# Integrating Learning Outcomes Throughout the Civil Engineering Curriculum to Meet Site Engineering Prerequisite Needs

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**Abstract** – The Accreditation Board for Engineering and Technology (ABET) has promulgated criteria for accrediting engineering programs in the United States under the heading ***ABET Engineering Criteria 2000***. Criterion 3 sets forth outcomes that every accredited engineering program must demonstrate that their graduates meet, using a process of assessment. These program objectives are commonly referred to as "a" through "k" outcomes. The American Society of Civil Engineers (ASCE) has published ***Civil Engineering Body of Knowledge for the 21st Century—Preparing the Civil Engineer for the Future***. This publication, which supports ***ABET's Engineering Criteria 2000***, has been referred to as the "Body of Knowledge" (BOK) by ASCE's Committee on Academic Prerequisites for Professional Practice. It describes what should be taught and learned, and incorporates the eleven "a" through "k" ABET outcomes while adding four additional ones addressing technical specialization, project management, construction, asset management, business and public policy and administration, and leadership. The BOK further delineates what level of competence a student is expected to achieve for each of the fifteen outcomes from either a Bachelor's Degree program plus a Master's Degree (or 30 hours plus experience) (**B+M/30**), additional experience, or additional post-licensure education and experience.

This paper examines what constitutes the practice of site engineering, the associated subject matter that provides a knowledge and skill base that will serve as a foundation required for this practice after graduation, the sequencing of material relating to site engineering as to when it should be presented to students, and at the level of achievement expected from the students in order to meet the intended ABET and BOK outcomes. One undergraduate institution's individual course goals are examined for subject matter pertaining to site engineering. Those particular courses that are involved are then further evaluated to see if, across the curriculum, the necessary subject matter is included. In addition, the continuity and sequencing of material between the freshman and senior level courses is checked. This paper also examines the role that "threads of knowledge" established by individual course goals play in creating/meeting pre-requisite requirements necessary to establish continuity of learning throughout the curriculum.

Finally, this paper provides a summary of findings and recommendations for improving a student's educational experience in the site engineering area of practice that could be used to better integrate courses within the curriculum.

*Keywords:* Prerequisites, Curriculum, Site Engineering, Learning Outcomes, Bloom's Taxonomy, ASCE BOK.

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## INTRODUCTION

The Accreditation Board for Engineering and Technology (ABET) has promulgated criteria for accrediting engineering programs in the United States under the heading ABET Engineering Criteria 2000. Criterion 2 provides for each institution seeking accreditation or re-accreditation to have in place a published list of program outcomes that are supported by a curriculum and process of ongoing evaluation that demonstrates achievement as well as continual efforts to improve program effectiveness. Criterion 3 provides for outcomes that every accredited engineering program must demonstrate that their graduates meet, using a process of assessment. These program objectives are commonly referred to as “a” through “k” outcomes. In addition, ABET has incorporated accreditation/re-accreditation provisions from the American Society of Civil Engineers (ASCE) pertaining to programs entitled “civil and similarly named engineering programs”, where graduates must demonstrate proficiency in at least four of the recognized major areas of civil engineering practice. Generally, these areas can include construction engineering, environmental engineering, fire protection engineering, general civil engineering, geotechnical engineering, material science engineering, structural engineering, surveying engineering, transportation engineering, and water resources engineering, Site engineering falls under the practice of general civil engineering.

ASCE has also published “Civil Engineering Body of Knowledge for the 21st Century—Preparing the Civil Engineer for the Future.” This publication has been referred to as the “Body of Knowledge” (BOK) by ASCE’s Committee on Academic Prerequisites for Professional Practice. It delineates skills that students should learn, and incorporates the eleven “a” through “k” ABET outcomes while adding four additional ones addressing technical specialization, project management, construction, asset management, business and public policy, and leadership (Table 1). The BOK further delineates what level of competence a student is expected to achieve for each of the fifteen outcomes from either a Bachelor’s Degree program plus a Master’s Degree (or 30 hours plus experience) (B+M/30), additional experience, or additional post-licensure education and experience.

**Table 1 ABET/ASCE-BOK Comparison.** [4]

| ABET<br>Criterion 3, a –k | ASCE-BOK<br>Outcomes, 1 – 15 |
|---|---|
| a | 1. Technical core |
| b | 2. Experiments/analyze and interpret |
| c | 3. Design |
| d | 4. Multi-disciplinary teams |
| e | 5. Engineering problems |
| f | 6. Professional and ethical standards |
| g | 7. Communication |
| h | 8. Impact of engineering |
| i | 9. Life-long learning |
| j | 10. Contemporary issues |
| k | 11. Engineering tools |
| | 12. Specialized area of civil engineering |
| | 13. Project management, construction and asset management |
| | 14. Business and public policy |
| | 15. Leadership |

### Defining Site Engineering

Site engineering generally involves the process of creating (and usually implementing) a plan to improve the conditions on a site, or parcel of land, so that some intended or desired activity can take place there because of the improvements being made. In addition to the client, civil engineers practicing site engineering are required to work closely with the land surveyors who provide the measurements defining the existing topographic and cartographic conditions at the locale where the improvements will take place. The scope of activity can range all the way from improving a piece of property in its natural state into a developed site to altering previously made improvements on an already developed site. Improvements typically involve new or improved roads, storm drainage, potable water, and sanitary sewer systems, and can generally include site grading & paving, drainage, flood control, utilities, roadways, sedimentation & erosion control, and parcel configuration. A good example of a large site engineering project would be an improved land subdivision. In this case, a developer's project initially involves an unimproved piece of property that is converted into a site having new roads, storm drainage, water, and sewer systems. These improvements are available to service newly created residential lots that either individuals or builders can purchase upon which to construct a dwelling unit. A small site engineering project might involve a small neighborhood "tot-lot" where some minor earthwork is involved.

