Undergraduate Research Mentoring Model in Construction Engineering and Management

Osama Abudayyeh, P.E.[1]

Abstract: The construction industry is a major player in the nation's economy. The complex nature of the construction industry, coupled with the challenges of global competitiveness and changing regulatory requirements, has created the need for providing higher levels of education, experience, and training for construction professionals. An essential and integral component of the required education and training must be the research training of undergraduate civil and construction students, encouraging them to pursue advanced education and research careers in this area. With this in mind, the writer developed a Research Experiences for Undergraduates (REU) summer program at Western Michigan University that focuses on construction engineering and management issues and problems. This construction-oriented undergraduate research training program is the first REU site in the United States to be funded by the National Science Foundation. This paper will describe the structure of the REU program, the types of activities undertaken by the REU participants, and the results of the program evaluation and assessment.

DOI: 10.1061/(ASCE)0733-9364(2003)129:1(65)

CE Database keywords: Undergraduate study; Engineering education; Construction; Construction management.

Introduction

The construction industry plays a significant role in the nation's economy. Its annual contribution to the national gross domestic product exceeds $470 billion (NIST 1994). The industry faces numerous challenges and barriers that require better training of construction professionals. Such challenges include global competitiveness, lack of leadership, advanced construction techniques and materials, new regulatory requirements, and protecting the environment (ASCE 1990; NIST 1994). Consequently, providing formal education and training of construction professionals is necessary to meet future industry challenges (ASCE 1990; Sheehan 1991; Tener 1996). Therefore, an essential and integral component of the required formal education must be the research training of undergraduate civil and construction students, encouraging them to pursue advanced education and research careers in this area. With this in mind, the writer developed a Research Experiences for Undergraduates (REU) summer training program for civil and construction students that focuses on construction engineering and management issues and problems. The program was the first U.S. construction REU site to be funded by the National Science Foundation (NSF). The site is located at Western Michigan University (WMU). This paper will describe the structure of the REU program, the types of activities undertaken by the REU participants, and the results of the program evaluation and assessment.

[1]PhD, Associate Professor, Construction Engineering and Management, College of Engineering and Applied Sciences, Western Michigan Univ., Kalamazoo, MI 49008. E-mail: Abudayyeh@wmich.edu

Note. Discussion open until July 1, 2003. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on June 20, 2001; approved on December 11, 2001. This paper is part of the ***Journal of Construction Engineering and Management***, Vol. 129, No. 1, February 1, 2003. ©ASCE, ISSN 0733-9364/2003/1-65–69/$18.00.

Research Mentoring

A key factor in motivating students to pursue advanced degrees and research careers in science and engineering is a positive research experience as an undergraduate. Such experiences can be highly effective in helping students who are uncertain or lack confidence regarding attending graduate school. One of the recommendations of the NSF Curricular Developments in the Analytical Science Workshop was ''more students be offered hands-on learning opportunities.'' (''Curricular developments in the analytical sciences.'' *NSF Rep.*, October 1996, March 1997). To achieve this, the workshop report suggested providing undergraduate research opportunities with faculty as a means of developing familiarity and comfort with the scientific method and analytical process, and as a means for building skills in problem solving and critical thinking. Therefore, the goals of this REU site in construction engineering and management at WMU are to encourage more construction and civil engineering students to pursue graduate studies and to develop a sense of pride in their chosen professional career and field of study.

Objectives of REU Program

Exposing undergraduate students to research and professional experiences are among the best ways to encourage them to pursue graduate studies and research. Therefore, the objectives of the REU summer program are to

- Provide participants with the opportunity to conduct independent research projects under the supervision of experienced mentors (faculty members and/or graduate students) and to expose them to the research process;
- Educate the participants about the importance of construction research by visiting major research institutions and/or laboratories and by listening to well-known researchers in the field;
- Emphasize the importance of graduate education and research by interacting with graduate students and faculty mentors,

Table 1. REU Program Research Goals and Learning Outcomes

Activity	Duration	Goal	Learning outcome
Research	10 weeks	Develop interest in research	How to research topic
		Understand research process	How to write technical papers/reports
Student-mentor interactions	Once per week	Develop interest in research	How to conduct research
		Understand research process	What is involved in graduate studies
Research abstract presentations	One half day	Research dissemination	Prepare professional presentation
			Present research results
REU symposium	One full day	Research dissemination	Prepare professional presentation
			Present research results

- Expose participants to the dynamics of the construction industry and the challenges facing it by visiting construction sites and owner organizations; and
- Provide students with training in ethics in the construction industry by providing an ethics workshop that deals with relevant ethical issues, dilemmas, and case studies.

