An Assessment of How the Sooner City Project Addresses ASCE's Body of Knowledge

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Abstract.

ASCE's Policy Statement 465 (PS 465), the result of a decade-long process, outlines the Body of Knowledge (BOK) that students should possess in order to enter the practice of civil engineering. Similar to ABET's EC 2000, PS 465 advocates an outcomes-based assessment by promoting 15 outcomes, 11 of which duplicate the ABET criteria; the four new ones promote greater technical depth and breadth. This initiative is in response to the increasingly complex and broad civil engineering projects of the 21st century.

Since 1996, civil engineering at the University of Oklahoma has also been undertaking a curriculum reform project, Sooner City, for many of the same reasons, i.e., to promote outcomes not normally addressed in traditional civil engineering curricula, such as leadership, design, communication, and critical thinking. Basically, the Sooner City theme unifies the traditional civil engineering curriculum by threading a common design project, civil infrastructure, throughout the curriculum, beginning in the freshman year. To the extent possible, the student learning is project-driven and delivered "just-in-time."

At a workshop in 2004, representatives from the OU faculty and ASCE PS 465 met to assess the extent to which a Sooner City-based curriculum meets BOK outcomes, as well as how Sooner City could be modified to meet more of the BOK outcomes within the confines of the undergraduate degree program. This manuscript, solicited by Stu Walesh for "The Civil Engineering Body of Knowledge Where Are We Today?" session, presents the results of that workshop, which has implications for other schools who use the Sooner City approach to address PS 465.

1. Background of Sooner City.

Basically, Sooner City is a comprehensive, integrated, infrastructure design project that is threaded throughout the University of Oklahoma (OU) civil engineering curriculum, beginning in the freshman year. Freshmen are given a plat of partially developed land that, by the time they graduate, is turned into a blueprint for Sooner City's infrastructure (26). Among other things, the project promotes five outcomes not fully addressed by traditional curricula, but which are emphasized by the NSF Engineering Education Coalitions and ABET 2000: team building, communication, leadership, design, and higher level learning skills.

Starting in 1996, the Sooner City project has been funded by three NSF grants, shown in Table 1, as well as significant support from OU.

Table 1: Summary of NSF Support for Sooner City.

NSF Award Number	NSF Program	Project Title	Amount	Start	End
DUE-9652973	CCD	TLC Design: Integrating Team Learning, Computing, and Design in Undergraduate Engineering Education	$100,000	3/15/97	2/28/00
EEC-9872505	Action Agenda	Sooner City - Design Across the Curriculum	$750,000	9/1/98	8/31/03
EEC-0230681	Planning Grant	Pilot Study for a "Course-less" Curriculum	$100,000	1/1/03	12/31/03

Prior to this NSF support, several of the authors had experimented with integrated design projects within a course. Success with this venture (23, 24) led to a pilot study (first row in Table 1), which explored the possibility of applying this idea to multiple courses. Thus, 1996, the year of the pilot study, represents the "founding" of Sooner City. Further success with these early projects led to the large Action Agenda proposal, which funded the full development of Sooner City, details of which are given below. Our current project (row 3 in Table 1) is discussed at the end of this section.

1.1. Sooner City Project Philosophy.

In the Sooner City project, students are taught to view engineering design as a constrained optimization problem, viz, given a design task, raw data, and constraints (technical, political, economic, or social), they develop the "best" solution from among multiple alternatives. Each engineering course is devoted to a different component of the overall design, but they are structured so that the solution often requires cross-course integration, both vertical (e.g., freshman/junior) and horizontal (e.g., two concurrent senior courses). For example, one design task is to size a water supply reservoir to meet municipal demands. To complete the design, a junior-level water resources class (water supply) interfaces with a senior-level hydrology class (inflows) and a junior-level soil mechanics class (earth dam). Distinct classes act as sub-consultants with design data and calculations shared between them via common meetings, the web, or formal engineering reports.

1.2. Key Features.

Sooner City provides an ideal venue for other reform initiatives, such as team learning, peer mentoring, wireless laptops in the classroom, and just-in-time learning (students gain skills as needed). Thus, students learn technical material using the latest hardware and software, while at the same time learning how to communicate (design reports/presentations), how to function effectively on a team, how to balance the political/social/ethical aspects of engineering projects, how to teach themselves (researching design solutions/new analysis skills), how to engage in higher level thinking skills (critical analysis of multiple design alternatives), how to self-assess (learning portfolios (13, 21)), and how to be effective leaders on projects.

