA) perspective, the phased array radar technology developed at the NWRT will be used enhance the safety and capacity of the National Airspace System. Moreover, this project is consistent with one of NOAA's *Mission Goals for the* 21^{st} *Century*: to serve society's needs for weather information (NOAA 2003).

Long-term warnings have improved greatly over the last five years and are now being used for critical decision making (NRC 1999). Further improvements are being aimed at providing longer warning lead times before severe weather events, better quantification of forecast uncertainties in hurricanes and floods, and tools for integrating probabilistic forecasts with other data sets. Many other industries, groups, and individuals use, or could use, weather information. For example, the construction industry uses weather information to schedule specific activities and to purchase materials. Fisheries managers use weather information to manage fleet operations and monitor fish stocks. The recreation industry uses weather information in a variety of ways ranging from issuing avalanche warnings, backcountry conditions, and boating conditions to managing snowmaking operations for skiing. The legal industry uses certified weather and climate information in court cases. K-12 teachers use weather data to develop math and engineering skills in their students, which is essential for the future (NSTC 2000; NCMST 2000; Camp 1997). The list of potential uses is long and growing longer as the accuracy and reliability of weather forecasting improve and the portfolio of weather services offered to the public grows (NRC 1999).

Following the classic Boyer Report, it is very important that no gap exists between teaching and research (Boyer 2002). In addition, faculty members who creatively combine teaching with research are essential to the improvement of undergraduate education (Moskal 2001; Jenkins 2003). Phased array technology is currently being explored at OU and the NSSL, and it will help forecasters of the future provide earlier warnings for tornadoes and other types of severe weather (NSSL 2003). The proposed laboratory/teaching program will provide abundant opportunities for individuals may concurrently assume responsibilities as researchers, educators, and students. The NWRT will facilitate joint efforts that infuse education with the excitement of discovery and enrich research through the diversity of learning perspectives.

3. Approach

Integrated Curriculum and Science Plan: The laboratory modules that accompany the proposed following suite of courses are oriented around the adaptation of a nationally known radar program at Colorado State University (CSU). The CSU-CHILL radar facility is funded by the National Science Foundation and the State of Colorado for the purpose of supporting the atmospheric research community by providing data and evaluating experimental techniques in remote sensing of the atmosphere (`http://chill.colostate.edu`). Carried further, their Virtual CHILL (VCHILL) concept at the CSU radar facility allows remotely located users to access realtime displays and control the operation of the radar *over the Internet*. Thus, the

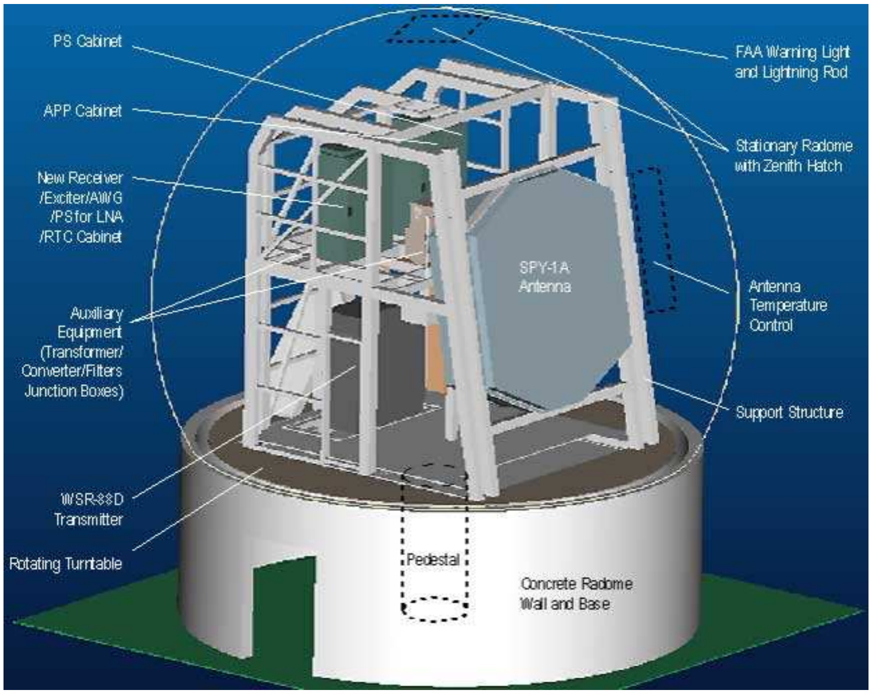

Figure 2: *Face of the SPY-1 phased array radar inside its dome – like a fly's eye, it has approximately 4000 sub-antenna elements that comprise its octagonal array.*

goal of the VCHILL initiative is to provide the educational experience of polarimetric radar at a remote location, without compromising the features of an on-site radar console.

