

## The ASCE BOK – A Case Study of the Evaluation and Design of a BOK Curriculum

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### Introduction

The American Society of Civil Engineers (ASCE) in ASCE Policy Statement 465 advocates a post baccalaureate educational requirement for professional licensure and broadly describes a body of knowledge (BOK) appropriate for professional licensure<sup>1</sup>. The BOK was more specifically defined in terms of specific knowledge, skills and attitudes necessary to practice as a licensed professional civil engineer by the ASCE Task Committee on Academic Prerequisites for Professional Practice (TCAP<sup>3</sup>). The BOK can be attained through a combination of formal education, both baccalaureate and post-baccalaureate, and experience. Several engineering colleges, including Rose-Hulman Institute of Technology (RHIT), were invited by TCAP<sup>3</sup> to design model curricula compliant with the formal education component of the BOK. We will discuss the process used to evaluate our curriculum with the goal of designing a BOK curriculum within our four-year undergraduate program. Interestingly, TCAP<sup>3</sup> did not explicitly designate what parts of the formal education are to be attained in a baccalaureate program.

Rose-Hulman Institute of Technology is a four-year, private, non-sectarian college of engineering, science, and mathematics located in Terre Haute, IN. Current enrollment is approximately 1,900 students. The most recent freshman profile includes 94 percent in top 20 percent of their high school classes with a median SAT of 1,320 and an average SAT of 30. The Civil Engineering Department consists of 6 faculty and has an enrollment of approximately 110 students. The Department offers a M.S. Environmental Engineering degree.

The BOK consists of 15 outcomes a civil engineer must demonstrate through a combination of formal education and work experience for professional licensure. The first 11 are the “a through k” Accreditation Board for Engineering and Technology (ABET) outcomes:

1. An ability to apply knowledge of *mathematics, science and engineering*
2. An ability to design and conduct *experiments*, as well as *analyze* and *interpret* data
3. An ability to *design* a system, component, or process to meet desired needs
4. An ability to function on *multi-disciplinary teams*
5. An ability to identify, formulate, and solve *engineering problems*
6. An understanding of *professional and ethical responsibility*
7. An ability to *communicate* effectively
8. The broad education necessary to understand the *impact of engineering solutions* in a global and societal context
9. A recognition of the need for, and ability to engage in, *life-long learning*
10. A knowledge of *contemporary issues*

11. An ability to use the techniques, skills, and modern *engineering tools* necessary for engineering practice

The four additional outcomes provide for depth in a specialized technical area, outcome 12, and additional breadth, outcomes 13 through 15:

12. An ability to apply knowledge in a *specialized area related to civil engineering*
13. An understanding of the elements of *project management, construction, and asset management*
14. An understanding of *business and public policy and administration fundamentals*
15. An understanding of the *role of the leader and leadership principles*.

The level of knowledge required for each outcome is identified by three levels of competency: level 1- recognition, level 2 - understanding, and level 3 - ability. Recognition is a reasonable level of familiarity with a subject, understanding is a thorough mental grasp and comprehension of the concept or topic, and ability is the capability to perform with competence. Each level is associated with a setting where that outcome is achieved. For example, the BOK requires the engineer have an understanding (level 2 competency) of the role of the leader and leadership principles (Objective 15). Level 1 competency is achieved in a formal education setting while level 2 competency is achieved through work experience. Formal education is a combination of Bachelor of Science (BS) degree and 30 additional hours of course work or a Masters of Science (MS) degree. The BOK is conveniently represented graphically in Figure 1.

Outcome	Recognition	Understanding	Ability
9 Life-Long Learning		Experience	Post-Licensure
15 Leadership			
14 Business and Public Policy			
13 Management			
10 Contemporary Issues			
8 Impact of Engineering			
6 Professional/Ethical		Experience	Experience
7 Communication			
4 Multi-Disciplinary Teams			
3 Design	Formal Education		
12 Specialized Area			
11 Engineering Tools			
5 Engineering Problems			
2 Experiment, Analyze, Interpret			
1 Technical Core			

Figure 1 BOK Outcomes and level of competencies.