Sooner City's web-based nature (41) facilitates distance learning and outside-of-class activities. Included in the development are content-rich multimedia modules that combine animation, graphics, text, and sound to enhance student learning (37).

Sooner City unifies the curriculum by promoting horizontal and vertical integration, so students learn a holistic systems approach to engineering projects, rather than taking isolated courses that appear as independent entities. Sooner City also provides a framework for multidisciplinary integration.

Sooner City essentially turns the engineering curriculum into a four-year design experience. Consequently, when students enroll in the traditional senior "capstone" course, they are better prepared to handle complex, multidisciplinary projects involving other engineers (mechanical, electrical, and industrial) and environmental scientists, the hallmark of our department's capstone course (20).

1.3. Portability.

Sooner City is very portable, both in concept and in wholesale adoption. Because no change is required in the traditional course sequencing, other civil engineering departments can adopt the design project without a major curricular overhaul (except for, perhaps, an obvious name change in the city!), which enhances faculty buy-in. Moreover, any engineering discipline that requires integration of knowledge to solve complex problems lends itself to the methodology. For example, industrial engineering could identify Sooner Factory and tie operational and managerial studies to this workplace, or petroleum engineering could define the Sooner Bay oil field and tie extraction, transportation, and processing activities to it.

1.4. Local and National Impact.

Within OU's College of Engineering (CoE), Sooner City serves as a catalyst for one of the Dean's strategic initiatives, which seeks to make project-based education the norm for the college. To reach beyond OU, the project team hosted national workshops in 2000 and 2003 attended by 44 faculty from diverse institutions (25). Based on feedback, many of the participants are eager to try to adapt part or all of the Sooner City concept. In fact, a special session at the 2001 ASEE National Conference, organized by workshop participants, was dedicated to project implementation issues. Rowan University is at the forefront of testing the project's portability, with support coming from an NSF A&I (Adaptation and Implementation) grant. The University of Wisconsin-Platteville also received an NSF A&I grant and is piloting some aspects of the Sooner City project. Most recently, we have been contacted by faculty at Texas A&M University, the University of Cincinnati, and the University of Illinois-Chicago about implementation issues. Clearly, the project is serving as a catalyst for infusing more design into the curriculum.

1.5. Indicators of Excellence.

The following metrics indicate the degree to which members of the Sooner City project team have achieved excellence in engineering education.

Selected Educational Awards to Members of the Project Team:

- 3 NSF CAREER Awards (integrating research and education)
- ASEE (American Society for Engineering Education) Fred Merryfield Design Award
- 3 ASEE Dow Outstanding New Faculty Awards
- NSPE (National Society of Professional Engineers) Design in Education Award
- 6 OU teaching and research awards

Regional Awards:

- Oklahoma Regents Instructional Technology Excellence Award (1999)
- Oklahoma Williams Faculty Innovator Award (2000)

Other Project/Individual Recognition:

- 5 Invited Presentations at National Conferences (1998 and 1999 ASEE/NSF Project Showcase, 1998 and 2002 ASCE National Convention, 1998 NSF CAREER Workshop).
- Featured in ASEE's Prism Magazine (4)
- Featured in NSPE's Engineering Times Newsletter (35)
- Featured in OU's "Spotlight on Teaching" Newsletter (14)
- Numerous ASEE journal articles and conference presentations (e.g., 1, 20, 22, 26, 37)

1.6. Current Planning Grant Activities.

As stated earlier, the original Sooner City model fits a systems project into an *existing* "course-dictated" curriculum. The objective of the planning grant (third row in Table 1) is to pilot the concept of a "course-less" curriculum, so that teaching and learning activities are not bound by the constraints of a 50-minute, MWF class format (a system that has been optimized for the traditional lecture/note taking paradigm). In order to realize our long-term vision of a curriculum driven by student projects and student learning (and not by students checking courses off of a list), three essential components must come together: 1) a protocol for delivering technical information on an as-needed basis (i.e., "just-in-time" learning, the subject of the planning grant); 2) well-defined, comprehensive, multidisciplinary projects (e.g., Sooner City); and 3) a flexible, yet rigorous assessment tool in the form of a student learning portfolio (currently in a pilot phase and is the subject of a forthcoming proposal).

