AC 2007-822: BUILDING A CONSTRUCTION ENGINEERING PROGRAM

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Building a Construction Engineering Program

Abstract

Giving birth to a new multidisciplinary engineering program is an interesting and rewarding task. Accomplishing this task at a university which previously had not offered classical engineering programs is a truly unique endeavor. This paper looks at the newly established Bachelor of Science in Construction Engineering program at Southern Polytechnic State University and examines the process by which it has become a reality. Lessons learned during this process are presented along with advice to those who seek to follow a similar path.

Special emphasis is given to the interaction between multiple academic departments, the collaboration of several colleges and universities and the vital role industry played in the process. Input was obtained from universities in several states including sister universities within the state of Georgia. The program's development was unique in that civil engineering technology, construction management, and architecture faculty all played key roles as full partners in the process. Their contributions/interactions throughout the project is presented as well as development of a curriculum which meets the needs of constituents and satisfies criteria for accreditation under the Engineering Accreditation Commission of ABET. A continuous quality improvement plan with assessment and evaluation methods is presented as well.

Introduction

Existing engineering programs find themselves evolving more and more as the presence of advanced technology, the global economy, the effects of telecommunications, and the dynamics of engineering education are changing the practice of engineering. Indeed, many educators find it difficult to design curricula which are sufficiently broad such that they address the needs of the engineering marketplace. Also, graduates of programs which are more interdisciplinary in nature than the more traditional disciplines of engineering are finding themselves in high demand by the profession.

As a result, new types of engineering programs such as mechatronics engineering, both interdisciplinary and multidisciplinary in nature, are being developed which address the dynamic bent of engineering. In addition, disciplines such as construction engineering which have traditionally been more interdisciplinary in nature than other types of engineering are emerging as important segments of the engineering profession of the future. It is the aforementioned recognition of the ever changing needs of engineering in the world and the desire to serve those needs that led our university to develop and implement a construction engineering program.

Addressing the Need

In 2004 our university was first approached by industry with the need for graduates who could combine the best of construction management with the best of civil engineering.

Indeed, employers were attempting to satisfy their needs by hiring civil engineering technology graduates of our school and having them enroll in our graduate program in construction management to obtain the construction knowledge needed in the workplace. The industry was frustrated with this approach since it did not properly prepare their workforce for a position as a construction engineer. While other schools had very successful construction engineering programs and produced very capable graduates, these programs did not produce sufficient graduates to satisfy the needs of the industry nor were they within our geographic region.

At that time the university had no traditional engineering programs but had, and still does have, many successful engineering technology programs it was thought that a construction engineering technology program could satisfy the industry's needs. However, further investigation of the desirable characteristics of the graduates being sought combined with the industry's requirement that the graduates be able to sit for the professional engineer exam in any state ruled out a technology degree program at that time. What became clear to us was that the industry wanted an ABET accredited construction engineering program which could produce the next generation of leaders.

Some Hurdles

While starting a new program at any university can be a daunting task, we found that our university had several hurdles to overcome in the creation of this engineering program that others were not likely to encounter. Since the university had no traditional engineering programs, there was no engineering department per se to take ownership of this new effort. As previously stated the university has a number of very strong engineering technology programs, several with enrollments in their ABET accredited baccalaureate programs exceeding 400 full-time students. However, they are not engineering programs and we could not see how they could satisfy many of the needs of a new engineering program.

Also, any construction engineering program needs to draw on expertise in construction, civil engineering, and management among others. At our university involving faculty who have expertise in these areas involves crossing department lines and school lines. One faculty member cynically stated that getting representatives from each discipline to work together across these perceived boundaries would be more difficult than creating the United Nations.

Indeed, as in any interdisciplinary undertaking, all parties involved must become vested stakeholders in the effort or they will not put forth their best efforts. Note that this does not imply that our faculty only respond to well defined reward systems; it is quite the contrary. The faculty are ready and eager to go the extra mile when asked. However, given their high work loads and limited available time, it was expected that it would be difficult to designate what little available time they had to the development of this program. As will be explained later, we were pleasantly surprised by their enthusiasm.

We agreed that if the construction engineering program was to be realized, then we would first have to explore how others developed interdisciplinary programs within a university which functioned, as most do, as multidisciplinary teams.

