AC 2005-185: REAL ENGINEERING PRACTICE IN THE CLASSROOM: CAN ASCE'S BOK BE DONE IN 4 YEARS?

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Summary
The baccalaureate civil engineering program at Western Kentucky University (WKU) is unique in how it integrates practice into the curriculum while also being a joint program with the University of Kentucky. The program graduated the first cohort of students in the Spring Semester of the 2003-04 academic year. The paper briefly discusses how the program was developed in the context of ABET's EC2000, how it compares to ASCE's BOK, and the performance of students. In particular, the authors explore to what degree the joint program at WKU accomplishes the major objectives of ASCE's BOK in a project-based, 4-year program.

Program Background[1,2]

The joint engineering programs at Western Kentucky University (WKU) utilize project-oriented course delivery with emphasis placed on student engagement. Courses are facilitated by faculty who practice engineering via the scholarship of application. Student involvement follows the educational paradigm of learner, observer, assistant, to practitioner.[3] The programs (civil, electrical, and mechanical engineering) arose from discussions and need assessments for engineering education in the South-Central Kentucky region. That study began in 1993 and culminated in a Framework of Agreement in 2001 with all amendments signed in 2004 in time for the first student cohort to graduate in Spring 2004. Identified stakeholders included academic, industrial, political, and economic development leaders of the region and state.

Key goals that emerged from the development process included:

- Project-based engineering programs.
- Activities of faculty and students focused around (applied research) projects for regional industries and other entities.
- Four-year, integrated engineering curricula rather than upper division entry programs.

The state's Council on Postsecondary Education decided to leverage the state's academic engineering resources by coupling the engineering programs at WKU with another of the state's engineering programs. The electrical engineering program is jointly offered with the University of Louisville whereas the civil and mechanical programs are jointly offered with the University of Kentucky.

The essence of the joint relationship is that WKU students enroll in 16 credit hours of technical courses taught by faculty from the respective joint institution via distance learning (Instructional Television, or ITV). ITV utilizes electronic classrooms with two-way audio/visual feeds. Instructors may use web-based tools to electronically conduct office hours in addition to periodic visits to the WKU campus. Official transcripts are housed at the host institution (WKU) and

bear the names of both joint universities. Curricular and programmatic decisions are made by the combined faculty from both institutions with equal voting authority. Each institution has one vote regardless of actual number of identified contributing faculty members. Administrative matters are handled by the host institution. A Steering Committee comprised of the deans and provosts from participating institutions resolves higher-level issues and conflicts.[2]

WKU-UK Joint Program Civil Engineering Degree Overview

The baccalaureate degree in civil engineering (CE) in the joint program requires 136 credit hours, or units. General education requirements total 39 units while math and science requirements add 32 units. The remaining 65 units include required and elective engineering courses. Civil engineering majors must have at least a two-course sequence (depth) in one of four recognized civil engineering sub-disciplines (breadth). Via required courses, students develop depth in structural, geotechnical, and construction engineering. Students then use one of three technical electives to fulfill the depth requirements of the fourth (breadth) area, e.g., surveying, materials, water resources, or transportation. A two-course, two-semester sequence (described later in the paper) culminates the learning experience.

Teachers as Practitioners

WKU faculty members in the joint engineering programs are expected and to participate in regionally relevant engineering activities. Activities may be applied research or practice-based. It is highly desirable that students be engaged with those activities. Professional licensure is expected as is continued professional development. To date, several faculty members have successfully advanced in the tenure-track system based upon the "scholarship of application."[4]

Project-Based Environment

Each of the three joint engineering programs implements the project-based mission in a different way. The mechanical engineering program has a design course at each level (first-year, second-year, etc.) with students receiving instruction and practice in design, communication, computer tools, and ethics. In addition, other courses integrate projects directly into the course delivery.[5]

The project-based mission in the civil engineering program is seen primarily via student deliverables rather than in the organization or description of the curriculum. In most courses, students work in either formal or informal group structures. Deliverables typically require professional style formats. Students also see the project-based emphasis through case studies.

Projects are often selected so that there is a means of validation, often demonstrated via a physical model. For instance, in a recent offering of the materials course, students used a modified version of ACI's Egg Protection Device Competition[6] as motivation for the course project. The essence of the project was to design, fabricate, and test the highest-impact-load resistant plain or reinforced concrete device made of concrete thereby safely and economically protect an egg. Students made choices about admixtures, reinforcement, pre- or post-tensioning, and received bonuses for creative uses of recycled materials.