Program Design

The REU summer program is designed to span a 10-week period. At the end of the REU program, each participant (or team) is required to prepare a technical report and a five-page conference paper that is included in a conference proceedings (a description of the conference is provided in the next section). The program comprises two main components: research and professional development. The activities undertaken in each component are described in the following subsections.

Research Activities

One of the important goals of this experience is creating an interest in research as early as possible through the active involvement in a research project and through the interactions between students and faculty. To achieve this goal, students are presented with a list of possible projects before they arrive at the REU site and asked to rank these projects according to their interests. Then each student is assigned a project based on their ranking before they join the program. This approach gives the students the feeling that they are involved in selecting their topics and allows them to prepare for the projects before they start the summer program. The students spend the majority of their time at the REU site researching the topic they selected. Some of the activities in this component that complement the research project include the following (Table 1 summarizes the research goals and learning outcomes):

- ***Student-mentor interactions:*** Participants meet regularly with their research project mentors. They also have close interactions with graduate students assigned to their projects (when applicable) as well as with the graduate assistant hired through the REU NSF grant.
- ***Research abstract presentations:*** Each participant (or team) is required to present to the group a project description and a plan of work at the end of the second week of the REU program. The presentations are conducted in a conference format. All participants and their mentors attend this presentation session.
- ***REU symposium:*** At the end of the REU program, a symposium is organized to expose the participants to the professional conference environment. Each participant (or team) is required to prepare a five-page conference paper according to a set of guidelines. The papers are published in a conference proceedings. Each participant (or team) is also required to prepare a professional conference presentation for his or her paper. All mentors attend the conference session.

Professional Development Activities

To achieve a wholesome construction experience for the participants during the 10-week program and to create in them a sense

Table 2. REU Program Professional Development Goals and Learning Outcomes

Activity	Duration	Goal	Learning outcome
Ethics workshops	2 days	Exposure to ethical issues	Analyze and address ethical cases
CEM short course	3 half days	Exposure to construction concepts and principles	Learn construction engineering and management topics
Site visit to construction sites	Two 2 h trips	Exposure to dynamics of construction	Learn how project is constructed
		Instill sense of pride in profession	Learn project management and control techniques
Visiting owner organization	2 h	Exposure to owner's operation	Learn how project is prepared for construction
		Instill sense of pride in profession	Learn about contract administration
Paper discussion sessions	3 h	Critical thinking	Learn how to critically assess paper
			Learn how to write paper (what to do and what not to do)
Visits to research centers/laboratories	1 day	Appreciation for construction research	Learn how construction research is useful to profession
Research speakers	1 day	Appreciation for construction research	Learn how well-known researchers view and conduct research
Professional conference participation	1–2 days	Appreciation for construction research	Learn how other researchers conduct and present research
			Networking opportunities

J. Constr. Eng. Manage., 2003, 129(1): 65-69

of pride in their chosen field of study and career, the program is designed to include a host of other professional development activities that complement the research component. These professional activities include the following (Table 2 summarizes the professional development goals and learning outcomes):