Interdisciplinary Programs within a Multidisciplinary Structure

Multidisciplinary may be defined as of, or relating to, making use of several disciplines at once which leads to the definition of a multidisciplinary team as one where each member does the work in their specialty and only their specialty. This definition of the multidisciplinary team fits most universities. The team members are the departments and each department has its list of duties, or programs, which it administers for the greater good. However, unless the leadership of the institution is very active in the day to day activities of the university, the departments rarely if ever look beyond their own boundaries and interdisciplinary efforts are not initiated.

Interdisciplinary can be defined as a knowledge view and curricular approach that consciously applies methodology and language from more than one discipline to examine a central theme, issue, problem, topic, or experience. Therefore, at the risk of oversimplification, an interdisciplinary team can be described as one where all team members work together to integrate their many specialties together to achieve a goal or solve a problem. Ideally, this also is the definition of a university-wide committee. Recognizing the aforementioned, the goal became how to overcome the multidisciplinary structure of the university to obtain interdisciplinary results.

Looking to Others

In order to accomplish the program's development we examined interdisciplinary programs at other universities. Focusing mostly on construction engineering programs we identified some common characteristics of successful interdisciplinary programs as well as characteristics of programs which were attempted but failed. Whether the effort was one in engineering or some other discipline, the qualities of success were identifiable.

Successful interdisciplinary degree programs were housed within a department with a program director having authority over the fate of the program. In some cases the program director was the department head but it most cases it was not. In addition, all faculty associated with the program regardless of their department affiliation were identified as program faculty and took part in the development and continuous improvement of the program. These faculty in conjunction with the program director served as a steering committee and were rewarded each year via their annual evaluation for their service to the program.

While it was difficult to know if a program had been initiated and failed, it was even more difficult to obtain information regarding why it had failed. However, diligence was rewarded and it was discovered that failed interdisciplinary programs never obtained the support of the faculty, administration or students in part because there was no assigned

"champion" or director for the program. If one were assigned, they had no fiscal responsibility and no authority to assign faculty and resources to meet the needs of the program. While nearly all successful programs had a budget consisting of limited funding and assigned faculty, failed programs had neither.

Last, but certainly not least, nearly every successful program had very well defined program educational objectives, program outcomes, and curricula which were the products of input from all stakeholders of the program. All of these are necessary parts of a usable continuous improvement plan, a requirement for ABET accreditation.

Given all of the above, it was decided that the construction engineering program would be developed by a committee consisting of faculty from all affected departments as well as student and industry representation. The committee was lead by a dean and directed its deliberations in two directions. First, it would develop the details of the baccalaureate in construction engineering using the development of an assessment and improvement plan as a vehicle. This is explained later in this paper. Second, the team would generate the proposal needed to obtain authorization from the university and the state to offer the program.

It was decided that the program would be lead by a director who would be given both responsibility and authority to see that the program was a success. The director would be responsible for the management of the program's budget and its faculty. Initially, all students majoring in the construction engineering program would be advised by the director. Also, program faculty would be identified in various departments with identifiable responsibilities.

What follows is a description of the continuous improvement plan which resulted from the program development process.

Development of the Assessment and Improvement Plan

The Construction Engineering program was designed to meet ABET accreditation criteria for engineering programs[1]. The most recent criteria effective for evaluations during the 2007-2008 accreditation cycle can be found at ABET's website www.ABET.org. The criteria are set forth by the Engineering Accreditation Commission (EAC) of ABET and apply to all accredited engineering programs. Program criteria specific to Construction Engineering must also be met. These program criteria are set forth by the American Society of Civil Engineers and are included in the published ABET criteria.

The criteria allow some flexibility in program emphasis but are very explicit in that all engineering programs must have:

- A set of "Program Educational Objections" which are statements of career and professional accomplishments that the program is preparing graduates to achieve.

- A set of "Program Outcomes" which are statements of what students are expected to know at graduation.

- An assessment process which measures the level of achievement of the educational and program objectives

- A process through which results of assessment are applied to improve the program educational objectives and program outcomes

Development of an assessment and improvement plan for the construction engineering program is in progress and has followed a four step process:

- Develop program educational objectives, program outcomes, and the supporting curriculum.

- Integrate program outcomes and curriculum.

- Develop an assessment plan.

