Sequential Course Outcome Linkage: Integrating Learning Outcomes Throughout the Civil Engineering Curriculum to Meet Geotechnical Engineering Needs

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Abstract - The Citadel's Department of Civil and Environmental Engineering has recently adopted an expanded set of twenty-four outcomes identified in the second edition of the American Society of Civil Engineers Body of Knowledge (BOK2) and undertaken work to develop course goals at the appropriate cognitive levels of achievement based on Bloom's taxonomy. In addition, the department has continued to examine and analyze the linkage of individual course goals in various discipline-specific areas of concentration within the curriculum. A major objective has been to develop sequential course outcome maps or "threads" for each of the department's major discipline tracts (structural, environmental, site development, transportation, and geotechnical) to evaluate the effectiveness of continuity in course goals and to provide framework for assessment based on BOK2. This paper describes the process utilized to develop the sequential course outcome maps and presents an example outcome thread for the geotechnical engineering curriculum. As such, this paper examines what constitutes the practice of geotechnical engineering, the associated subject matter that provides a knowledge and skill base for this practice after graduation, the sequence of course material related to geotechnical engineering, and the levels of cognitive achievement expected from students in order to meet the intended BOK2 outcomes. Finally, a summary of findings and recommendations resulting from the development of course threads as a framework for assessment are provided. These findings could be utilized to improve a student's educational experience in the geotechnical engineering area of practice and to better integrate courses and learning objectives within a civil engineering curriculum.

Keywords: ASCE-BOK, ABET, Assessment, Learning Threads, Geotechnical

INTRODUCTION

The American Society of Civil Engineers (ASCE) developed and adopted Policy Statement 465 entitled "Academic Prerequisites for Licensure and Professional Practice." Professional registration could ultimately require a baccalaureate degree plus 30 additional hours of graduation work (B+M/30) as an outcome of this policy [6]. In order to assist in the implementation of this policy on engineering education, ASCE prepared the first Body of Knowledge for the twenty-first century (BOK) to provide guidance for engineering programs regarding what should be taught and learned, how it should be taught and learned, and who should teach and learn it [3].

In response to feedback provided for BOK, the ASCE Body of Knowledge Committee developed the second Body of Knowledge for the twenty-first century (BOK2). ASCE-BOK2 refines the ideas presented in ASCE-BOK by defining: (1) the knowledge, skills, and attitudes required to enter into professional practice, (2) how the BOK can be fulfilled by tomorrow's aspiring engineers, and (3) who should guide the learning of the engineering student and engineer intern [4].

Two substantial changes have been made to ASCE-BOK. First, the number of outcomes has been expanded from 15 to 24 in an effort to enhance clarity and specificity, rather than increase the scope of the body of knowledge [4].

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Additionally, the ASCE-BOK2 officially uses Bloom's Taxonomy as the basis for defining achievement levels. The six levels of Bloom's taxonomy are summarized as follows [7]:

Table 1. Bloom's Taxonomy

Achievement Level	Characterization
Knowledge	consists of facts, conventions, definitions, jargon, technical terms, classification, categories, and criteria.
Comprehension	the ability to understand and grasp the meaning of material, but not necessarily to solve problems or relate it to other material.
Application	the use of abstract ideas in particular concrete situations
Analysis	consists of breaking down complex problems into parts
Synthesis	involves taking pieces and putting them together to make a new whole.
Evaluation	a judgment about a solution, process, design, report, material and so forth using expertise/experience in the area.

Table 2 lists and relates each of the program outcomes of the Accreditation Board for Engineering and Technology (ABET), ASCE-BOK, and ASCE-BOK2. This paper will reference ASCE-BOK2 designations 1-24 as program outcome criteria.

Many academic institutions, including The Citadel, have already integrated ASCE-BOK and Bloom's Taxonomy into the civil engineering curriculum by creating detailed assessment plans and maps. A literature review documenting these processes has previously been presented in Bower et al. [2]. The Citadel recently adopted ASCE-BOK2 and is currently integrating it into the civil engineering curriculum. It is expected that in the near future more academic institutions will continue to integrate ASCE-BOK2 into the assessment process of their curriculum.

