AC 2009-1461: IMPLEMENTING BOK2: A MODULAR POST-B.S. CIVIL ENGINEERING EDUCATION PROGRAM

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Implementing BOK2: A Modular Post-BS Civil Engineering Education Program

Abstract

The ASCE publication "Civil Engineering Body of Knowledge for the 21st Century" (BOK2) specifies 24 educational outcomes that are deemed essential for civil engineering graduates to practice at the professional level. Recognizing that it is impossible to meet all of the outcomes within the confines of a nominal four-year BS program, BOK2 envisions that some of the outcomes will be met through a program of study equivalent to approximately 30 credits of advanced coursework. The authors have just completed a process at their institution of mapping the post-BS outcomes to a series of course modules of non-traditional one to three credit hour graduate courses. These courses will be intended for three groups of students, including seniors and graduate students as well as practicing engineers planning to become licensed professional engineers. We present our educational assumptions, the general outline of our new system of courses, and several examples of new courses, and discuss how industry involvement was obtained to define these new course modules.

Project Justification

The ASCE recently published "Civil Engineering Body of Knowledge for the 21st Century" (BOK2)[5], which specifies 24 educational outcomes that are deemed essential for civil engineering graduates to practice at the professional level. Recognizing that it is impossible to meet all of the outcomes within the confines of a nominal four-year BS program, BOK2 envisions that some of the outcomes will be met through a program of study equivalent to approximately 30 credits of advanced coursework. The BOK2 report leaves open the question how individual civil engineers take the courses and how they will be offered and taught by various departments. The fundamental assumption is that civil engineers need to acquire an advanced body of knowledge, equivalent to at least 30 credits, before they become professional engineers. BOK2 also suggests (but does not mandate) how the total body of knowledge needed for practice should be distributed across the undergraduate program, the advanced study component, and on the job training obtained during the engineering apprenticeship period. Hence the exact content of the advanced component at a particular institution will depend to some extent upon how it is articulated with the undergraduate component, and assumptions or analyses made about the educational backgrounds of those entering advanced component courses who have completed their undergraduate education at other institutions.

Our Department is a medium size civil engineering department in terms of undergraduate students (more than 250 today, with growth of about 10% from 2008 to 2009) but small in terms of faculty, with only eight full time civil engineering faculty, two of whom have significant administrative responsibilities. This contradiction means that our faculty members are overloaded with teaching, research, and professional services with little time to invest in making fundamental changes and improvements in the existing graduate program. In other words, it is difficult to add to our offerings any traditional three-credit graduate courses, which require a substantial commitment of time to prepare and teach. On the other hand, our graduate student population is relatively small and stable with about 50 graduate students. Due to this relatively small enrollment many elective courses are cross-listed as combined undergraduate and graduate courses. The small number of exclusive graduate courses hurts our reputation and makes it more difficult to attract the best domestic and foreign student. Also, the lack of graduate courses in high demand areas such as structures significantly reduces our ability to attract local graduate students.

In this situation, we made a collective decision to pursue two complementary approaches to enhance the quality and content of our post-BS program. The first is a novel educational paradigm called "bridge courses." (Note: the word "bridge" is used metaphorically rather than literally here, even though an example used later is in the area of structural engineering.) The second is a collaboration with industry to identify the most important foci for our graduate programs and to expand our academic programs in these directions. The courses and programs developed through these approaches will serve three purposes: to expand learning opportunities for our undergraduate students; to create attractive courses for our graduate students; and to offer courses to local practicing engineers interested in advancing their careers and planning to become professional engineers. The courses might also help to fill the need for engineers to engage in lifelong learning as a condition for maintaining professional engineering licensure, though serving that need was not a primary design objective.

Bridge Courses

Our concept of bridge courses was based on several assumptions or design criteria:

1. The defined set of bridge courses comprises a flexible system of post-BS 500-level (i.e., first-year graduate) courses. Students are allowed to take various combinations of courses.

2. The courses are intended to expand the knowledge provided in our existing undergraduate courses and to meet the BOK2 outcomes, particularly outcome 15 ("technical specialization"), and to a lesser extent outcomes 7 and 8 ("experiments" and "problem recognition and solving").

3. The courses are offered for our seniors, for graduate students, and for practicing civil engineers who need to acquire at least 30 credit hours in post-BS education to qualify for licensure as a PE.

4. All courses are offered as one-credit units, but each three units in a given area will be an equivalent of a typical three-credit course. The first course in each three-course sequence is available to all students (an introduction and overview of a given area) while the remaining two courses require as a prerequisite the first one. All three units of a specific course topic will typically be offered in the same semester, end-to-end, in the same time slot, which allows progress through the program to be maintained at the normal pace for traditional degree-seeking

students. However the flexible one-credit format means that scheduling exceptions can be made as warranted to meet the demands of any given semester.