- Develop an evaluation and improvement plan.

Program Educational Objectives, Outcomes, Curriculum

As discussed earlier in this paper, the construction engineering proposal committee developed the program educational objectives, program outcomes, and curriculum. Program constituencies were identified and consulted. The committee communicated with the university administration, faculty and students of the Construction Management and Civil Engineering Technology departments, industry and professional organizations, and universities with accredited construction engineering programs. The final objectives and outcomes were compatible with the university mission and goals of the School of Architecture, Civil Engineering Technology, and Construction Management.

With respect to ABET criteria for accrediting engineering programs[1], most flexibility for addressing the uniqueness of individual programs lies within the program educational objectives. The university places emphasis on practical application in all its programs, thus the program educational objectives for the construction engineering program focus on professional registration, industry practice and advancement in leadership and engineering positions. The program educational objectives are:

- Graduates meet the educational requirements to pursue registration as a professional engineer in the State of Georgia and other states in the nation.

- Graduates demonstrate career advancement with increasing responsibility in the (heavy) construction industry as owners, managers, lead engineers, or other key positions of leadership.

- Graduates are capable of pursuing graduate education in construction engineering, civil engineering, and related fields.

The program outcomes were developed to support achievement of the program educational objectives and meet ABET criteria for accrediting engineering programs. Although ABET encourages unique outcomes specific to individual programs; all engineering programs must produce graduates that attain eleven specific outcomes described in the criteria for accrediting engineering programs.[1] The prescribed eleven outcomes and outcomes defined in the program criteria must be achieved by the time of graduation. The final program outcomes for the construction engineering programs were developed to address the aforementioned ABET criteria as well as meet needs of the program constituents. The developed program outcomes are:

a. Graduates will recognize careers in the construction engineering field and appreciate the importance of life-long learning, participation in professional societies, and continued professional development.

b. Graduates are able to communicate effectively in written, oral, mathematical, and graphical formats as appropriate to construction engineering projects.

c. Graduates can function as productive team leaders and team members in defining and solving construction engineering problems.

d. Graduates are able to conduct design of a construction engineering system, process, or component using standard design methods, practice, and procedures; synthesize an engineering process or system by integrating solution components; and critically evaluate alternative solutions and designs.

e. Graduates are able to apply and interpret appropriate software to improve accuracy and efficiency in developing construction engineering solutions.

f. Graduates are able to identify, formulate and solve construction engineering problems and designs and correctly apply science, mathematics, statistical analysis, and suitable engineering principals in these solutions.

g. Graduates are able to recognize and analyze ethical, legal, safety, environmental, global and contemporary social issues in developing and applying engineering decisions.

h. Graduates are able to design and conduct experiments and collect, analyze, and interpret data (from experiments or other processes) for application in construction engineering designs and solutions.

i. Graduates are able to conduct economics and cost analyses of construction designs processes, systems, or components.

j. Graduates are capable of applying modern business, accounting and management practices in conducting and analyzing construction designs, processes, and systems.

k. Graduates are able to apply modern construction practices and materials to construction designs, processes, systems or components.

l. Graduates are competent in the organization, planning and management of construction processes, components, systems and resources.

m. Graduates are prepared to evaluate ethical, societal, and environmental issues as they affect construction engineering decisions and designs.

n. Graduates are trained to effectively apply engineering principles to create, design, analyze, or improve construction processes, devices, or systems.

The curriculum was then developed to support the attainment of these program outcomes by all students. A copy of the curriculum is shown on the following page.

Construction Engineering

Suggested Course Sequence

First Semester

CE 1000	Orient. to Engr & Surv	1
CHEM1211K	Chemistry I	4
ENGL1101	Composition I	3
ENGR2160	Engineering Graphics	3
MATH 2253	Calculus I	4
	Total	15

Second Semester

CHEM1212K	Chemistry II	4
ENGL1102	Composition II	3
MATH 2254	Calculus II	4
PHYS2211K	Physics I	4
SPCH2400	Public Speaking	2
	Total	17

Third Semester

Core C Grp 1	Literature	3
Core E Grp 3	Behavioral Sciences	3
ENGR2214	Statics	3
MATH2306	Differential Equations	3
PHYS2212K	Physics II	4
	Total	16