The purpose of this paper is to document course objectives within the civil engineering curriculum at The Citadel that the author's feel are essential to the development of the geotechnical engineering curriculum. These course objectives, referred to as threads, have been linked together using ASCE-BOK2 program outcomes and the methodology outlined in Bower et al. [1].

DEFINITION OF GEOTECHNICAL ENGINEERING AT THE CITADEL

In order to properly process and compile data relating to the sequenced course thread in geotechnical engineering, it is necessary for the authors to define what comprises the geotechnical educational background at The Citadel. This educational background is rooted in the definition of geotechnical engineering as used in professional practice. For example, according to the South Carolina Department of Transportation (SCDOT):

"Geotechnical engineering is defined as the investigation and engineering evaluation of earth materials including soil, rock, groundwater, and man-made materials and their interaction with structural foundations, earth retaining structures, and other civil engineering works." [8]

Additionally, the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) clarifies the scope of geotechnical engineering as follows:

"Ground investigation, design, construction, and maintenance for: Building, industrial and offshore foundations, Slopes, Fills and embankments, Retaining structures, Tunnels and underground space facilities, Roads, airport, and industrial pavements, Waste containment systems, Remediation of contaminated sites" [5]

Table 2. ABET/ASCE-BOK/ASCE-BOK2 Comparison [4]

ABET Outcomes a-k	ASCE-BOK Outcomes 1-15	ASCE-BOK2 Outcomes 1-24
a	1. Technical core	1. Mathematics 2. Natural sciences 5. Materials science 6. Mechanics
b	2. Experiments	7. Experiments
c	3. Design	9. Design 10. Sustainability 12. Risk/uncertainty
d	4. Multidisciplinary teams	21. Teamwork
e	5. Engineering problems	8. Problem recognition and solving
f	6. Professional and ethical responsibility	24. Professional and ethical responsibility
g	7. Communication	16. Communication
h	8. Impact of engineering	11. Contemporary issues and historical perspectives
i	9. Lifelong learning	23. Lifelong learning
j	10. Contemporary issues	11. Contemporary issues and historical perspectives 19. Globalization
k	11. Engineering tools	8. Problem recognition and solving
	12. Specialized area related to civil engineering	15. Technical specialization
	13. Project management, construction, and asset management	13. Project management
	14. Business and public policy	17. Public policy 18. Business and public administration
	15. Leadership	20. Leadership 22. Attitudes
	EAC/ABET Criterion 5	3. Humanities 4. Social Sciences
	Program Criteria for Civil and Similarly Named Engineering Programs	14. Breadth in civil engineering areas

Geotechnical engineering is an integral and essential component of almost all engineering projects because the ground is complex and requires specialist skills in order to minimize risks associated with construction, while attempting to reduce costs. [5]

Based on the SCDOT and ISSMGE definitions and the individual course objectives related to geotechnical engineering, the authors define geotechnical engineering as follows:

Geotechnical engineering is the application of scientific and engineering principles to analyze the interaction of earth materials with structural foundations, retaining structures, and other civil engineering works as well as to investigate, evaluate, and design sustainable earthworks systems for serviceability and life safety.

At The Citadel, geotechnical engineering encompasses a range of introductory, fundamental, and practical design topics:

- Introduction to Soil Properties
- Introduction to Soil Classification
- Introduction to Permeability and Groundwater Flow
- Introduction to Subsurface Investigation Methods
- Fundamentals of In-Situ Stresses in Soils
- Fundamentals of Settlements in Soils
- Fundamentals of Shear Stresses and Strength in Soils
- Fundamentals of Lateral Earth Pressures
- Fundamentals of Slope Stability
- Design of Shallow and Deep Foundation Systems
- Design of Earth Retaining Structures