Culminating Engineering Experience

The culminating engineering design experience occurs in a two-course, two-semester sequence. The first course, CE 400 Civil Engineering Senior Design Seminar, focuses on professional,

ethical, and decision-making issues related to the civil engineering design process. CE 400 is one-credit hour and includes a proposal prepared by the student teams. The second course, CE 498 Senior Project, is a 3-credit hour course. Although the academic credit is unevenly divided amongst the two semesters, the students allocate significant work-hours in both semesters.

For the senior project, student teams typically select the annual national concrete canoe or steel bridge competitions. Key deliverables of the professional component are the project management and engineering science notebooks. The notebooks document design calculations as well as the project management, construction management, asset management, team organization and function, safety, quality control, and cost accounting tasks.

As before, an additional critical feature of proposed projects is the opportunity for a constructed deliverable that can be tested. The proof of concept aspect is a critical element in the feedback system for the projects that is often not available in typical civil engineering senior projects. Projects of this type often require students deliver plans for the development of a tract of land including utilities, surface runoff systems, and/or structural framing plans. However, even if the plans are reviewed by practicing engineers, architects, clients, or a jury panel, opportunities for proof of concept by constructing these facilities are rare.

Rubric for Program Comparison to ASCE's BOK

The rubric shown in Table 1 is adopted from ASCE's Body of Knowledge[7] (BOK). The rubric is a three-level, hierarchical model. The authors have added their interpretation of the BOK rubric in terms of Bloom's hierarchical taxonomy of cognitive skills.[8] Descriptions of behavior criteria are also included to provide a basis for measuring student performance. Ability at a higher level assumes ability at lower levels.

Table 1: Description of BOK Competency Rubric

BOK Level	Bloom's Level(s)	Authors' Behavioral Description
3. Ability	6. Evaluation 5. Synthesis 4. Analysis	• Student can judge the value of various options, material, and concepts when no clear correct or wrong answers exist. • Student can creatively or divergently apply knowledge or skills to produce something new. • Student can apply concepts to new problems that may require breaking complex situations into component parts
2. Understanding	3. Application 2. Comprehension	• Student can apply concepts to a new concrete problem with a relatively constrained solution • Student can explain and/or relate concepts in their own terms perhaps specializing for their intended audience.
1. Recognition	1. Knowledge	• Student can recall, identify, repeat definitions, describe, enumerate, label, list, state terminology, concepts, relationships.

WKU ABET Self-Study and FE Exam Results

WKU's joint engineering programs underwent an ABET review during the Fall 2004 semester. The self-study[1,2] indicated achievement levels at or above the target performance levels for Formal Education as defined in the BOK for Outcomes 1 to 11. These outcomes are essentially ABET outcomes (a) through (k). Areas of improvement identified in the self-study were associated with inclusion of ethics more deeply into the program. Hence, senior project was modified from a single 3-credit course to the two-course sequence described earlier and implemented in the 2004-05 academic year.

It should be noted that the success rate for the Fundamentals of Engineering (FE) exam was 100% (9 students) for academic year 2003-04. Four of these students were in the program's first cohort of students. Overall, the results favorably provide validation of minimum engineering science competency; the aggregate exam results indicated areas of improvement in the areas of ethics and material science. The ethics area was addressed as mentioned earlier. The material science area is not an area of focus in the program and therefore no changes were recommended.

Results from October 2004 indicate that 4 of 7 students passed the exam; all seven took the general PM exam section. National aggregate scores indicate an 81% pass rate for those taking the general section in the PM portion of the exam. No one specific area was noted as a problem area for the October 2004 results although performance in ethics exceeded average national performance levels. It is likely that the higher performance is associated with the students concurrently enrolled in the CE 400 Senior Design Seminar course that focused on ethics. One of the students indicated that he knew going into the exam that he had not sufficiently prepared.

WKU and BOK Outcomes 12 through 15

BOK Outcomes 12 through 15 represent in the authors' minds the significant elements that "raise the bar" for graduates of the future. Outcome 12, ability in a specialized area related to civil engineering, represents technical disciplinary competency. The authors interpret Outcome 12 to include not only the depth and breadth criteria for civil engineering baccalaureate programs but also some level of depth as provided by a typical post-baccalaureate degree program. BOK Outcomes 13 to 15 appear to focus on important skills associated with the context of real civil engineering practice. These include understanding of management (project, construction, and asset; BOK 13), business and public policy and administration fundamentals (BOK 14), and leadership principles (BOK 15).