The first item above is the subject of the planning grant and will be piloted next year in a junior-level water resources class with fluid mechanics delivered on a just-in-time basis. More specifically, through a series of meetings with faculty who teach fluid mechanics, we dissected the course and identified its core intellectual content. This exercise included identifying topics specific to fluid mechanics (e.g., Bernoulli's equation) and those that are first introduced in other courses and merely applied to new situations in fluid mechanics (e.g., distributed loads and moments of inertia). For each fluid-specific topic, we are developing a self-paced, interactive, stand-alone module to introduce the student to the topic; subsequent *application* of the topic will come through the Sooner City design task at hand. The finished information technology (IT) module will have theory, examples, tutorials, exercises and feedback to the user. An on-line system will track the user progress and present problems at the end of each module for the student to complete. The final product will be presented on the web in the form of an eBook^{TM}, which includes an instructor administrative management system and on-line collaboration tools. Students must master the topic, as indicated by assessment testing, before proceeding to the design task.

2. Need for Engineering Education Reform - A National Imperative.

At many institutions, undergraduate engineering education has become outdated. During the past five decades, the following paradigm, for the most part, has become the norm: lectures on technical concepts, little or no discussion, individual homework on idealized problems, and problem-solving exams. Complex design problems, if used at all, tend to be introduced in upper-level capstone courses. Moreover, many institutions have been slow to adopt IT into the classroom, relying instead on hand-held calculators and traditional design charts and nomographs. While this traditional formula has produced generations of competent design engineers, it is ill-suited to produce graduates who can contribute in a dynamic, team-oriented environment, who have advanced critical thinking skills, who are proficient with computers, and who can communicate effectively with management and the public. This same traditional system is also discouraging many talented engineering students; the attrition rate in engineering exceeds 40% at many leading institutions. Students commonly leave engineering because they fail to see relevance in introductory classes and because of a lack of nurturing during the first few years, particularly by faculty members from the student's chosen discipline. A particularly disturbing aspect of this trend is that it comes at a time when engineering can ill afford to lose the best students to other disciplines. (3, 5, 6, 7, 10, 11, 12, 15, 16, 17, 19, 20, 27, 28, 29, 30, 32, 33, 36, 38, 40)

Engineering education reform is part of a larger movement (8). Perhaps the highest profile report about the need for reinventing undergraduate education came from the Boyer Commission, entitled, *Reinventing Undergraduate Education: A Blueprint for America's Research Universities* (9). According to the commission, research universities have failed the undergraduate student population. The commission recommended ten pivotal approaches to radically improve today's educational paradigm. Likewise, the Kellogg Commission on the Future of State and Land-Grant Universities recommends that we create new learning environments (18). Both commissions indicate that major curricular innovations are needed, not minor adjustments. Seely (34) documents similar major innovations in engineering education in the early part of the 20th century.

Regarding our focus on Sooner City, we note that extensive research has shown the importance of project-based learning for retention and in-depth understanding of concepts (39). A recent resource that provides the scientific basis for project (experiential-based) learning is *How People Learn: Brain, Mind, Experience, and School*, a publication of the National Academy of Sciences that summarizes the current state-of-knowledge with respect to educational pedagogy (31). Table 2, taken from *How People Learn*, illustrates the factors that are important in a well-designed learning experience.

Table 2: Cognitive Activity and the Structure of Knowledge.

Organized Cognitive Activity	Structure of Knowledge	
	Fragmented	Meaningful
Problem representation	Surface features and shallow understanding	Underlying principles and relevant concepts
Strategy use	Undirected trial-and-error problem solving	Efficient, informative, and goal oriented
Self-monitoring	Minimal and sporadic	Ongoing and flexible
Explanation	Single statement of fact or description of superficial factors	Principled & coherent

Referring to Table 2, we note that use of well-designed projects (e.g., Sooner City) facilitates structuring the knowledge to support meaningful learning. For instance, the project context supports the development of goal-oriented strategies. The project structure must be augmented with education and explanation about the underlying principles and concepts. Self-monitoring is reinforced by requiring teamwork and intra-team feedback. Students in Sooner City must continually self-assess the multiple design options.

3. ASCE and the Body of Knowledge (BOK).

ASCE, the predominant professional organization for civil engineering, also recognizes the need for reform in engineering education in order for graduates to meet the challenges of the 21st century: globalization, information technology, a diverse society, new technologies, enhanced public awareness, and a deteriorating infrastructure. A task force (now referred to as CAP^3), has prepared a report that lays out the “Body of Knowledge” that civil engineers should possess in order to meet these challenges (2). CAP^3 proposes to assess whether or not students attain this Body of Knowledge through a flexible, outcomes-based educational matrix (shown in Table 3 below). Note that ASCE recognizes that students cannot reach the same level of competence in all proposed outcomes. Thus, they have defined three levels as follows (2).