- *Ethics workshops:* The ethics workshop is offered over two days (five hours each). The workshop instructor utilizes a number of relevant case studies (research and practice) that are discussed and analyzed over the two-day workshop. The case studies are given to the participants before attending the workshop. The format of the workshops relies heavily on group discussions and interactions instead of a lecture format. The workshop instructor acts as a facilitator for group discussions.
- *Construction engineering and management short course:* The participants are introduced to basic concepts in construction engineering and management such as project planning, scheduling, estimating, equipment and methods, safety, and information technology. The short course is delivered in three half-day seminars during the first week of the REU summer program. Each participant receives a course manual prepared by the writer. The course delivery method consists of lectures, videos, and group discussions. Additional hands-on computer instruction and electronic library and Internet literature searches are also provided.
- *Visit to construction sites:* The REU participants visit a construction site two to three times during the 10-week summer program. They are required to document each visit by a report and photographs. These reports are discussed and compared to the previous ones to analyze progress from one visit to the next. This hands-on experience is an excellent way to expose the students to the dynamics of the construction environment. A safety orientation is provided prior to each site visit.
- *Visiting an owner organization:* REU participants visit an owner organization during the summer program. They tour the various engineering divisions that develop and administer construction projects. This experience along with the visit to a construction site expose the students to the real-life construction industry and its major players (owner, contractor, designer, and so on). Examples of owner organizations visited by the REU participants included the Michigan Department of Transportation (MDOT) and the City of Kalamazoo Engineering Division. During MDOT's visit, participants toured the bridge management unit, the materials testing laboratory, and the highway maintenance unit.
- *Paper discussion sessions:* A paper critique session is conducted during this summer program. A relevant journal article is selected, which the participants are asked to read prior to the session. Then the participants are divided into teams of two or three participants. Each team is asked to read the paper and list the main point of the paper, three strengths of the paper, and three areas for improvement. The writer facilitates the discussions and the recording of the findings of the teams. This exercise provides training in reading articles critically. It also provides insights into preparing papers for publications in scientific journals.
- *REU visits to research centers and laboratories:* REU participants visit one or two research centers/laboratories for a full day during the summer program. We are fortunate in Kalamazoo, Michigan, to be close to a number of research institutions that can be visited, such as the Construction Technology Laboratory in Illinois, which is 2.5 h from WMU: the Argonne National Laboratory in Illinois, which is also 2.5 h from WMU; and the U.S. Army Construction Engineering Research Laboratory (CERL) in Illinois, which is 3 h from WMU. These visits give REU participants appreciation for construction research and provide an opportunity to assimilate the latest research results in construction engineering and management. During these visits, the group tours the facilities, learns about the various research activities and projects, and meets with a number of researchers in these laboratories.
- *REU research speakers and professional conference participation:* The aim of this activity is to allow REU participants to meet and interact with well-known researchers in the field. This activity is accomplished in two different ways. The first method is to invite a well-known researcher to visit the REU site for one full day. During the morning the speaker gives a talk on some aspect of his or her research. In the afternoon an informal discussion session is held where REU participants are free to interact with the speaker. The second method is to take all REU participants to a professional conference where they attend technical sessions and interact with researchers and professionals.

Examples of Research Projects

Each summer, REU participants work full-time on their chosen projects. This section presents three examples of research projects completed by REU participants, along with the resulting publications. Each of these projects had a topic appropriate for the 10-week duration, allowing each participant to bring a conclusion to his or her project.

As-Built Data Management for Bridge Construction

Abstract
Bridge management systems involve numerous data collection and data analysis techniques. Of particular significance in this data-intensive environment are the timely and accurate acquisition, storage, and presentation of as-built data and information pertinent to bridge maintenance and rehabilitation programs. As-built data provide historical information related to the design, construction, operation, and maintenance of bridges that is necessary for planning maintenance and rehabilitation programs. However, there is a lack of coordinated effort during the design or construction phases to collect and store necessary as-built information. Hence there is a need to investigate as-built data collection and storage issues and to properly design and structure as-built information to use it effectively in the maintenance and rehabilitation processes. Therefore the primary objective of the research project is to design a conceptual information model for storing and presenting as-built data and information needed by the bridge maintenance and rehabilitation functions. This as-built information model would then facilitate and enhance bridge maintenance and rehabilitation decision-making abilities by providing the much-needed data and information. The modeling methodology is divided into three major steps: (1) analysis and problem definition; (2) modeling; and (3) prototype implementation (Abudayyeh et al. 2000, 2001a; Hurley et al. 2000).

Intranet-Based Project Control System for Construction Management

Abstract
Information plays a key role in construction project management. In order for a construction project to be well managed, data from

J. Constr. Eng. Manage., 2003, 129(1): 65-69

past projects, stored in a historical database, as well as data from the project at hand, must be readily available. It is an essential and valuable resource for project planning, control, reporting, and decision-making tasks. In each of these tasks, effective management of information is an integral part of a successful project management system, whose primary objective is completing the project on time and within budget limitations while meeting established quality requirements and other specifications. In this project, the design and implementation of an Intranet-based cost control system was achieved. The Internet is utilized as a mechanism for communicating project control data and information (Temel et al. 1999; Abudayyeh et al. 2001b).

Mechanical and Electrical Contracting Injuries, Illnesses, and Fatalities

Abstract
The purpose of this project was twofold: (1) to determine jobs/tasks associated with current injury, illness, and fatality trends in the mechanical and electrical contracting branches of the construction industry; (2) and to identify current safety practices associated with the prevention of these injuries, illnesses, and fatalities. In order to achieve the project objectives, a survey was designed and sent to Michigan mechanical and electrical contractors. To design an adequate survey, the research team first collected background information using the U.S. Bureau of Labor Statistics online database, published research, and contractor interviews (Fredericks et al. 2000, 2001, 2002; Palmquist et al. 2000; Abudayyeh et al. 2002).