The Civil Engineering Department at RHIT believes there are important aspects of our program and those like ours that should be considered as civil engineering departments begin to formalize a BOK curriculum. In particular:

- Students may exceed the baccalaureate component of the BOK and may approach meeting the BOK within our current 4-year BS program.
- Coursework taken at the B.S. level that exceeds the baccalaureate component of the BOK is not credited towards a post B.S. educational requirement.
- Adoption of BOK guidelines for ABET accreditation can lead to an additional year of study and thus a significantly higher cost associated with additional course work beyond the traditional B.S. degree.
- Departments that do not have extensive graduate course offerings can have difficulty designing a curriculum that meets the complete formal education component of the BOK.

#### A 4-year BS BOK

We first considered whether our current Bachelor of Science curriculum could fulfill the complete formal education component of the BOK without additional course hours added to the curriculum. Our analysis focused on our ability to meet learning objective 12 (an ability to apply knowledge in a specialized area related to civil engineering). RHIT is on the quarter system and a four quarter hour course meets 40 times compared to 45 times for a typical 3-hour semester course. Faculty strive to cover the same, if not more, content as is covered in the equivalent three hour semester course. Techniques to accelerate the learning process include:

- identifying lower level learning that students can do on their own and removing that learning from the course meeting time while still holding students responsible, making room for more high level learning in the subject area
- providing a learning environment that features continuous access to faculty with learning centers near faculty offices so students can reduce “wheel-spinning” as they learn and make their learning more efficient
- continuous improvement efforts by faculty to make learning as efficient as possible

Therefore, we consider a 4-hour quarter course equivalent to a typical 3-hour semester course. Our current civil engineering B.S. degree requires a total of 194 credit hours, or approximately 48 equivalent courses. Conversion of 48 equivalent courses to a traditional semester system suggests our curriculum is equivalent to 144 semester hours.

In addition to an accelerated learning environment, many of our students begin their freshmen year with credit hours earned through advanced placement or transfer credit. We expect to see this trend continue with both the number of students and the credit hours earned. In addition, students are encouraged by faculty to take a humanities course during the summer to earn transfer credit. The result of these events is that many students have effectively decreased their 194 credit hour requirement to 182 credit hours or less. Data from our last three graduating classes show that the median credit hours earned at graduation is 200, six credit hours above the 194 required. These “off curriculum” hours create open credit hours in the curriculum that can be filled with courses that fulfill the BOK.

Our 145 equivalent semester hour curriculum and the use of “off curriculum” credit hours lead us to wonder if the BOK could be satisfied with no or minimal addition of credit hours to our current B.S. program. We needed to add outcomes 12 – 15 into our B.S. curriculum and assessment effort. After some study, we concluded our current B.S. curriculum would require too

much modification to satisfy the complete formal education component of the BOK and that it would be to our students' disadvantage to seek a BOK B.S. Our current B.S. curriculum emphasizes project-based design and a broad civil engineering education, with an outside-client-based senior capstone design project. Therefore, we can not achieve the Specialization Area outcome (outcome 12) with the existing curriculum. Further, it was clear that even with significant modification to the scope of course work, additional credit hours would have to be added to the curriculum. The Civil Engineering Department has a high success rate in graduating students in four years. The additional credit hours may reduce that success and lead to an increase in the cost of our student's education. For their extra effort in completing additional courses in four years, our students would earn only a B.S. degree, hardly a fair trade for the extra cost and better education. We believe our students would be better served by earning a M.S. degree to meet the BOK, especially since this is the likely path that would be followed by most civil engineers in attaining the formal education BOK.