5. The scheduling of courses was to be determined later, based on feedback from our students and practicing engineers.

6. After the courses become established and a reliable schedule is developed several new graduate certificates will be considered, including a "Graduate Certificate in Structural Engineering." Conforming to the prevailing pattern for graduate certificates in our School, each such certificate will require 15 credit hours in a specific area.

7. Students taking the "bridge courses" are allowed to use at least part of their credit hours toward the MS degree, as is true of courses taken toward other graduate certificates in our program. However, they also have to satisfy all MS degree requirements, which means taking our required MS courses in addition to the "bridge courses."

8. The levels of cognitive achievements for the individual bridge courses were selected in accordance with those suggested in BOK2.

We decided to develop a flexible system of courses because we believe that such courses are much more attractive to the practicing engineers and our students than the traditional courses. They allow students and engineers to customize their paths depending on their specific needs. For example, an engineer focused on construction management could take only a combination of the introductory courses in various structural engineering areas to develop a breath of understanding of structures, while an engineer specializing in structures will take all courses in various structural sequences to gain depth. Similar statements can be made about the bridge courses defined for other civil and environmental engineering specialty areas.

The one-credit format also has several advantages from a program management standpoint. Due to the small size of our faculty it will be necessary for many of these courses to be taught by qualified practitioners serving as adjunct faculty. Such prospective faculty may be more willing to take on a limited obligation to teach for five or six weeks, as opposed to the usual 16-week commitment for a regular three-credit course. Also the lower credit value allows innovative scheduling such as having the course meet on two or three Saturdays.

The proposed system of one-credit courses is also intended for practicing engineers in our metropolitan area, who are not presently graduate students at our university. Such students may choose courses at our university or they may take courses from a number of local universities or from universities located outside our area, which offer courses through various local branch campuses. For this reason, we compiled information on all graduate courses available in our region to practicing engineers in the individual areas of civil engineering. For example, in structures six other local universities offer a total of 93 courses. This compilation of courses offered by other universities helped us to identify opportunities for development of novel or overlooked course subjects.

The idea of a flexible system of one-credit courses is not entirely new. For example, our program already offers a one-credit course in experimental engineering that is taught at a nearby noted testing and research laboratory. We also offer one-credit modules related to our undergraduate internship program. Other departments in our School offer 1.5 credit courses in subjects such as statistical software and communications technology. However, this is not a common approach to traditional core engineering education subjects, and explaining the concept to the faculty members and adjunct professors required significant effort.

In order to test the proposed bridge course concept, and to produce some proposed actual offerings that could be used to start the program, our initial focus was on advanced structural engineering. Three potential instructors were identified, including one adjunct professor. This "design group" consulted other local practitioners and adjunct faculty and developed seven initial sequences of courses in structures, as shown in Table 1. Detailed course outlines for the entire set of 21 courses (7 areas with 3 one-credit courses per area) were prepared and put through the necessary levels of department, school, and university approval.

Table 1. Example Set of One-Credit Courses for the Structures Area

Area	Courses		
A. Steel Structures	A1. Advanced Steel Structural Design	A2. Steel Space Structures	A3. Steel Skeleton Structures
B. Reinforced Concrete	B1. Advanced Reinforced Concrete Design I	B2. Advanced Reinforced Concrete Design II	B3. Advanced Reinforced Concrete Design III
C. Prestressed Concrete	C1. Introduction to Prestressed Concrete	C2. Prestressed Concrete Flexural Member Design	C3. Prestressed Concrete Compression Member Design
D. Masonry Structures	D1. Reinforced Masonry Design I	D2. Reinforced Masonry Design II	D3. Reinforced Masonry Design III
E. Finite Element Method	E1. Two-Dimensional Finite Elements	E2. Gauss Quadrature in the Finite Element Method	E3. Advanced Finite Element Models and Applications
F. Foundation Engineering	F1. Introduction to Foundation Engineering	F2. Retaining Walls and Sheet Pile Foundations	F3. Piles and Drilled Shaft Foundations
G. Bridge Engineering	G1. Highway Bridge Superstructures	G2. Highway Bridge Concrete Superstructure Design	G3. Highway Bridge Steel Superstructure Design

This set of courses allows students to design sequences to meet their particular needs and interests. For example one such sequence for a student interested in bridge engineering might be:

A1 + B1 + B2 + C1 + C2 + F1 + G1 + G2 + G3

It would likely be difficult to find three traditional 3-credit civil engineering courses that would provide coverage of this set of subjects. Or a student interested in construction engineering and management might choose the 8-credit sequence

A1 + B1 + C1 + D1 + F1 + F2 + F3 + G1.