- Level 1 - Recognition (familiarity with a concept).
- Level 2 - Understanding (thorough mental grasp and comprehension).
- Level 3 - Ability (capability to perform with competence).

At OU, we evaluated the extent to which the current Sooner City-based curriculum meets the proposed Body of Knowledge; our assessment is shown in Table 3. Information to fill the table came from three sources: 1) data collected for ABET’s a-k criteria (CEES went through an ABET 2000 review in 1999); 2) exit interviews from senior civil engineering students (since 1998, we have asked each graduating student to rate the degree to which their education meets ABET a-k criteria); 3) faculty surveys. In the table, note that an “X” represents the evaluation of our current curriculum, while the gray shading represents the level of competence that ASCE is promoting.

Following the table are justifications for our responses. As can be seen, we believe the Sooner City-based curriculum takes a big step toward meeting the proposed BOK outcomes.

Table 3: Sooner City and ASCE's Body of Knowledge: A Self-Assessment. Gray shading indicates BOK recommendations, while X's indicate Sooner City curriculum.

Outcome	Level of Competence		
	Level 1	Level 2	Level 3
1. Technical core[a]	X	X	X
2. Experiments - analyze and interpret	X	X	X
3. Design	X	X	
4. Inter-disciplinary teams	X	X	
5. Engineering problems	X	X	X
6. Professional and ethical standards	X	X	
7. Communication	X	X	
8. Impact of engineering	X	X	
9. Life-long learning	X	X	
10. Contemporary issues	X	X	
11. Engineering tools	X	X	X
12. Specialized area of civil engineering	X	X	
13. Project mgt., construction and asset mgt.	X		
14. Business and public policy			
15. Leadership	X	X	

a. ABET originally defined this to be proficiency in four areas; ASCE is proposing to define this as understanding in several.

The following provides some of the reasoning for the CEES assessment shown in Table 3.

1. Technical core - Level 3. CEES maintains a science-based approach to engineering education, where students receive a grounding in mathematics, physics, chemistry, and engineering science before embarking on sub-specializations of civil engineering. Through this course sequencing, the students do have an ability in (at least) four areas.
2. Experiments - Level 3. Besides general chemistry and physics labs, six required courses have formal laboratory/field components. In addition, courses that have Sooner City design components use a combination of virtual and real data sets for the projects. Collectively, these experiences provide students with the ability to gather and analyze diverse data sets.
3. Design - Level 2+. Sooner City is all about design, beginning in the freshman year and

culminating with a multidisciplinary project that is organized and evaluated by practitioners. Thus, students successfully completing the curriculum will have had four years of experience with design and all that it entails, which is the reason for the 2+ rating. The only thing preventing a “3” rating is the ability to work through the bid and procurement aspects of design.

4. Inter-disciplinary teams - Level 2. Nearly all courses that have Sooner City projects use teams to complete the tasks, and they are required to work across sub-disciplines of civil engineering through integrated projects (see earlier sections). In capstone, the teams are truly inter-disciplinary, with students from mechanical, electrical, and civil working together on practitioner-driven projects. Students do receive some instruction on team dynamics, including personality testing, but we could infuse more earlier in the curriculum in order to increase their understanding.
5. Engineering problems - Level 3. The open-ended nature of the design problems used in Sooner City requires the students to practice good engineering problem solving skills, e.g., formulating alternative solutions, making assumptions, handling ambiguity, self-assessment, consideration of non-engineering factors, and finding sources of information.
6. Professional and ethical standards - Level 2. Ethical and professional issues are woven into the design projects and capstone, including, in the past, creating realistic scenarios in the context of the course. For example, one semester students collected water quality data for part of a project. The professor then purposely “falsified” some data to make the results look “better” for the intended client; students were confronted with the dilemma of presenting the falsified data, or presenting the original results at the risk of “upsetting” the professor. Afterwards, the students handling of the situation was critiqued. Furthermore, in our CEES seminar course, which is mandatory, students gain additional exposure through guest speakers, case studies, and movies. Finally, a required engineering core course and our pre-capstone course are devoted almost entirely to issues in professional practice.
7. Communication - Level 2. Nearly all Sooner City project courses culminate with the students providing written and oral presentations of their work; students are given guidelines on what makes an effective presentation. Several courses include intermediate progress reports as well. In fact, CEES stresses “communication across the curriculum” so that even non-Sooner City courses often have written or oral reports. Finally, we encourage students to participate in extra-curricular activities, such as the concrete canoe, steel bridge, and environmental (WERC) competitions, which provide more opportunities to practice their communication skills.
8. Impact of engineering - Level 2. As at most universities, OU requires a general education core to provide a broader perspective. Recently, the College of Engineering has taken this a step further by developing general education courses that are more engineering specific (e.g., the history of technology). With Sooner City, we provide projects with “real-world” context, with all the concomitant social, political, and economic issues. Some of these are formally addressed, while others are discussed in general.
9. Life-long learning - Level 2. Once again, the heavy-emphasis in the curriculum on open-ended design problems provides a venue to teach students about self-education, as many solutions require them to expand their knowledge beyond what is typically