Thus, to complete the cycle of innovation, whose annulus begins with the pioneering work at CSU, extending through the state-of-the-art radar facility in Norman, Oklahoma – this project offers the development of a revolutionary laboratory and coursework curriculum that coincides with the interdisciplinary development and integration of the School of Electrical and Computer Engineering and the School of Meteorology. Several courses will be developed and each course will be cross listed within the two departments. Cross listing will strengthen the bonds of this collaborative effort and welcoming/retaining students (Kenimer 2002). The program is carefully tailored to fit within the current degree plans of both schools. A sample of course offerings are as follows; each of which will be supported by specific laboratory modules.

Radar Meteorology. An established course (updated with new laboratory modules) that develops the quantitative relationships between a radar and its target – *i.e.*, interpretation of the data. It is a senior level course and is cross listed in both schools.

Weather Doppler Radar Signal Processing. A new course (with additional laboratory modules) that concentrates on the radar equation, time domain algorithms, and spectral analysis. It is a senior level course and is cross listed in both schools.

Radar Engineering. A new course (with additional laboratory modules) that concentrates on the radar equation, time domain algorithms, and spectral analysis. It is a senior level course and is cross listed in both schools.

Weather Radar Theory and Practice. A new course (with additional laboratory modules) that concentrates on the radar equation, time domain algorithms, and spectral analysis. It is a senior level course and is cross listed in both schools.

Adaptive Digital Signal and Array Processing. A new 3 credit course (with laboratory modules) devoted to the theory of adaptive algorithms for the discovery of interesting weather targets and for the development of adaptive beamforming techniques. It is offered as a senior level and graduate level course.

Hands-on Laboratory Modules: Within the sequence of courses, the learning of scientific phenomena, such as interesting atmospheric events, is greatly enhanced when students are allowed to make measurements and construct mathematical models that govern their behavior [13]. Several teamwork-oriented laboratory modules will be integrated into *each* of the four courses. These modules will be organized around four themes: 1.) *data collection:* developing different scanning patterns, 2.) *data processing:* computing and enhanced algorithms to extract weather information from the raw radar data, 3.) *data display:* placing the composite weather information on a user-friendly computer display, 4.) *data interpretation:* scientific understanding and discovery of the displayed data – this includes the locations and dynamics of storms, precipitation, tornados, downbursts, and the like. Each of the four items complement and build upon one another – thus solidifying the interaction between the courses. These hands-on laboratory modules are similar to the CSU experiments (Chandrasekar 2001; Gojara 2001; Bringi 1997).

Undergraduate Peer Teachers: We define a *peer teacher* to be someone who: 1.) is a very energetic and motivated student that will serve as a young teaching assistant, 2.) is a member of our engineering research program and radar curriculum, and 3.) is a diverse undergraduate student. The judicious use of peer teachers has been shown to be a highly effective means to motivate and retain undergraduates in engineering (Morgan 2002; Caso 2002; Garcia 1998). The peer teachers will have three primary duties: 1.) assist the instructor in the class/laboratory during periods of team-work activity, 2.) host tutoring sessions for fellow students outside of class/laboratory time, and 3.) assist with K-12 outreach (described later). Since the peer teachers are close in age to the students and highly familiar with NWRT's research plan, they will be in a position to add significant value to the integrated program.

The courses/laboratory modules supported by this project will teach students the knowledge, skills and interest necessary to transform radar data into meaningful interpretations of weather, based on information displays generated by the students themselves. Activities are included that will 1.) increase the number of K-12 students coming to college with an interest in weather radar and 2.) enable other universities to easily adopt similar programs. The evaluation plan is designed to assess how well the courses and other activities achieve their intended purposes (Angelo 1993; Bransford 2000; Bloom 1971; Fink 2003). This will involve the development of questionnaires, assessment instruments, and interview protocols for each project goal.