Our intention is to repeat this process in the other civil engineering technical areas that our program covers. That will require a combination of considering whether or how to parse the existing three-credit courses in those areas, and defining new one-credit modules from the ground up, as was done for the structures area.

Industry-Academy Collaboration

While industry collaboration in developing the structures proposal was achieved by involving practitioners who are active as adjunct faculty in our program, a second approach was used to define needed course offerings in the water resources area. This second approach involved collaboration with the local industry-based group that is our primary partner for serving the civil engineering education needs of our region.

Our department is fortunate to have an exceptionally strong relationship with industry. The Civil Engineering Institute, Inc. (CEI) was founded almost 20 years ago as a not-for-profit corporation with the sole goal of supporting civil engineering education at our university. The Board of Directors of CEI has worked with the department intensely and consistently over many years, providing, among other things: Summer internships for our undergraduates; advice and support for academic programs including ABET reviews, guest speakers and adjunct faculty; and financial support for undergraduate student activities such as steel bridge competitions and international travel by student leaders organized through the ASCE Student Chapter.

This collaboration was expanded in the last year to include intense efforts to develop an improved and expanded graduate curriculum. Several areas of mutual interest to industry and the university were identified. Water resources engineering and construction management were the first two important areas targeted for development. Both had strong support and acknowledged leaders or supporters from industry and the faculty. Water resources engineering was selected as the initial program to be developed, and it will serve as a template for future program development in other areas.

Development of the new graduate thrust in the area of water resources engineering proceeded as follows. A noted local practitioner and CEI Board member led the effort from the industry side. Over six months, a series of meetings was held with multiple industry and faculty representatives to ensure thorough discussion to elaborate the pressing issues confronting industry, to identify which of these issues should be addressed through university graduate education, and to develop an appropriate format for delivery of this education.

The result includes a variety of new or revised water resources engineering courses at the graduate level. The specific courses were developed to address needs of industry but are designed to have high academic standards. These courses may be taken individually to meet students' needs, or a group of them (15 credits or five courses) may be taken to earn a newly established graduate certificate in water resources engineering from the university. This new set of courses now also provides an option for civil engineering MS students to pursue a concentration in water resources engineering.

The development of the academic programs is under the purview of the faculty of the department, but the participating faculty believe that the final product is clearly superior because of the interaction with supportive and enthusiastic industry leaders. Future course enrollments and student and faculty evaluations of instruction will determine if this faculty belief is justified.

The new water resources engineering graduate program was a successful collaboration of industry and the university. The faculty oversaw development of the appropriate courses and programs to ensure academic rigor. Industry representatives provided counsel and support throughout development process. Both are pleased with the process and the final results. And both are convinced of the enhanced quality of the academic programs that resulted from the collaboration.

Conclusions

Our concept of "bridge courses" was developed to energize our stable but not growing graduate education program, and to begin the process of preparing ourselves to meet new demands that will be fostered by the inexorable push toward more education as an entrée into civil engineering practice. This effort had to be undertaken with very limited resources, and without the pull of a large graduate student body that would justify a more traditional approach. At this writing we still do not know the response of our potential students from industry, although we do know that our seniors will enthusiastically enroll in these new courses, even though they are presented in this new and somewhat unfamiliar package of one-credit modules. We know this from experience. As our student numbers and quality have both increased over the past few years the students have been quite vocal in seeking out advanced elective opportunities, and enrolling in our BS/Advanced MS option which essentially allows six credits of advanced study to count toward both degrees.

Our "bridge courses" in the structures area had an internal champion. However we had an entirely different situation in the water resources area, where we enjoyed the leadership and collaboration of a champion from industry. In this case those involved in developing the new educational offerings decided that a traditional three-credit format would better serve their needs. Even in this case, however, we will examine the possibility of offering at least some part of the new program content in the one-credit bridge course format.

The process of developing our post-BS program involved civil engineering practitioners in two important ways. First, they were an integral part of the team defining essential BOK elements that should make up the advanced level body of knowledge within specific areas of civil engineering practice. Second, they were intimately involved in recommending various modes of delivery of this knowledge, in this case as one-credit or three-credit modules, and as new or expanded graduate program emphasis areas or certificates. Equally important was the engagement of a faculty internal champion, and other faculty members as participants. It is hoped that this level of cooperation between industry and academia will continue to strengthen our program, at all levels.

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