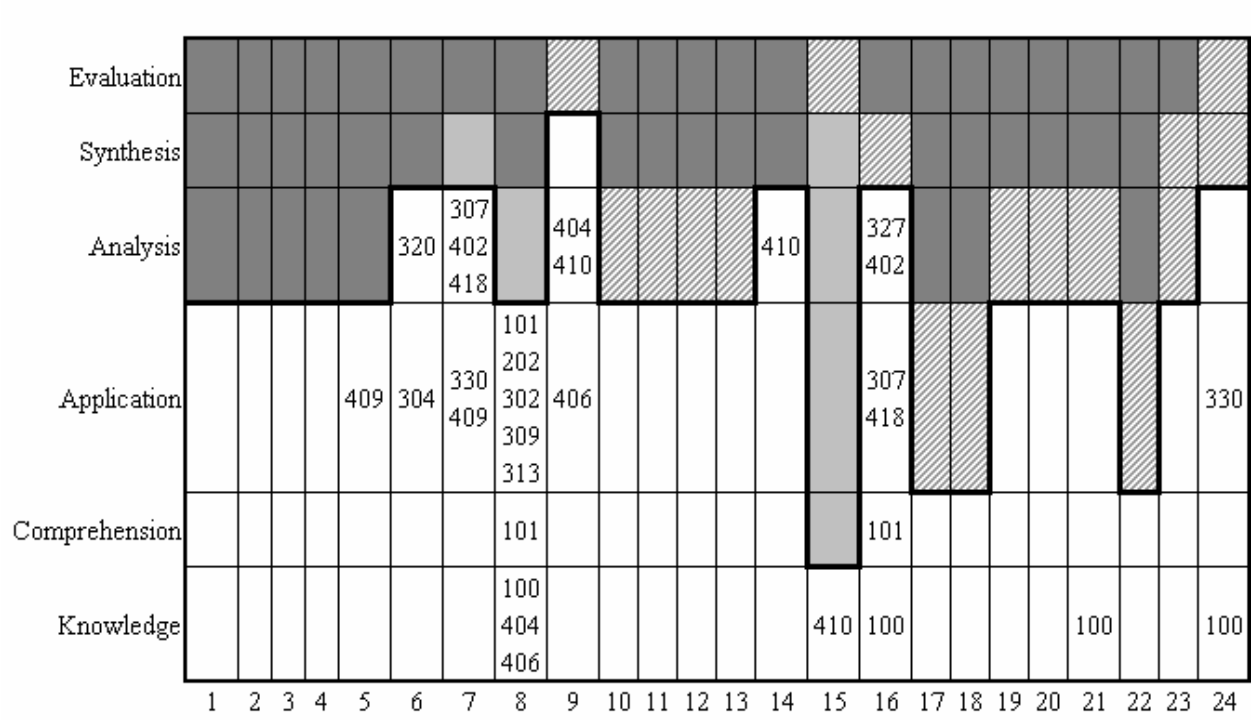
This broad definition of geotechnical engineering provides a generalized context from which the authors can discuss, assess, and improve a sequenced course thread with regards to the geotechnical engineering specialized sub discipline tract.