The target levels set by the BOK and the performance of WKU students for Outcomes 12 thru 15 are shown in Table 2. BOK target levels shown are associated with the formal education context as defined by a baccalaureate experience plus a master's program or 30 additional credit hours (B+M/30). Performance of the WKU students was evaluated from student deliverables such as project reports and oral presentations by mapping the average performance level to the rubric in Table 1. The (B) in the last column of Table 2 emphasizes that the WKU joint engineering programs are baccalaureate only.

Table 2: WKU Performance for BOK Outcomes 12 - 15

BOK Outcome	BOK Target Level for Formal Education (B+M/30)	WKU Performance Level (B)
12. Specialized area of civil engineering.	3. Ability	2. Understanding
13. (a) Elements of project management	1. Recognition	2. Understanding
13. (b) Elements of construction management	1. Recognition	2. Understanding
13. (c) Elements of asset management	1. Recognition	1. Recognition
14. (a) Business fundamentals	1. Recognition	1. Recognition
14. (b) Public policy and administration fundamentals	1. Recognition	2. Understanding†
15. Leadership principles and attitudes	1. Recognition	2. Understanding

†Topics covered in an elective course.

Outcome 12 Specialized Area of Civil Engineering
Although the WKU joint program meets ABET and ASCE criteria for breadth and depth at the baccalaureate level, the program obviously does not reach the B+M/30 criteria even with the project-based delivery mode. Additionally, WKU requires a proportionately greater number of general education requirements (a total of 39 credit hours) than many universities. This is a clear area where the graduates of the WKU joint program would simply need more credit hours to develop a comparable depth of technical competency to meet B+M/30.

Outcome 13 Management Fundamentals
One key feature of the joint civil engineering program is an emphasis on construction engineering. Required courses include CE 303/304 Project and Construction Management and CE 316 Equipment and Methods. CE 303/304 is a 4-credit hour course including a 1-credit hour laboratory (2 contact hours). Topics included in these courses are shown in Table 3 below. In addition to demonstrating proficiency in the listed course topics, students are also required to make a professional quality-based selection presentation. Student groups act as a management firm and must "sell" their management engineering services to a mock local municipality.

Many of the course topics listed in Table 3 compare well with the BOK articulation of Outcome 13 (a) and (b). Elements of asset management are covered only with specific applications to a construction firm. Hence, although students reach at least the Understanding level in this area, they are at the Recognition performance level from a B+M/30 perspective.

Outcome 14 Business, Public Policy and Administration Fundamentals
Within the courses briefly described in Table 3, a number of business fundamentals are covered including legal forms of ownership, organizational structure, income statements, balance sheets, decision economics, finance, billable time, overhead, and profit. The students primarily apply these fundamentals to the private sector. The applications are not of the same type of breadth that one might obtain via a post-baccalaureate experience in construction management and engineering. Hence, evaluation of student performance is placed at the BOK Recognition level.

Table 3: Management Topic in the WKU Joint CE Program

Course	**Topics** (Related to Management; BOK Outcome 13)
CE 303 Construction Management	• Project manager responsibilities • Project delivery systems • Risk assessment and management • Contractor negotiations • Project plans and specifications • Budget, bidding, estimating, planning, scheduling, and time management • Quality assurance, quality control • Dispute resolution, labor, and cost management.
CE 304 Construction Management Laboratory	• Plan and specification reading • Estimating • Scheduling using software (Microsoft Project)
CE 316 Equipment & Methods	• Construction operations • Production processes • Equipment utilization • Maximum production levels • Safety and quality

Public policy and administration fundamentals are covered in an engineering technical elective course (CE 416 Construction Administration). Topics include construction laws and regulations, financing, licensing and permits, electronic project administration, project specifications, public policy, and project safety. For students successfully completing the course, the performance level is observed to be at the BOK Understanding level.

Outcome 15 Leadership Principles

Leadership as a specific topic is addressed throughout the program via development of team citizenship skills. Nearly all CE courses in the program require students to work in groups. However, only specific courses contain formal team training exercises. The phrase "formal training" means specific training about effective team organization, functioning, citizenship, and assessment of individual members. Table 4 below indicates courses with formal team training.

Table 4: Courses with Formal Team Training Exercises

Course	Semester
CE 175 Freshman Experience	1
CE 303 Construction Management	3
CE 382 Structural Analysis	5
CE 383 Structural Steel Design	6
CE 384 Reinforced Concrete Design	7
CE 400 CE Senior Design Seminar	7
CE 498 Senior Project	8

For all aspects of team activities in these courses, students identify specific roles for group members. The roles are then rotated through-out the course. Note that the perspective of "team"

employed here is more general as compared to an applied model such as a building design team. In this latter case, one might discuss the role of the owner, architect, engineer of record, fabricator, etc. When appropriate, students identify and use these roles. More generally, though, students utilize roles such as facilitator, reviewer, preparer, timekeeper, devil's advocate, etc. Other features of the formal team training exercises include team formation, team charters, individual and team expectations and accountability, and communication.

