2006-2241: "CAMP CONCRETE" – AN EXPERIMENT IN UNDERGRADUATE RESEARCH

Chris Ramseyer, University of Oklahoma

Ph.D., P.E. is an assitant professor at the School of CEES at OU. He has spent 5 years as a structural steel designer. His research interests include cold formed steel, structural stability, bridge issues and concrete materials. His educational interests include undergraduate research in engineering and alternative learning paradigms. He received the OU-CEES George W. Tauxe Outstanding Professor Award in 2004.

Beth Brueggen, University of Oklahoma

Earned her B.S. and M.S. in the School of Civil Engineering and Environmental Science at the University of Oklahoma. During the summer of 2004 she was a post-graduate research assistant. She has earned the O.H. Ammann Fellowship twice, and received an NSF Graduate Research Fellowship while at the University of Oklahoma. She is presently working on her Ph.D. at the University of Minnesota.

"Camp Concrete" – An Experiment in Undergraduate Research

Abstract:

The students who participated in the inaugural 2004 program coined the name "Camp Concrete" after they cast and tested more than 50,000 pounds of concrete specimens at Donald G. Fears Structural Engineering Lab at the University of Oklahoma. The goal of Camp Concrete is to involve undergraduate students in high-quality cutting edge civil engineering research. Research projects are selected to address immediate needs of local businesses and agencies, such as the Oklahoma Department of Transportation. The students take ownership of their projects, which increases the quality of their experience and encourages them to pursue graduate study. This program is shown to improve student retention and in many cases this research will become a student's M.S. thesis. Three projects were completed in 2004 which led to three presentations at the semi-annual American Concrete Institute (ACI) convention and three journal papers in progress.

Overview:

Camp Concrete was not developed as an experiment in undergraduate research. It developed in response to the unique constraints and opportunities experienced by the structural engineering group at the University of Oklahoma (OU), Department of Civil Engineering and Environmental Science (CEES). It became apparent that the research experience, developed out of necessity, was beneficial as an undergraduate research experience and has became a key tool for recruiting students to our graduate program. It also proved to be an effective method for increasing the amount of high-quality research completed in our laboratory.

Background:

The structural engineering group at OU lost all five faculty members between mid 1999 and late 2000. As new faculty members were hired, there was a period of time during which very little research was conducted at Fears Structural Engineering Laboratory. Between 2001 and 2003, only two students completed thesis-based Masters of Science degrees with a structural engineering focus. While the undergraduate program in structural engineering had been relatively unaffected, the graduate program was virtually non-existent.

The new faculty realized that there was a pressing need to generate excitement about structural engineering at OU and to fill Fears Lab with research activity. Kyran Mish, the new senior structural faculty member, suggested that the structural group should be considered as similar to a start-up company during the rebuilding period. By this he meant that risks often avoided in academia should be realized as opportunities to a start-up. To support this idea materially, he plowed the majority of his start up funding into renovating the office space at Fears Lab.

Risks that became acceptable included:

- Encouraging a large number of undergraduate students to do significant, graduate-level research that could ultimately be used for a MS thesis. This encouraged undergraduate students to consider graduate study and demonstrated a commitment to renewing the

graduate program. Two of the authors had both taken advantage of an accelerated BS/MS program at OU and completed their MS research before completing their BS coursework, so this was not the first time undergraduate students had done significant research. However, it was the first time a large group of undergraduate students was approached about pursuing this option.

- Focusing on obtaining multiple relatively small grants from local funding sources, such as the Oklahoma Department of Transportation and local industry, rather than a single large grant from sources such as NSF. These smaller grants are less spectacular and provide limited support increasing the risk of insufficient research depth or continuity but the risk of receiving no funding whatsoever was reduced.
- Pursuing research that would be immediately useful to local industry and infrastructure. While less funding is generally available for applied research than for basic research, addressing immediate needs helped to generate excitement from the local community and to address the impression that the OU structures program was dead. It also allowed younger students to see the effects of their efforts quickly.

These risks were accompanied by significant opportunities, including nearly unlimited access to Fears Structural Engineering Laboratory, a fairly large undergraduate student body wanting to focus on structural engineering, and a very understanding administration. Accepting these risks and taking advantage of these opportunities led to adopting an unusual solution.

Development:

In 2003, the principle author was granted three small research contracts from the Oklahoma Department of Transportation (ODOT). These three projects addressed immediate needs identified by engineers at ODOT. The three projects included a study of the effects of corrosion on pre-stressed bridge girders, very early strength (VES) concrete for bridge decks and the effects of fibers in concrete for bridge decks.