REU Participants Recruitment and Selection

Eligibility criteria for applying to the REU program include the following:

- Applicant must be a sophomore, junior, or senior in a construction engineering, construction management, civil engineering, or architectural engineering program; and
- Applicant must have a GPA of at least 3.0.

Each candidate is asked to submit an application package that includes the following:

- Completed application form;
- Current official transcripts from all colleges and universities attended;
- One-page essay concerning career interests upon graduation and any relevant work experience; and
- Two letters of recommendation.

To facilitate the application process, the application form is available on-line for download as well as for on-line submission through the REU site Web page.

The following is the strategy used in recruiting students:

1. Advertise research opportunities in construction, civil, and architectural engineering programs nationwide through regular mail as well as through electronic mail servers;
2. Directly contact individuals known by writer by e-mail; and
3. Develop Web site for the summer program that provides details on the program, prior research and professional activities, REU site area attractions, and an on-line application.

REU Summer Program Evaluation and Assessment

Evaluation of the REU program is accomplished by two types of surveys: one for the participants and one for the mentors. The participant surveys consist of three questionnaires and the mentor survey consists of one questionnaire. Also, an assessment of the summer experience is conducted at the end of the program. The results are discussed in the next section.

Participant Surveys

The participant surveys consist of three questionnaires designed to evaluate the various components of the REU summer program:

1. The first questionnaire evaluates the CEM short course. The aggregate results of the evaluation indicated that the participants were satisfied with the contents, the structure, and the instruction of the short course. From year to year some participants suggest providing more details on certain topics. We continuously refine the course contents to incorporate some of these suggestions. For instance, participants suggested providing training on how to structure a technical report and a conference paper. This training was added to the following year's short course.
2. The second questionnaire evaluates the ethics workshop and is administered immediately after the conclusion of the workshop. The aggregate results of the evaluation indicated that the participants were very satisfied with the contents, the format, and the instructor of the ethics workshop. They all indicated that they would love to have more days allocated to the ethics workshop. Unfortunately, this request is not feasible, considering all the other activities that the REU program provides.
3. The third questionnaire evaluates the overall REU summer experience and is typically administered on the last day of the program. The aggregate results indicate that 75% of participants are satisfied with the summer experience. The aggregate satisfaction rate in the overall REU program is at 70%. The remainder of the participants are divided between dissatisfied at 12% and neutral at 18%. Also, 30% of participants indicated that they will definitely pursue graduate studies, 40% are not sure or are still considering their options, and 30% are definitely not pursuing graduate studies.

As for participants' evaluations of their mentors, the results generally indicate most participants were satisfied with the personality of and interaction with the REU mentors.

Mentor Survey

The mentor survey consists of one questionnaire designed to evaluate the contributions made by the REU participants to the mentors' research programs, to speculate as to whether or not the participants would succeed in graduate school, to evaluate the quality of participants' oral and written project presentations, and to suggest future REU activities. The analysis of the mentor survey results indicated that all mentors were satisfied with their mentees and all REU participants had satisfactory oral and written communication skills. Also, all participants have the potential to succeed in graduate studies. Additionally, most mentors are satisfied with the contributions made by the participants to their research programs. In fact, many REU participants become coauthors of publications that appear in national and international journals and conference proceedings.

REU Program Assessment

An overall assessment of the summer program was conducted by asking participants to identify the strengths of the program and to

J. Constr. Eng. Manage., 2003, 129(1): 65-69

enumerate areas for improvements. Below is a partial list of major issues identified by the REU participants' assessments:

Strengths

- Broad spectrum of interest activities and field trips;
- Ethics workshop;
- Gaining insights in documenting and disseminating research results through written (technical reports and papers) and oral (presentations) formats;
- Freedom in scheduling work activities;
- Work environment;
- REU mentors and assigned research topics;
- Available resources (computers, printing, copying, phone, fax, library access, and so on);
- Teamwork and overall REU program organization; and
- REU group diversity.

Areas for Improvement

- More social activities;
- Formal technical writing workshop for preparing papers and reports;
- Access to university gym;
- More frequent pay periods (that is, biweekly instead of only twice during summer); and
- Quicker reimbursement of expenses.

Some of the areas for improvement (mainly logistics) listed above are controlled by the university, such as access to the gym, reimbursements, and frequency of pay. However, access to university resources has improved since the first summer program by negotiating special arrangements with the appropriate university officials. On the other hand, programmatic areas for improvement are always a significant input to the continuous refinement of future summer activities. For example, technical report and paper writing were not initially discussed in the first offering of the CEM short course. Since then, this topic has become a major component of the course and has made significant improvements to the quality of the technical papers and reports produced by REU participants.