In keeping with the recent findings of the ASCE Curricula Committee, student movement from a B.S. at one school to a M.S. at another school to complete the BOK is best facilitated by all schools seeking consistent BOK coverage at the B.S. level. An appropriate goal is to have all BOK learning outcomes except Specialization Area (number 12) met within the B.S. degree. We believe this is a reasonable recommendation for development of B.S. and M.S. level curricula to meet BOK guidelines.

#### Achieving Specialization – the Master's at Rose-Hulman

Six faculty are in the Department of Civil Engineering at RHIT. Typical teaching course loads for individual faculty are between eight to twelve different courses per year. Despite these heavy loads, the department cannot easily support M.S. degrees in any specialty area other than environmental engineering. Our thesis based M.S. requires 48 quarter hours with 12 hours of research, leaving 36 quarter hours or nine "equivalent" graduate courses at the rate of four quarter hours per course. Our staff cannot easily specialize enough at the graduate level to provide sufficient classes, even with the inclusion of math and engineering science courses offered by other departments. Even so, we are currently modifying the scope of our M.S. in Civil Engineering to permit a structural/geotechnical option. Increased faculty teaching loads will be necessary. Our own students find it difficult to pursue the M.S. in Environmental Engineering because students interested in environmental engineering take some of our graduate courses as senior electives, thus reducing the courses available to them at the M.S. level. In summary, completion of the BOK Learning Outcomes at Rose-Hulman through a traditional technical M.S. might not be an easy matter for our students or faculty.

RHIT offers an exceptional M.S. in Engineering Management. The program has been well received in the professional community throughout central and western Indiana. The course selection is multi-disciplinary and entrepreneurial, and a quality supplement to traditional, technical graduate learning. We have thus concluded that specialization can be achieved by students pursuing either a technical M.S. in Civil Engineering or Environmental Engineering by supplementing an appropriate technical core with selected entrepreneurial Engineering Management courses. We feel technical specialization with additional management and

entrepreneurial training would prepare our students for rapid advancement and success in consulting and engineering management settings.

However, our current credit hour requirements remain a limitation. Though nearly all of our students complete their B.S. in four years, their heavy course load and senior level learning takes them to some extent into the realm of graduate study. Our M.S. requires nine courses plus a research thesis, also a heavy load compared to a traditional M.S. We would like to find a means to offer a combined B.S./M.S. without compromising our current standards. As described above, a review of the number of hours completed by most of our students for their B.S. indicates many of our students already take at least two classes beyond the requirements of their B.S. Many of our students also enter RHIT with 20 or more quarter credit hours before their first day of classes. It would thus seem possible for students to obtain a combined B.S./M.S. by taking perhaps one quarter of classes beyond four years and either completing a thesis or pursuing a non-thesis option that may become available in the future. Though the combined degree does not appear possible in four years, there is evidence that aggressive scheduling and better advising of our students at the freshman and sophomore level could make a BOK B.S./M.S. possible in slightly more than four years.

### The Evaluation and Design Process

Having concluded that our BOK curriculum plan should feature learning outcomes 1-11 and 13-15 in our BS degree, we explored whether we already meet those learning outcomes or whether change was needed. A thorough review of the required courses and course content in our curriculum revealed we did not likely meet BOK learning outcomes to a satisfactory level in learning outcomes 13-15: management, policy and leadership. Further examination of our required curriculum also revealed we might also choose to modify our program to better address outcomes 9 and 10, lifelong learning and contemporary issues. We also studied elective courses taken by our students over the past three years and considered that many of our students come to RHIT with college credit and thus often taken 200 or more credit hours before graduation. We concluded that although many of our students take more than 200 credit hours before receiving their B.S., their course selection does not, in general, help meet the BOK learning outcomes. It became clear that some curriculum evolution would be appropriate to achieve the desired B.S. level BOK outcomes.