SEQUENCED COURSE THREAD FOR GEOTECHNICAL ENGINEERING

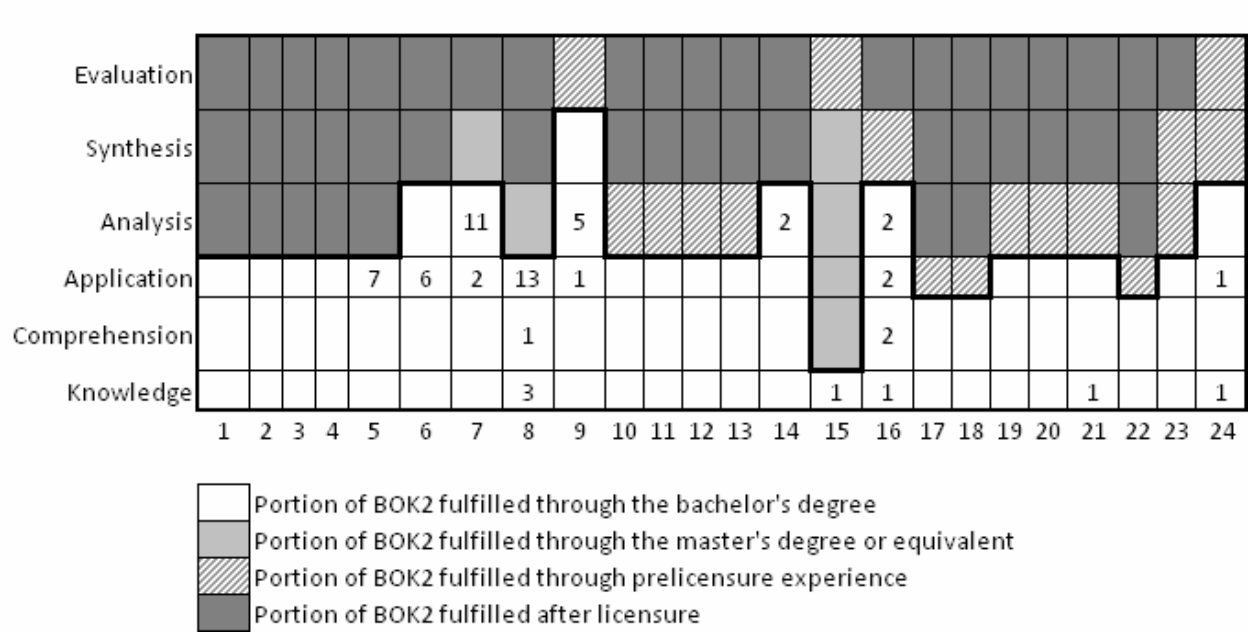
The creation of sequenced course threads for each of the major discipline tracts within the Civil and Environmental Engineering program allows faculty to examine the links between course goals across the four-year undergraduate curriculum. Table 3 demonstrates these links for the geotechnical thread by providing a list of the number of course goals across the curriculum and the associated ASCE-BOK2 outcomes. It provides an illustration of each course containing an objective related to geotechnical engineering, and the BOK2 outcomes to which these objectives are mapped. Table 3 facilitates further analysis of the geotechnical engineering thread. Another useful method to map the course goals related to geotechnical engineering was to cross-tabulate ASCE-BOK2 outcomes with Bloom's levels of competency across the number of contributing course goals listed in Table 3. Figure 1 provides a useful manner to visualize the distribution of course goals across both cognitive level of competency and BOK2 program outcomes for the geotechnical course thread. For example, Figure 1a demonstrates that there are course goals for CIVL 410 that address ASCE-BOK2 Outcomes 9 and 14 at the Analysis level of competency and ASCE-BOK2 Outcome 15 at the Knowledge level of competency. Additionally, the data can also be tabulated as in Figure 1b where only the number of course goals for each ASCE-BOK2 outcome is specified for a given competency level.

Table 3. Sequenced Course Thread – Courses within Curriculum which contain Course Goals Related to Geotechnical Engineering

Semester	Course No.	Course Title	Number of Contributing Course Goals	BOK Outcomes	BOK2 Outcomes
Fresh. 1st	CIVL 100	Introduction to CEE	4	4,5,6,7	8,16,21,24
Fresh. 2nd	CIVL 101	Engineering Graphics	3	7,11	8,16
Soph. 1st	CIVL 209	Computer Applications for CEE	5	11	8
Soph. 2nd	CIVL 202	Statics	6	5	8
Jr. 1st	CIVL 330	Measurements	3	1,2,6	7,12,24
Jr. 1st	CIVL 304	Mechanics of Materials	4	1	6
Jr. 1st	CIVL 307	Materials Laboratory	3	2,7	7,16
Jr. 1st	CIVL 320	Fluid Mechanics	2	1	6
Jr. 2nd	CIVL 302	Highway Engineering	5	11	8
Jr. 2nd	CIVL 322	Intro to Environmental	1	5	8
Jr. 2nd	CIVL 309	Structural Analysis	1	5	8
Jr. 2nd	CIVL 327	Asphalt & Concrete Lab	1	7	16
Sr. 1st	CIVL 409	Introduction to Geotechnical Engineering	8	2,5	5,7
Sr. 1st	CIVL 404	Reinforced Concrete Design	2	3,5	8,9
Sr. 1st	CIVL 418	Fluid Mechanics Lab	2	2,7	7,16
Sr. 2nd	CIVL 402	Geotechnical Engineering Lab	9	2,7	7,16
Sr. 2nd	CIVL 410	Geotechnical Engineering II	7	3,12	9,14,15
Sr. 2nd	CIVL 406	Steel Design	2	3,5	8,9



(a)



(b)

Figure 1. ASCE-BOK2 Outcomes versus Bloom's Levels of Competency for (a) Courses in the Geotechnical Engineering Sequenced Thread, and (b) Number of Course Goals in the Geotechnical Engineering Sequenced Thread.