Summary and Concluding Remarks

This paper described the structure of an REU mentoring program at Western Michigan University that is focused on construction-related research. The goals of this REU program are to encourage more construction and civil engineering students to pursue graduate studies and research careers and to develop a sense of pride in their chosen professional career and field of study. The activities of the REU program discussed in this paper achieve these goals. More of these research training programs are needed to increase the number of individuals seeking graduate studies, advanced degrees, and research careers. This is particularly true in construction engineering and management, where the number of individuals seeking graduate studies does not meet the demand needed to face the significant increase in the challenges facing the industry. The REU program at Western Michigan University has been very successful and is a timely contribution to the many efforts aimed at enhancing the quality of construction education and at providing ways to face the challenges.

Acknowledgments

The REU summer program was funded in part by the National Science Foundation (NSF) Research Experiences for Undergraduates (REU) program (Grant No. 9820310) and in part by Western Michigan University. The support of NSF and WMU are greatly appreciated.

References

Abudayyeh, O., Al-Battaineh, H., and Hurley, B. (2000). ''As-built data management for bridge construction.'' *Technical Rep. No. CEM-00-04*, Dept. of Construction Engineering, Materials Engineering, and Industrial Design, Western Michigan Univ., Kalamazoo, Mich.

Abudayyeh, O., Al-Battaineh, H., and Hurley, B. (2001a). ''An as-built information system for bridge management.'' *Proc., 2nd IEEE Electro/Information Technology Conf.*, Oakland Univ., Rochester, Mich., June.

Abudayyeh, O. Y., Temel, B., Al-Tabtabai, H., and Hurley, B. (2001b). ''An intranet-based cost control system.'' *Journal of Advances in Engineering Software, January*, 32(2).

Abudayyeh, O., Fredericks, T., Palmquist, M., and Torres, H. (2002). ''Safety management in the electrical contracting industry,'' *Proc., 10th Int. Symp. Construction Innovation and Global Competitiveness*, University of Cincinnati, Cincinnati.

ASCE. (1990). ''The challenges of the 90's.'' *Civ. Eng. (N.Y.)*, October.

Fredericks, T., Abudayyeh, O., Palmquist, M., and Torres, H. (2000). ''Mechanical and electrical contracting injuries, illnesses, and fatalities.'' *Technical Rep. No. CEM-00-03*, Dept. of Construction Engineering, Materials Engineering, and Industrial Design, Western Michigan Univ., Kalamazoo, Mich.

Fredericks, T., Abudayyeh, O., Palmquist, M., and Torres, H. N. (2001). ''Mechanical contracting safety issues.'' *J. Constr. Eng. Manage.*, 128(2), 186–193.

Fredericks, T., Abudayyeh, O., Palmquist, M., and Torres, H. (2002). ''Safety management in the mechanical contracting industry.'' *10th Int. Symp.: Construction Innovation and Global Competitiveness*, Univ. of Cincinnati, Cincinnati.

Hurley, B., Abudayyeh, O., and Al-Battaineh, H. (2000). ''Analysis of as-built bridge construction data.'' *Proc., 1st NSF REU in Construction Engineering and Management Symp.*, Western Michigan Univ., Kalamazoo, Mich.

Palmquist, M., Torres, H., Fredericks, T., and Abudayyeh, O. (2000). ''Mechanical and electrical contracting injuries, illnesses, and fatalities.'' *Proc. 1st NSF REU in Construction Engineering and Management Symp.*, Western Michigan Univ., Kalamazoo, Mich.

''Rationale and preliminary plan for federal research for construction and building.'' *Rep., Subcommittee on Construction Building, NISTIR 5536, Rockville, Md.*, National Institute of Standards and Technology (NIST). (1994).

Sheehan, J. (1991). ''Discussion of 'dilemmas facing construction education and research in 1990' by C. H. Oglesby.'' *J. Constr. Eng. Manage.*, 117(4), 795–797.

Temel, B., Abudayyeh, O. A., Hurley, B., and Al-Tabtabai, H. (1999). ''An Intranet-based cost control system.'' *Technical Rep. No. CEM-99-01*, Dept. of Construction Engineering, Materials Engineering, and Industrial Design, Western Michigan Univ., Kalamazoo, Mich.

Tener, R. K. (1996). ''Industry-university partnerships for construction engineering education.'' *J. Prof. Issues Eng. Educ. Pract.*, 122(4), 156–162.