covered in a text. We also discuss this issue in the aforementioned CEES seminar class. In addition, some classes have started using "reflective writing" as another means of assessment, as well as a mechanism to have students look inwardly at their own learning and see if they are progressing toward their personal goals. Finally, the senior capstone project further exemplifies the need for life-long learning.

10. Contemporary issues - Level 2. Again, "real-world" Sooner City projects force the students to see the connectedness of their work to the rest of society. This is taken to the next level of competence in the two-semester capstone sequence, where the projects themselves are chosen from complex, contemporary problems, such as the environmental cleanup of the Tar Creek Superfund Site in northeast Oklahoma. For the capstone, we enlist practitioners to help devise and judge the projects.
11. Engineering tools - Level 3. Since 1996, the College of Engineering has required students to purchase wireless laptops so that each classroom can become a networked computer lab. Within the Sooner City curriculum, students learn both general purpose "office" software, as well as industry standard analysis and design tools, such as AutoCAD, Eagle Point, and Haestad Methods. For a specific example, students in our Introduction to Continuum Mechanics course use web-based finite element applications to simulate and visualize sample problems. In general, access to the network gives students the power of the web and the many wonderful applications being developed for that medium.
12. Specialized area of civil engineering - Level 2. Our civil engineering curriculum allows for three professional electives, which the students can use to take a sequence of courses in one specialty area. This, combined with the general core, gives them more in-depth knowledge of a certain sub-discipline. Yet this stops short of "master's-level" knowledge that is being promoted by the BOK.
13. Project management, construction and asset management - Level 1-. Currently, students are introduced to basic concepts in these areas in the capstone and one or two of the earlier Sooner City courses. Students can get "hands-on" lessons in these areas through the aforementioned competitions (e.g., concrete canoe, steel bridge, and environmental design); however, participation is voluntary so the benefits do not reach all students. A required course from OU's construction science department would be needed for all students to reach a higher level of competence.
14. Business and public policy - Level 1-. We show level 1- because these topics are not dealt with in great depth in the Sooner City sequence of courses. The College does require all students to take a sophomore level course, Engineering Practice I, which introduces business and project management principles via a multi-disciplinary engineering design experience. In addition, the College offers courses/seminars on entrepreneurship, and we do allow students to take some of their electives outside of the College of Engineering, including business/policy courses. (Some of these may be required in the future.) Thus, with proper planning, students could reach a full Level 1 competence with the current curriculum.
15. Leadership - Level 2. Item 4 above about teams discusses the project-based nature of the curriculum; items 7 and 13 above discuss extra-curricular activities, such as the concrete canoe, steel bridge and environmental design competitions. (The projects are typically student-run, with faculty taking a secondary role.) Collectively, these venues

provide ample opportunity for students to develop their leadership skills within the context of project teams. Furthermore, the College offers a course in leadership, taught by a retired general from the U.S. Air Force, which many of our students take as a professional elective.

4. Summary.

Because the Sooner City-based curriculum originated out of a desire to address many of the same weaknesses identified by ASCE's CAP^3 task force, it is not surprising that we feel the current curriculum goes a long way toward satisfying proposed BOK outcomes. Except for the areas of technical specialization and business/public policy, we believe we meet or exceed the proposed BOK's level of competence in 13 areas. For the two that we fall short on, we would require some additional education beyond the current curriculum. What form that takes is yet to be determined.

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