Fourth Semester

Core C Grp 2	Arts	3
ENGR3131	Strength of Materials	4
ENGR3343	Fluid Mechanics	3
MATH2335	Numerical Methods I	3
SURV2200	Constr Measurements	4
	Total	17

Fifth Semester

Core E Grp 1	U.S. History/Pol/Sci.	3
CE3701	Geotechnical Engr	3
ENGR3305	Data Collection &Analysis	4
CNST3160	Bldg. Tech. & Methods II	3
ENGR3324	Project Cost Analysis	4
	Total	17

Sixth Semester

CE3201	Structural Analysis	3
CE3702	Environmental Engr.	3
CNST3420	Construction Est. II	4
CNST3180	Bldg. Tech. & Methods III	4
CNST4510	Scheduling	3
	Total	17

Seventh Semester

CE4177	Transp Engr	4
CE4202	Steel & Conc Design	3
CE4703	Engr. Hydrology	3
CNST4560	Project Management	3
STS2400	Science & Tech. In Society	2
	Total	15

Eighth Semester

Core E Grp 2	World Civilization	3
Core E Grp 4	International Issues	3
CE4178	Highway Des & Constr	3
CE4800	Senior Project	3
CNST4639	Constr Safety & Law	3
	Total	15

Total Hours 129

Integration of Program Outcomes and Curriculum

A Committee for Assessment and Improvement was formed in fall 2006 and given the charge of completing an Assessment and Improvement Plan for the Construction Engineering Program with implementation to begin by the end of the spring 2007 semester. The committee consists of:

- The Director of Planning for Engineering
- The Program Coordinator of Construction Engineering program who is a faculty member from the Civil Engineering Technology Department
- A lead faculty member from the Construction Management Department
- A lead faculty member from the Civil Engineering Technology Department
- The Chair of the Civil Engineering Technology Department which is where the Construction Engineering program is housed

With the educational objectives, program outcomes, and curriculum in place, the first task of the committee was to integrate or map the curriculum to the program outcomes. Several new civil related courses had to be created to serve the Construction Engineering program. Course learning outcomes were developed for new courses or revised as need for existing courses to meet the program outcomes of the Construction Engineering program. The committee chose to place heavy emphasis on course learning outcomes when integrating the curriculum to the program outcomes.

Learning outcomes which are what students are expected to learn from a course rather than course content syllabi which are what subjects the instructor intends to teach in a course are much more reliable in mapping curriculum courses to program outcomes. The committee developed a table in the form shown below.

CURRICULUM COURSES	PROGRAM OUTCOMES A-N				
	A	B	C	ETC.	
ENGLISH 1101	0				
ENGLISH 1102		1			
MATH 2253			2		
ETC.					

The degree to which a program outcome was addressed in each course was indicated by a 0, 1, or 2 which were defined as:

Not covered: 0
Awareness: 1
Understanding: 2

Assessment Plan

The Committee for Assessment and Improvement divided the Assessment Plan into three parts:

- Assessment of course learning outcomes
- Assessment of program outcomes
- Assessment of program educational objectives

Assessment of Course Learning Outcomes

Assessment of course learning outcomes is the foundation of a successful assessment and improvement plan. Student achievement of course learning outcomes is critical to achievement of the program outcomes by the time of graduation.

The Committee for Assessment and Improvement recommended that course learning outcome assessment involve both a self-assessment by students in the course and assessment of student achievement by the instructor. At the end of the spring 2007 semester, students in the major courses will have completed a self assessment of their achievement of each outcome through an on-line survey. Correspondingly, the course instructor will have rated each student's achievement of each outcome. Course outcomes that students or faculty indicate as low level of achievement will have been flagged for improvement.

Assessment of Program Outcomes

Assessment of program outcomes must occur prior to graduation. The level of achievement of each program outcome must be assessed with subsequent improvements made as needed in course content and outcomes or curriculum. Details of program outcome assessment will be completed by the end of the spring 2007 semester. Each program outcome will be assessed by the following three methods:

- Self assessment by graduating seniors: Through a written or on-line survey graduating seniors will rate their level of achievement of each program outcome.
- Assessment within key courses and/or the senior project course: Key courses including senior project will be identified in which it is expected that students should demonstrate competency in one or more program outcomes. Level of achievement will be assessed by direct observation of performance and/or evaluation of student work.
- Assessment by comprehensive examination: Graduating seniors will complete a comprehensive examination designed by the faculty. Level of achievement will

be assessed based on overall performance on the exam or performance on certain portions or questions relating to individual program outcomes.