The projects were to start in October of 2003 and be completed by October of 2004. Due to a lack of current experience executing contracts between OU and ODOT, they were not signed until February of 2004. For appropriation reasons, the completion dates could not be moved. The research timeline was reduced to only seven months, and it was estimated that obtaining the necessary materials to begin the research would take at least one month. Because the spring semester had already begun, hiring students to help complete the projects was difficult. It was decided to forego hiring of student research assistants until the end of the spring semester.

While only four months would remain to complete the work, students are generally able to spend much more time doing research during the summer, when they do not have as many class requirements. Rather than supporting three students for a full year, twelve students were supported for the three month period between the end of the spring semester and the beginning of the fall semester. The hiring of more students met many of our short term goals for Fears Lab. It meant we would be getting as many undergraduate students as possible involved in research plus it would generate excitement about structural engineering at OU, filling Fears Lab with research activity

In order to find twelve willing undergraduate students, the civil engineering student body was approached early in March. It was critical to approach students during the time when they were looking for summer employment or internships, and not after most were already hired. An email was sent to the entire student body advertising the opportunity, and a small presentation was made in several classes. The principle author was teaching both Civil Engineering Materials, with sophomore and junior students, and Steel Design, with senior students, which brought him into direct contact with many undergraduate students.

Building a sense of community and avoiding feelings of drudgery were critical to the success of this endeavor. Besides helping to build community between the students, it was important that the leader was able to get to know each student individually. This helped to avoid students feeling that they were slave labor. From experience it was known that the lab would be extremely hot and humid during most of the summer. A social component was vital. It was decided that providing lunch, cooked and served by the faculty advisor, on Fridays might meet this need. While the menu was never complicated, pizza and hamburgers were never served. Figure 1 shows the students eating kabobs during the first Friday lunch of the summer. It was hoped that Friday lunch would help build the sense of community quickly and also that it would also send the message that the principle investigator was committed to and involved in both the research and the development of the students.

Figure 1 – Friday lunch in the conference room

Learning Skills Emphasized:

At any university, the undergraduate student can be considered the primary product. With this in mind, our institution's long term success or failure will be gauged by the students we graduate. After studying the impact of departmental research and teaching climates on undergraduate growth, Volkwein and Carbone at SUNY-Albany have concluded that "students in exclusively research-oriented departments report more growth than those in exclusively teaching-oriented departments," but that departments which exhibit "…a combination of strong research and strong teaching…" make the most "…significant contributions to undergraduate intellectual growth."[1] Camp Concrete provides a research oriented component for our undergraduates. Time will determine if this can be considered a "strong research component".

Schoenfeld and Magnan[2] conclude that a typical "pure" research standard includes:

- To conduct research with appropriate methodological techniques and vigor;
- To conceptualize and theorize in an original way, with logical and mathematical formulation as appropriate;
- To synthesize, criticize, and clarify extant knowledge and research;

- To innovate in the collection or analysis of empirical data;
- To relate research to the solution of practical problems of individuals, groups, organizations, or societies.

Camp Concrete involved all five points of "pure" research as defined above.

Implementation:

Due to the time constraints involved in this research program, the research topic and the specific objectives were developed before the students were hired. There was a strong need to avoid wasted time at the beginning of the summer. Any delay at the beginning of the summer could translate into a perception on the research assistants' part that either time was not critical or that a failure to complete the work by summer's end could be blamed on a lack of preparation by the principle investigator. Neither of these outcomes was considered appropriate. Materials were ready to complete improvements to the laboratory work area to increase efficiency, and all materials and testing equipment required for the first eight weeks were available on the first day of Camp Concrete.

Figure 2 – New shelves in use

To further instill a sense of mission and urgency, each day of the first week was pre-planned with group meetings and work. The meeting topics included an orientation to the summer's goals, introduction to the research topics and instruction on completing literature reviews, creating a test matrix, planning work, keeping records of the research in a lab book and writing a research report. The work sessions included initial cleaning and organization of their work area, rebuilding several pieces of equipment, removing the old racking system from the environmental chamber and replacing it with a more efficient rack system built from raw materials and modifying a surplus table to serve as a batching table. Figure 2 shows the new shelves in use. Having the students clean and improve their work space before starting helped them to take ownership of the area and encouraged them to maintain the area in an acceptable manner. The students did an excellent job of maintaining the space and monitoring each others behavior. The lab management did not have to hold a special "lab cleaning day" during the entire summer.