4. Teaching Assessment

Students in the courses offered in the spring of 2005 were surveyed to provide quantitative and qualitative course evaluations through ranked responses and open-ended questions, respectively. The assessment tools were developed in cooperation with professionals from the Instructional Development Program on campus. For the ranked response sections, respondents indicated how successful the course was in meeting specific objectives according to an integer scale from 1 (low success) to 5 (high success).

a. *Radar Meteorology*
METR 4623 (*undergraduate*), **5613** (*graduate*) taught simultaneously: The purpose of this class was to develop for the students quantitative relationships between the physical characteristics of a target illuminated by a radar pulse and the quantities measured by weather radar. From opinions on the surveys, students left the course with an understanding of radar theory and application. Students recognized and appreciated that the material presented was valuable and applicable in real-life situations. The survey results are as follows:

Course Objectives:

- Students in both the undergraduate and graduate course believed that they understood the strengths and limitations of radar, proven by average ratings 4.4 and 4.8, respectively.
- With an average rating of 4.25, students believed that they were able to interpret radar date, the second course goal.
- Students believed that the third goal (using Doppler radar to address scientific problems and new situations) was only somewhat accomplished, with average graduate and undergraduate rankings of 3.7 and 3.9, respectively.

Course Activities:

- Students believed that lectures clarified the course concepts in addition to teaching them problem-solving skills.
- While students felt that they applied their knowledge to real-life situations using the lab exercises, they agreed that knowing the answers to lab questions would have been beneficial.
- Students agreed, with rankings of 4.3 and 4.1, that homework assignments prepared them for exams.

Midnight Labs:

- 23 of 33 undergraduates and 10 of 18 graduates participated in these experiments held at night.
- While some students felt that the lab should be offered at an alternate time, students agreed (with an average score of 4.2) that the midnight lab allowed them to apply concepts learned in the classroom and recognize how radar is useful in understanding atmospheric phenomena.
- Because they enjoyed using the mobile radar, students believe that hands-on activities are critical and the use of actual radar data in the classroom should be expanded.

b. *Weather Doppler Radar Signal Processing*
ECE 5283/4973: The purpose of this new class was to teach students about the acquisition, processing, and interpretation of weather Doppler radar signals.

Course Objectives:

- Most students agreed, with an average rating of 4.6, that this course helped them understand the acquisition process of weather data.
- Students comprehended the statistical properties of weather signals and the basic processing techniques, with average ratings of 4.1 and 4.6 respectively.
- This course taught students how to accommodate the limitations of radar.

Course Activities and Projects:

- Students were in nearly unanimous support of the field trip to the National Severe Storms Laboratory.
- Team teaching (ranked 3.8) and the availability of online course material (ranked 4.0) were both viewed favorably by students.
- Students enjoyed the first three labs in which they simulated weather signals, comparatively analyzed ground clutter, and verified weather signal statistics.

General Comments:

- Students were impressed with the broad range of topics covered by this course. They were fascinated with radar and enjoyed learning how radar works.

c. *Introduction to Meteorology I*
The purpose of the weather radar unit within the Introduction to Meteorology I class was to introduce students to the types and limitations of radar used in atmospheric studies. This teaching module was introduced into this sophomore level course to inform students about the operation of weather radars and to encourage enrollment into other radar courses – thus making a nice point of entry into the new curriculum.

Course Objectives :

- While many students felt that radar hardware was complicated, they indicated that they understood the major parts of a radar system, with an average ranking of 3.9.
- According to the students surveyed, this course provided a sound introduction to weather radar. (average ranking 4.6)
- Students considered the homework assignments helpful in reinforcing concepts presented in class.

General Comments:

- Students consider radar “very important” in meteorology and felt that the weather radar unit gave them a thorough introduction to the uses and limitations of radar.

5. Summer 2005 Outreach

During the summer of 2005, the Oklahoma Climatological Survey partnered with a team of professors and students to develop several teaching modules for K-12 teachers. The goal was to spark students’ interest in science and encourage college enrollment in the areas of math, science, and engineering by presenting educational materials concerning weather radar. OCS facilitated the EarthStorm Summer Institute on 18 July 2005 through 22 July 2005. Approximately 48 teachers for 6th through 8th grade signed up to attend.