We have learned that assessment activities drive our curriculum evolution. The RHIT Student Learning Outcomes are primarily assessed through student portfolios. However, a faculty/senior end of year roundtable, alumni surveys, and alumni employer surveys, among other instruments, encourage continuous improvement and innovation in our curriculum. Based on the insight that these continuous improvement activities clearly influence our curriculum, we resisted the urge to do course versus outcome curriculum mapping and instead examined how our assessment scheme should be modified. An example of this can be found in our current assessment and continuous improvement program. The ten RHIT Outcomes are

- 1) *Ethics* - A recognition of ethical and professional responsibilities
- 2) *Contemporary Issues* - An understanding of how contemporary issues shape and are shaped by mathematics, science, & engineering

- 3) *Global* - An ability to recognize the role of professionals in the global society
- 4) *Culture* - An ability to understand diverse cultural and humanistic traditions
- 5) *Teams* - An ability to work effectively in teams
- 6) *Communication* - An ability to communicate effectively in oral, written, graphical, and visual forms
- 7) *Problem Solving* - An ability to apply the skills and knowledge necessary for mathematical, scientific, and engineering practices
- 8) *Interpreting Data* - An ability to interpret graphical, numerical, and textual data
- 9) *Experiments* - An ability to design and conduct experiments
- 10) *Design* - An ability to design a product or process to satisfy a client's needs subject to constraints

Note the definitions and intended use of “ability” and “understanding” in the RHIT Learning Outcomes are not the same as defined in the BOK. RHIT outcomes 1-6 are assessed by a campus-wide assessment team, while 7-10 are assessed by each department. The RHIT Learning Outcomes in contemporary issues, global and culture extend beyond the minimum requirements of ABET and BOK. We admittedly struggle to meet the outcomes in these areas with a majority of our students to our satisfaction. The presence of a higher standard in these areas, however, is probably because the development of our outcomes and their assessment has been significantly influenced by our non-engineering faculty in the humanities and social sciences, who are some of the leaders in our continuous improvement/assessment processes. We consider this an essential and beneficial component to our curriculum evolution. In addition to the above RHIT outcomes, the Civil Engineering Department includes preparation for life-long learning in the Department Goals.

Multiple criterion within each RHIT and Civil Engineering Department learning outcome encompass more than the ABET outcomes. However, a mapping of RHIT Learning Outcomes to BOK Outcomes reveals the current RHIT and Civil Engineering Department assessment program does not feature learning outcomes in management, policy, and leadership. Regardless of whether the ASCE Body of Knowledge, or something similar, becomes a requirement for professional licensure, these are crucial skills of a professional, and civil engineering departments would do well to examine how their undergraduate curricula satisfy these outcomes. In fact, examination of other professions shows that *service* is also an ideal characteristic of the complete professional. The phrase “pro bono” should be more frequently heard by students during their education. Examination of our total educational process in the Department of Civil Engineering reminded us that service is a significant part of our students’ education, though it is currently not a part of our assessment program. In the BOK, service appears in both outcomes 9 and 14. We are hopeful other civil engineering departments will recognize the presence of service in the BOK and embrace this aspect of the professional with earnest. In summary, while we continue to work for improvement in meeting our current learning outcomes, meeting the BOK guidelines and our own current standards shows we should develop additional learning outcomes in management, policy, leadership and service, plus we should probably move lifelong learning from the department goals to our collection of department-assessed learning outcomes.

Assessment of new outcomes in management, policy, leadership and service would utilize the current tools in use. Within each outcome, we would establish 3 to 6 measurable criterion in

keeping with descriptions of skills already identified in BOK materials. Students would be expected to make submittals to their electronic portfolios to demonstrate competency at the level designated by the department. The BOK has identified that these outcomes need only be met to the lowest level, recognition (level 1). At the recognition level, students would be expected to demonstrate familiarity with a concept without demonstrating a thorough mental grasp or comprehension (understanding – level 2) or ability (level 3). An example of this for the management outcome (BOK Outcome 13) would feature students submitting documentation that would demonstrate familiarity with perhaps three different criterion: management essentials, owner-engineer relationships, and asset management. Once the outcomes and criterion are established, the department would begin encouraging student submittals to each criterion for assessment. Our assessment process includes use of both department faculty and outside alumni or Board of Advisors members to rate student submittals. The inclusion of outside professionals as raters of student work strongly motivates our faculty to assure the students are doing quality work. We think this is an important part of the department's assessment program.