Table 3 and Figure 1 were developed to organize the data in a way that provides meaningful insights about the instructional progression of students through the curriculum at The Citadel within the geotechnical engineering sub discipline tract. The data were tabulated such that relationships could be evaluated between the course subject goals, program outcomes, and levels of competency. The analysis and evaluation of these relationships is presented collectively due to the linked nature of the course goal, outcome, and competency data. A number of interesting and useful quantifiable observations regarding the geotechnical engineering curriculum can be noted from the data presented in Table 3 and Figure 1:

- Of the 31 courses offered within the departmental curriculum, 18 courses contain elements of geotechnical engineering and are presented in the geotechnical sequenced course thread in Table 3. The number of applicable course goals varies considerably. For example, only one course goal in CIVL 327 Asphalt and Concrete Lab is applicable to the geotechnical thread, whereas all the course goals for fundamental courses such as CIVL 409 Introduction to Geotechnical Engineering contribute to the instructional thread.

- In total, students are exposed to 69 individual course goals within the sequenced course thread for geotechnical engineering, as tabulated in Table 3. Additionally, geotechnical engineering subject matter is presented to all students during every semester of the four-year undergraduate curriculum.

- Examining the course goals and ASCE-BOK2 outcomes as tabulated in Figure 1a, it is observed that 11 of the 24 ASCE-BOK2 outcomes are addressed within the courses linked to the geotechnical engineering thread.

- Figure 1a illustrates that 100 and 300 level (introductory) courses taken during the freshman and junior years appear more towards the lower range of the Bloom's taxonomy scale, which is consistent with a sound sequential educational process.

- As illustrated in Figure 1, the highest concentration of course goals is spread across ASCE-BOK2 outcomes 7, 8, and 9 which correspond to Experiments, Problem Recognition and Solving, and Design. This demonstrates that a considerable amount of instruction is focused on these key engineering skills over a large number of courses in the curriculum within the geotechnical instructional thread.

- The tabulations from Figure 1 also allow the identification of gaps in the distribution of course goals within the sequenced course threads. This is apparent for ASCE-BOK2 outcome 7 (Experiments) where only 2 of the 4 levels of Bloom's taxonomy are covered and outcome 9 (Design) where only 2 of the 5 levels are covered. The department is in the process of developing a plan to address these discontinuities.

- A number of prerequisites are required prior to the main geotechnical courses, which are taught in the senior year. These prerequisites are primarily taken the during a student's junior year in the curriculum. As illustrated in Figure 1, it would be expected that a large number of those prerequisite course objectives appear for ASCE-BOK2 outcomes at Bloom's levels 3 and 4, which correspond to Application and Analysis.

- Examining the distribution of course goals in Figure 1, it is evident that there are very few course goals within the geotechnical engineering thread associated with ASCE-BOK2 outcomes 1-4, 10-13, 17-20, and 22-23. A plan is currently being developed to address this for outcome 12, Risk/Uncertainty, because this subject matter plays a significant role in geotechnical engineering. The other outcomes are

more broad-based in application across all discipline concentrations and should be evaluated at the curriculum level, independent of specific discipline tracts.

SUMMARY

Development of sequenced course threads for each of the sub discipline tracts within the curriculum and subsequent analysis of the linked course goals with respect to ASCE-BOK2 outcomes and Bloom's levels of competency have proven to be an effective method of evaluating the educational subject matter presented throughout the curriculum. Use of this framework allows the department a more efficient and systematic method to assess course goals and outcomes as well as a means for continuous course improvements. Plans are underway by the department to examine sequenced course threads for all disciplines of civil engineering (structural, site development, transportation, and environmental) with respect to ASCE-BOK2. Additionally, development is also underway of a uniform means for evaluating the more broad-based outcomes at the curriculum level, independent of discipline specific tracts.

CONCLUSIONS

The authors feel that other civil engineering faculty faced with similar assessment requirements might find benefits to their programs by incorporating the thread analysis approach that is presented in this paper. Some of these benefits could include improved continuity of course content throughout their curriculum, validation of essential course prerequisite requirements, while possibly adding or eliminating other prerequisites to streamline their curriculum.

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