EarthStorm was a one-week seminar that provided K-12 teachers in Oklahoma the knowledge and materials necessary to integrate real-time weather data into classroom activities. Participants in EarthStorm received appropriate materials and instruction to present a thorough curriculum and to complete hands-on activities in their own classrooms. EarthStorm grants schools access to current weather data from the Oklahoma Mesonet, the Atmospheric radiation Measurement Program, and the National Weather Service network of WSR-88D radars. EarthStorm trained instructors to access, implement, and analyze data. Experiments presented involved multiple disciplines including meteorology, climatology, computer graphics, telecommunications, geography, and agriculture. Teachers from urban, suburban, and rural school districts throughout Oklahoma participated in EarthStorm. As a result of their participation, schools can enhance their classrooms through access to sophisticated equipment and weather data that is not traditionally available. Gifted students as well as high-need students alike will collect and analyze weather data upon implementation of EarthStorm materials.

a. *EarthStorm Assessment*

Teachers participating in EarthStorm completed project evaluations describing what they learned from the project, the most and least helpful aspects, further information they would like to learn, concerns and suggestions, and appropriate changes.

Information learned: Respondents were overwhelmed by the wealth of knowledge they gained from EarthStorm 2005. Respondents indicated having a new understanding of the intricacies involved in weather; participants did not previously understand the number of variables affecting weather. In addition, participants valued the information presented concerning radar data analysis and interpretation. EarthStorm presented the past, present, and future of weather radar as well as potential applications of radar data. Respondents expressed appreciation for the thorough discussion of technical applications including WeatherScope, the EarthStorm web page, and online radar data.

Helpful aspects: EarthStorm participants found the thorough lesson plans and step-by-step instruction for classroom activities to be very useful. Several participants identified the comprehensive WeatherScope tutorial as the most useful aspect of EarthStorm. A majority of respondents identified detailed computer instruction as the most helpful feature. In order to improve EarthStorm content, survey respondents were asked to share the least helpful parts of EarthStorm. Several teachers believed that the portion of EarthStorm concerning inquiry teaching was unnecessary.

Further learning: EarthStorm generated an interest in gaining additional knowledge about weather and weather radar. Several teachers expressed curiosity about the fundamental aspects of weather; teachers wanted to learn more about basic weather elements, climate, forecasting, severe weather, tornadoes, and hurricanes. While respondents appreciated technical aspects of EarthStorm, they wanted more material covering simplified meteorology.

Appreciation, concerns, suggestions: Teachers expressed overwhelming appreciation of the friendly, knowledgeable, professional, and helpful staff. The variety of speakers provided a well-rounded week. Most respondents enjoyed the NWS tour and weather balloon launch. The EarthStorm participants were thankful for the impressive computer lab used throughout the project; participants could work individually on computer-based labs. Teachers appreciated the staff and service at Sooner Hotel. It was clear that participants were impressed with EarthStorm material, presentation, organization, and staff.

6. Conclusions

There are two special features in this research-oriented teaching program: (1) it will be the only program in the country with a full and equal collaboration between the School of Meteorology and the School of Electrical & Computer Engineering for the purpose of providing an integrated curriculum on weather radar, and (2) it will have access to weather data from the recently constructed National Weather Radar Testbed (NWRT) at the University of Oklahoma. Students will have a unique opportunity to take advantage of the weather data derived from this new phased array radar, specifically suited for weather observations. In essence, the project will decentralize this major research facility and make it available at zero-cost to a wide array of students across the nation. By placing the radar's data on a website, a diverse population of students will be able to use this state-of-the-art facility. To bolster the undergraduate education aspects of this project, a small, diverse team of six undergraduate peer teachers will be employed – differing from a limited number traditional graduate student(s) that will assist with the laboratory experiments. The judicious use of peer teachers has been shown to be a highly effective means to motivate and retain undergraduates. The principal investigators will partner with the Oklahoma Climatological Survey (OCS) to adapt and implement project materials directly to K-12 students and teachers via the OCS Earth-Storm outreach program. Finally, an assessment plan has been devised by an expert at OU who specializes in learning and course development. Moreover, assessment tools will be developed to identify at-risk students who will receive enhanced training.

Acknowledgement Partial support for this work was provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement program under grant 0410564. Eight participants contributed to the installation of the new radar in Norman, OK. These are: NOAA's National Severe Storms Laboratory and National Weather Service Radar Operations Center, Lockheed Martin, U.S. Navy, University of Oklahoma's School of Meteorology and School of Electrical and Computer Engineering, Oklahoma State Regents for Higher Education, the Federal Aviation Administration, and Basic Commerce and Industries. We also wish to thank the Oklahoma Climatological Survey (OCS). The OCS was established in 1980 to provide climatological services to the people of Oklahoma, conduct research on the impacts of climate on human activities, and serve as a support facility for the State Climatologist. The OCS is a research unit of the College of Geosciences at the University of Oklahoma.