Assessment of Program Educational Objectives

Assessment of program educational objectives can only occur following graduation; where as program outcomes must be achieved and assessed before graduation. The idea being that achievement of the program outcomes will support achievement of the program educational objectives and expected accomplishments some years after graduation. Thus, program educational objectives cannot be assessed until graduates are working in the field. The program educational objectives will be assessed by three methods:

- Alumni surveys: Alumni will be surveyed three to five years after graduation and asked to rate their level of achievement or ability to achieve the educational objectives.

- Employer surveys: Employers of graduates will be surveyed three to five years after graduation and asked to rate the graduate's employee level of achievement or ability to achieve the educational objectives.

- Alumni-employer focus groups: A focus group consisting of selected graduates three to five years after graduation and employers will be interviewed together. The group will address professional work, career advancement, and overall achievement of the educational objectives.

The next step in the assessment and improvement process is to close the loop. That is to evaluate assessment information and make improvements in the construction engineering program.

Evaluation and Improvement Plan

ABET criteria for accrediting engineering programs[1] requires that results of assessment "be applied to further development of the program". The Committee for Assessment and Improvement is in the process of developing an evaluation and improvement plan which will insure that assessment results will be evaluated and used to make improvements in the construction engineering program. The plan consists of four parts:

- Assessment Targets: Ultimately, each objective and outcome will be scored and compared to a target as shown below:

Objective Or Outcome	Beginning	Developing	Accomplished	Exemplary
	1	2	3	4

Score _____ Target _____

- Schedule of Assessments: A preliminary schedule of assessments has been set as shown below; however, the schedule will remain flexible and controlled by the Committee for Assessment and Improvement:

    - Course outcomes: each offering
    - Senior self assessment: each graduation
    - Key courses: each offering
    - Comprehensive examination: each graduation
    - Alumni and Employer surveys: three to five year intervals
    - Focus groups: (schedule to be determined)

    The Committee for Assessment and Improvement will review and make necessary changes to the assessment schedule at the beginning of each academic year.

- Evaluation of Assessments: The Committee for Assessment and Improvement will be responsible for evaluating all assessment results. Individual course learning outcomes will be assessed and evaluated by the instructors with only a summary of achievement levels reported to the committee. Assessment of program outcomes within the senior project course or other key courses will be conducted and evaluated by the instructors. All other assessment results will be evaluated and summarized by the committee.

- Application for Improvement: To effect timely improvements in the construction engineering program, assessment results must be evaluated in a timely fashion. There must also be a process in place for recommending and implementing program improvements. At the beginning of each semester the committee will summarize evaluation results and make recommendations to the faculty for action necessary to improve achievement of program educational objectives and outcomes. Actions recommended can include, for example, changes in course content, curriculum, or even changes in the program educational objectives and outcomes themselves. Recommended changes in course content and curriculum will be presented to the faculty for approval. Ultimately, it is the faculty that owns the curriculum and only with their approval will program changes be formally proposed, and implemented through normal university procedures. Broad changes in educational objectives and program outcomes will also involve discussion with all other program constituencies.

Summary

As has been shown, building a new interdisciplinary program such as the construction engineering program is not an easy task. However, recognizing that such a program must function in a multidisciplinary environment and by providing the components necessary for it to succeed in such an environment can ensure success. Furthermore, by using the continuous improvement plan as a vehicle to design the program, collaboration among departments and within departments can be realized and a quality program maintained.

Epilogue

The culmination of our deliberations was realized in June of 2006 when the Construction Engineering program was approved by the state's board of regents. With little advertising other than two newspaper announcements, 37 students enrolled in the program in the fall semester of 2006. Enrollments increased in the Spring semester of 2007 and are expected to continue to rise.

REFERENCES

1. "Criteria for Accrediting Engineering Programs" Effective for the 2007-2008 accreditation cycle, ABET, Engineering Accreditation Commission (EAC), 11/15/06, ABET Inc., 111 Market Place, Suite 1050, Baltimore, MD 21202.