During orientation on the first day of Camp Concrete, the summer research assistants learned what the research topics were. They were each given copies of the research proposals and asked to list their preferences. By the third day of Camp Concrete, the students were divided into five teams with specific goals. Each team had a leader and one or more team members. None of the teams was large enough to be self sufficient. They all needed to trade labor between each other to complete the more physically challenging portions of the research.

By the end of the first week, the work area was ready and each team had developed a test matrix, which the principle investigator reviewed. By the beginning of the second week, research was in

progress. Each member was required to bring in copies of two research papers relevant their research weekly for the first eight weeks. By the middle of the summer, each team's notebook included 25 to 40 papers. The students quickly became familiar with the latest research on their topics.

Due to the nature of the research, a rigid work schedule was not possible. The teams were sharing a limited work space. Four of the teams were working on concrete material studies and needed to batch concrete, but Fears Lab only has one small batch mixer. For most of the summer, batching began at six in the morning and extended until mid-afternoon. Specimen testing often ran into the evening, and material preparation often went on until after midnight. No single student was in the lab during the entire 20 hour work day, but at any given time several students could be found working. The students created a work schedule that would have seemed draconian if the principle investigator had suggested it. Several students also took an intersession or summer session class during part of the summer, and coordinated their working hours around time spent in class and studying.

During the first four weeks of the summer, the teams required a lot of help and direction. The principle investigator was careful to suggest courses of action but not to dictate a work regime. This allowed the research assistants to rapidly gain control of the day to day operation of their research. At end of the summer each team gave a presentation of their work and turned in a completed research report.

Lessons Learned:

Difficulties were encountered during the twelve weeks of Camp Concrete, but many lessons were learned from them.

- In general, the student teams were extremely productive. More than 50,000 pounds of concrete specimens were cast and broken over the 15-week period. The research material on hand at the start of Camp Concrete did not last eight weeks as expected. By week four, the principle investigator was scrambling to find another 26 cubic yards of aggregate and 15 drums of portland cement. Brief non-productive periods occurred during the summer while the teams were waiting for materials. These surprises could be avoided in the future by creating a simple inventory management system.
- Not all teams integrated well. One research assistant was not motivated to help with the labor of batching. There was a definite personality clash between this person and the team leader. They were not fighting, but rather they were ignoring each other. After discussing with the individuals involved, the principle investigator moved this team member to a new team. The team member worked much better with the new leader.
- One of the teams had some trouble starting their research. This team was the only team with a graduate student as a team leader. The graduate student did not feel a sense of urgency to complete the work during the summer, and neither team member wanted to start any research until they fully understood the expected outcome. They were not used to a problem with multiple possible solutions. Several meetings with the principle investigator were required to help these students understand that a "failed" test was acceptable so that they could move forward.

- Students want ownership of their work. By allowing the students to determine their own work schedule and to create their own test matrices, the students achieved much more than anticipated. The students far exceeded the principle investigator's expectations for both breadth and depth of study. Several groups initiated investigations into possible solutions that were not in the initial proposals or test matrices. Their initial pilot studies have led to additional research funding.
- Failure is not to be avoided, and the principle investigator must resist the temptation to micro-manage undergraduate students out of fear that they are incapable. One of the most productive teams discovered at mid-summer that all of their previous work was flawed. They identified the flaw and the action required to address it with only minimal guidance. They decided on their own to redo all of their previous work. Within four weeks, they had recovered and were back on their schedule.
- Community building is extremely important. The Friday lunches provided by the principle investigator were a much needed social event every week. After the first week, this became the only time all of the students were present at once. By the end of the summer, several students had volunteered to show off their own cooking skills to each other. In addition to community building the lunches also became an excellent avenue for the principle investigator to assess the progress of the teams without creating any undue pressure. It also became a good method for the research assistants to address issues with one another and the principle investigator.
- Undergraduate students are capable of both performing laboratory research and reporting it. The teams wrote the final project reports, which were submitted to ODOT with only minor editing by the P.I.
- Management of a large group of students is not easy. Acting as the principle investigator and faculty advisor on this type of project is time consuming. Camp Concrete and the associated research were the primary activities the faculty advisor worked on during the summer of 2004.
- Be prepared for administrative difficulties. One of the most difficult roadblocks to making Camp Concrete a success was hiring undergraduate research assistants for the summer. We could not appoint them to a position for the summer. Hiring them required extra time, effort and paperwork.