We would expect early submittals to encounter some difficulty in achieving senior-level standards, but feedback from the assessment of portfolio submittals would motivate faculty to reconsider their treatment of these outcomes, and curriculum evolution would begin. In our experience, over a period of years, changes would occur to accommodate better compliance with the learning outcomes, and without making conscious choices to change our curriculum in a single event, the curriculum would evolve to better accommodate student success in meeting our learning outcomes.

Just as the final four of the current RHIT Learning Outcomes are passed on to each department, we believe assessment of the specialization outcome at the Master's level, is a subset of department assessment that should be passed down to the subgroup specialist(s) in the department. We would thus likely not include a department learning outcome in the specialization part of the BOK, but rather leave the identification of adequate specialization to the appropriate department subgroup. Due to the undergraduate emphasis at RHIT, development of the Master's or equivalent component of the BOK remains a challenge that is under review by our faculty.

### New Learning Outcomes

CE Outcome: Students will demonstrate recognition of the need for and an ability to engage in, lifelong learning.

- Criterion 1: Students will demonstrate that they have explored some of the options available to professionals to foster lifelong learning.
- Criterion 2: Students will demonstrate that they have attended and participated in at least one professional development seminar or workshop in the professional community.
- Criterion 3: Students will demonstrate recognition of professional characteristics of service, mentoring, and professional society activity.

CE Outcome: Students will learn the fundamentals of project management, construction, and asset management.

- Criterion 1: Students will understand project management fundamentals
- Criterion 2: Students will demonstrate understanding of owner-engineer-contractor relations.
- Criterion 3: Students will demonstrate recognition of the fundamentals of important elements of construction in the areas of project delivery, scheduling, and cost control.
- Criterion 4: Students will demonstrate understanding of estimating and construction costs.
- Criterion 5: Students will recognize the fundamental elements and importance of asset management

CE Outcome: Students will recognize the importance and fundamental principles and issues associated with business policy, public policy, and administration with respect to the civil engineering profession.

- Criterion 1: Students will recognize the fundamental principles and importance of business policy as applied to successful operation of a civil engineering business.
- Criterion 2: Students will demonstrate recognition of how public policy affects civil engineering practice.
- Criterion 3: Students will demonstrate recognition of how civil engineers can and should play a role in the development of public policy.
- Criterion 4: Students will demonstrate recognition of the role of professionals in community service.
- Criterion 5: Students will demonstrate recognition of the role of administration in the successful operation of civil engineering practice.

CE Outcome: Leadership principles will be a part of the essential knowledge of the students.

- Criterion 1: Students will demonstrate recognition of the fundamental role of professionals serving as leaders in the community.
- Criterion 2: Students will demonstrate recognition of the fundamental principles of leadership and the positive characteristics of many successful leaders.

## Conclusion

Based on a careful review of our curriculum we can not meet the complete formal education component of the BOK with the existing curriculum. In addition, modification of the curriculum to meet the complete formal education component was not considered to be in the best interest of the department or our students. We feel we can meet the BOK with the exception of objective 12 – specialized area of learning. Outcome 12 is best delegated to a M.S. program. RHIT and similar programs without extensive graduate course offerings may have difficulty providing outcome 12 to its students at the M.S. level.



A review of required courses and course content in our curriculum revealed we did not likely meet BOK learning outcomes to a satisfactory level in learning outcomes 13-15: management, policy and leadership. In addition, we need to better address outcomes 9 and 10, lifelong learning and contemporary issues. Instead of using course versus outcome curriculum mapping to drive our curriculum evolution towards the BOK we considered how our assessment scheme should be modified to such that assessment activities drive our curriculum evolution.

#### Bibliography

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