References

[NRC 2002] National Research Council Committee on Weather Technology Beyond NEXRAD, 2002: *Weather Technology Beyond NEXRAD*. Washington, DC: National Academy Press.

[NOAA 2003] National Oceanic and Atmospheric Admin., *New Priorities of the 21st Century*, www.noaa.gov, pp. 1-23. March, 2003.

[NRC 1999] National Research Council, *Making Climate Forecasts*. Washington, DC: National Academy Press, 1999.

[NSTC 2000] National Science and Technology Council, *Ensuring a Strong U.S. Scientific Technical and Engineering Workforce in the 21st Century*, Washington, DC: Office of Science and Technology Policy. 2000.

[NCMST 2000] National Commission on Mathematics and Science Teaching for the 21st Century, *Before It's Too Late*, Washington, DC: U.S. Department of Education. 2000. Available at http://www.ed.gov/americacounts/glenn

[Camp 1997] T. Camp, "The Incredible Shrinking Pipeline," *Communications of the ACM*, vol. 40, no. 10, pp. 103-110, 1997.

[Boyer 2002] Boyer Commission on Educating Undergraduates in the Research University. Shirley Strum Kenny, Chair, University of Stony Brook. *Reinventing Undergraduate Education: Three Years After the Boyer Report*, 2002.

[Moskal 2001] B. Moskal, D. Lasich, N. Middleton, "Improving the Retention of Women and Minorities through Research Experience, Mentoring and Financial Assistance," *Proceedings of the American Society for Engineering Education Annual Conference*, session 1392, pp. 1-11, 2001.

[Jenkins 2003] A. Jenkins, R. Breen, R. Lindsay, and A. Brew, *Reshaping Teaching in Higher Education : Linking Teaching and Research*, London, Kogan Page, and Educational Development Association. Distributed by Stylus in the USA. 2003.

[NSSL 2003] www.nssl.ou.gov

[Kenimer 2002] A. Kenimer, J. Morgan, "Building Community through Clustered Courses," *Proceedings of the ASEE Annual Conference*, 2002.

[Nelson 1999] G. Nelson, "Science literacy for all in the 21st century," *Educational Leadership,* vol. 57, no. 2, October, 1999.

[Chandrasekar 2001] V. Chandrasekar, D. Brunkow, A. Jayasumana, S. Bolen, "Development of a virtual radar environment" *International Geoscience and Remote Sensing Symposium*, vol. 6, pp. 2599-2601. July, 2001.

[Gojara 2001] K. Gojara, S. Bolen, V. Chandrasekar, "Undergraduate research on remote sensing at Colorado State University," *International Geoscience and Remote Sensing Symposium*, vol. 6, pp. 2757-2758. July, 2001.

[Bringi 1997] V. Bringi and V. Chandrasekar, "The CSU-CHILL fully polarimetric s-band weather radar facility: Providing research experience to undergraduates," *International Geoscience and Remote Sensing Symposium*, vol. 2, pp. 954-956. July, 1997.

[Morgan 2002] J. Morgan, A. Kenimer, T. Kohutek, J. Rinehart, M. Lee, "Peer Teacher From an Instructor's Perspective," *Proceedings of the Frontiers in Education Conference*, 2002.

[Caso 2002] R. Caso, *et. al.*, “A Systemic Change Model in Engineering Education and its Relevance for Women” *Proceedings of the ASEE Annual Conference*, 2002.

[Garcia 1998] A. Garcia, G. Keller, A. McHenry, F. Begay, “Enhancing Underrepresented Student Opportunities Through Faculty Mentoring and Peer Interactions,” *Proceedings of the ASEE Annual Conference*, 1998.

[Angelo 1993] T. Angelo and P. Cross, *Classroom Assessment Techniques*, 2nd ed., San Francisco, CA: Jossey-Bass, 1993.

[Bransford 2000] J. Bransford, A. Brown, and R. Cocking, Editors *How People Learn: brain, mind, experience, and school*, Washington, DC: National Academy Press, 2000.

[Bloom 1971] B. Bloom, J. Hastings, and G. Madaus, *Handbook of Formative and Summative Evaluation of Student Learning*, New York: McGraw-Hill, 1971.

[Fink 2003] L. Fink, *Creating Significant Learning Experiences*, San Francisco, CA: Jossey-Bass, 2003.