Administrative Support:

The University of Oklahoma is a research one university that places enormous emphasis on under-graduate education and the Department of Civil Engineering and Environmental Science in the College of Engineering is known for actively supporting this emphasis and for its leadership in education research. The department has fostered several large National Science Foundation research projects in engineering education such as Sooner City, Authentic Learning Alliance and Adventure Engineering. So when the concept of "Camp Concrete" was presented to the department and university administration this project found an audience receptive to new ideas.

Typically pre-tenure metrics of faculty performance often involve items such as nationally funded research dollars and graduate students being mentored. The University of Oklahoma follows a similar approach but because of their strong belief in under-graduate education the pre-

tenure metrics of faculty performance also include state funded research dollars and under-graduate students being mentored. This approach to tenure system metrics allowed a program such as "Camp Concrete" to be recognized as a significant portion of the faculty members annual evaluation without needing to modify or adjust the metrics system.

Bob Knox, the CEES director and Kyran Mish, the senior structures faculty member were totally supportive. Without this support it is doubtful if "Camp Concrete" would have had such a positive outcome or even if it would have been possible in the first place. They actively supported the program and arranged for the use of a significant portion of Fears Structural Engineering Lab

Conclusions:

Camp Concrete improves the undergraduate experience and is an excellent retention and recruitment tool for graduate school. Several of the students who were initially not planning to earn graduate degrees returned to continue the research they had begun and to develop their own theses. Figure 3 shows the number of undergraduate civil engineering students with a structural emphasis who entered the CEES graduate program over a nine year period. The students shown for the 2006 year are students who have officially entered the accelerated masters program and who have completed a significant amount of their research by participating in Camp Concrete.

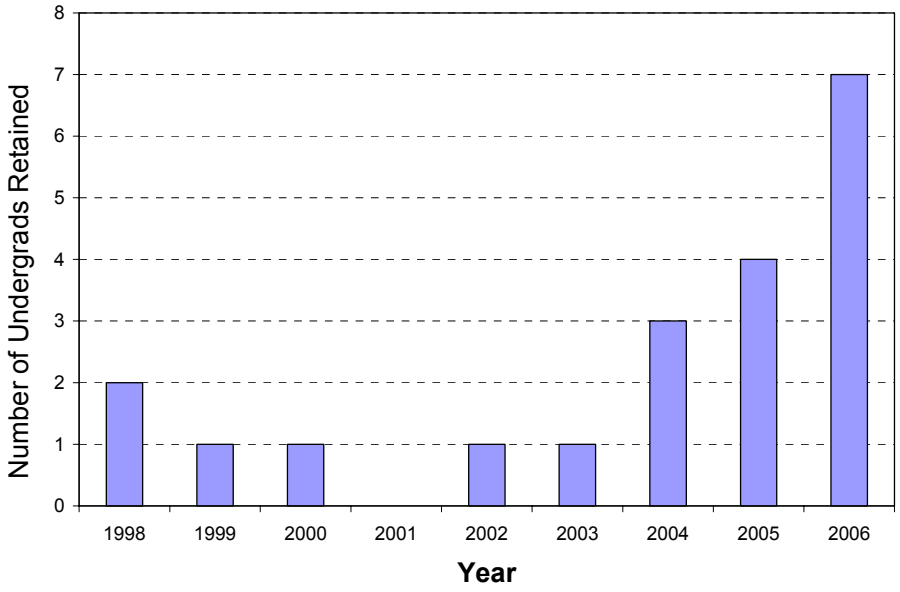

Figure 3 – Number of CEES structural grad students with a B.S. in civil engineering from OU

During the period shown on Figure 3 there was not a significant change in the number of undergrad students pursuing a structural emphasis. All of the students retained in 2005 and 2006 participated in Camp Concrete. As pointed out by the spike in retention in 2005 and 2006, Camp Concrete is an excellent retention and recruitment tool for graduate school.

While the initial contracts were fulfilled in 2004, continuation contracts were obtained to pursue the expanded studies proposed by the students. Three presentations at the semi-annual ACI convention were generated by this work, three journal papers are being written and this work will form the bases of five masters thesis. Because of the success of the inaugural Camp Concrete, the program was repeated in 2005. The number of students was increased to 23, and cold-formed and large structural steel projects were added to the concrete materials projects.

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