Whenever formal team training occurs, feedback instruments identifying individual citizenship and contributions are implemented. The instruments provide a multiplying factor used to adjust an individual's grade from the team's score at the end of the project. Team citizenship and contributions to the team effort are emphasized rather than academic skill.[9,10] Yet, the point needs to be made that regardless of an individual's level of effort and desire to contribute to the team, the team will first be evaluated based on the team's deliverables. The score from a deficient deliverable is not adjusted into an exemplary individual score. The instruments are also used at the mid-point of the project. Students then have the opportunity to make mid-course adjustments without influencing their course grade.

With regard to *leadership* skills, the rotation of roles in group assignments in prerequisite courses prepares each student to take on leadership roles within their senior project team. The projects in the CE 400/498 sequence are of sufficient scope that each student is expected to take on leadership for an identified project task. The tasks sometimes only involve one or two students but often require three. Hence, some students achieve a BOK level of Recognition in leadership whereas others achieve Ability level in terms of actually being an *effective leader.* Most students achieve at least the BOK Understanding level.

The WKU team training process does not explicitly address BOK topics such as: entrepreneurship, sensitivity, rational thinking, openness, consistency, and discretion with sensitive information. To a lesser or greater degree, these are discussed by the faculty advisor with senior project team leaders on an as needed basis but not typically directly addressed with the teams at large. Some students develop connections between their formal team training exercises and the attitudes and behavior listed above, but not all.

Response to "Can ASCE's BOK be done in 4 years?"

The current WKU baccalaureate program clearly has strengths associated with professional oriented outcomes of the BOK, strengths that distinguish it from other baccalaureate driven programs. Factors that contribute include: (1) the project-oriented environment, (2) the required courses in construction management, and (3) the faculty model of teachers as practitioners (as opposed to researchers). Based upon the BOK, the WKU joint CE program provides value-added to an otherwise traditional and sound undergraduate experience. (The authors avoid, here, the tempting designation "B plus.")

The current program clearly focuses on a construction orientation, an orientation that will evolve in response to recently hired faculty in the materials, structures and water resources areas. One difference between the WKU-UK joint program and the outcomes recommended in the BOK may be in the area of breadth. That is, WKU graduates arguably develop performance skills at or beyond BOK target levels, but are the students able to apply those skills in the breadth of

applications intended by the BOK? Desire to keep graduation criteria to no more than the current level (136 credit hours) likely directs the joint program be the "B" in whatever direction B+M/30 evolves.

Moving Towards B+M/30

The joint program may be in reach of the B+M/30 criteria. If the mandated university general education requirements are reduced by 15 credit hours to 24 credit hours and replaced with technical depth courses, and if in addition the practice community accepts graduates with proficiency in each of the 15 BOK outcomes but not necessarily extensive breadth in each, then the answer to the original question might be a qualified "yes."

Qualifications not only include the "if's" above but also additional questions. For instance, what precisely is meant by application of knowledge of a specialized area? Is this the standard of existing baccalaureate ABET civil engineering specific criteria? Or, is there an implied depth associated with B+M/30? Is there an alternative middle ground? The BOK seems to imply that more technical training is needed beyond the typical baccalaureate degree experience.

In short, then, the answer probably is "no." ASCE's BOK simply requires additional credit hours beyond that available in typical programs and particularly in the existing WKU program. This conclusion should not detract, though, from the significant value added within the WKU program with is project orientation.

Final Comments

The fifteen outcomes set forth by the BOK definitely "raise the bar" for aspiring licensed civil engineers. Overall, the WKU baccalaureate program is at or beyond the BOK target levels for the B+M/30 criteria for many professional oriented aspects. Factors that contribute to this assessment include: (1) a project-oriented environment, (2) required courses in construction management, and (3) a faculty model of teachers as practitioners (as opposed to researchers). Technical depth, though, is limited essentially by credit hour constraints. Curricular restraints from the university likely mean that the WKU program cannot reach the full version of BOK without adding credit hours. However, the intended breadth of the BOK is a critical area that merits deeper formal exploration and may alter the conclusions herein. It does seem possible, though, that the major elements of the BOK may be achievable with a B+15 model, or some variation therein.

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