Whatever the size of the project, the proposed improvements must be integrated properly on site, as well as with the environment and the surrounding neighborhood, community, and region. Because site engineering involves a wide range of activities, practitioners are usually required to meet and communicate with many different parties, including affected neighborhoods, town/city & county officials, as well as those involved at the regional, state, or federal levels.

**What a Site Engineer Does**

Because site engineering falls under the practice of "general civil engineering", the practitioner must be versed in many different aspects of civil engineering that focus on land improvements. In the beginning, the site engineer must be able to clearly communicate with the client about the intended scope of work to be provided, and the relationship of the site engineer with other involved professionals of the multi-disciplinary project team.

Every site engineering project begins with an inventory of existing conditions. This involves a boundary and topographic map of the site and possibly surrounding area. Site conditions relating to geotechnical factors, flood plane proximity, historic & natural resource features, environmental assessment, availability of utilities, wetlands, determination of the presence of endangered species, traffic & transportation conditions, site drainage features, and adverse noise conditions must be evaluated as warranted—depending on the scope of the project. In addition, information pertaining to land use planning, zoning, and development regulations must be obtained and used as part of the process in evaluating the suitability of the site for the purpose the client intends. Some sites are unsuitable for a client's use, while others may be better suited that others. Less suited sites, if chosen by the client, usually involve additional improvements to overcome the deficiencies, resulting in increased construction time and costs. Therefore, knowledge of costs and how to estimate construction time is important to the site engineer.

When the background information is acquired, the site engineer can begin the process of evaluating the good and bad points of the site under investigation, while considering the client's intentions. Usually the client has an idea, or theme, that would guide in the preparation of the conceptual plans. Themes can include residential developments with golf courses or marinas, site work associated with commercial office building parks, commercial shopping centers, recreational parks, schools, medical facilities, or libraries. Once the client chooses the conceptual plan to be followed, the site engineer then undertakes a preliminary design of the various improvements, and produces a preliminary plan and cost estimate that is approved by the client and financial institution, if one is involved. Once these approvals are obtained, the site engineer must seek preliminary project approval from all local, regional, state, and applicable federal regulatory agencies. Whenever approval is obtained from all involved agencies, the site engineer can then proceed with the final design of the project. This involves the preparation of the final construction drawings, bid documents, construction specifications, estimated project construction schedule, and final cost estimate. Again, once the client and financial institution approve these documents, the site engineer must re-submit and obtain final approval for construction from the previously contacted regulatory agencies.

During the construction phase, the site engineer may assist the client in procuring a contractor to construct the project in accordance with the approved plans and specifications through the competitive bid process. Once the contractor begins work, the site engineer monitors progress, and can further assist the client by processing contractor requests for payment, review of shop drawings, and conducting the final inspection. The amount of involvement is decided by the client and site engineer based on the scope of the project.

From the varied activities involved with site engineering, one can readily see that the site engineer must have a foundation in mathematics and science fundamentals. In addition he or she must have the ability to communicate well (verbally, when writing, and graphically), as well as work as a member of a multi-disciplinary team. The site engineer must also possess design skills and be familiar with various activities involving land surveying, transportation & highway engineering, water resources & hydrology, environmental engineering of water and sewer systems, geotechnical engineering, and know how costs and construction time impacts a project's potential for success. Along with all of this, the site engineer must be grounded in good ethical behavior and possess an excellent professional work ethic. In order to be prepared as an entry level engineer beginning to practice in the area of site engineering, one's undergraduate coursework must be structured to impart to the student the required knowledge and skills to undertake these varied activities.

## EXAMINATION OF ONE INSTITUTION'S CURRICULUM AS IT RELATES TO SITE ENGINEERING

The Department of Civil and Environmental Engineering at The Citadel has a long history of graduates entering the practice of Civil Engineering as site engineers. Notably, over the past 30 years, one hundred percent of the graduating students having an interest in site engineering, have had jobs before graduation. Therefore, in order to satisfy this sector of the department's stakeholders—in this case potential employers looking for site engineers, an effort has been made along the way to insure that those students interested in site engineering be given an opportunity as undergraduates to obtain enough skill and knowledge to be productive as entry level site engineers upon graduation. Each student graduating from the program must complete twenty-nine required core courses offered by the department covering all aspects of the practice of Civil Engineering, using the classical approach. The opportunity to specialize is limited to two additional courses offered during the senior year. For students interested in site engineering, they can enroll in a technical elective (Civl 421—Subdivision Planning and Design) and a follow-up elective capstone type course (Civl 425—Comprehensive Design Project in Engineering Practice).

The department recently adopted the ASCE BOK as a basis for conducting course assessment. As part of the process, individual course goals have been evaluated and modified for improved alignment with the BOK outcomes. In addition, each goal has also been given a level of desired competency based on six levels of Bloom's taxonomy summarized in Table 2 below [9].

**Table 2 Summary of the six levels of Bloom's taxonomy.**

| | |
|---|---|
| Knowledge | Consists of facts, conventions, definitions, jargon, technical terms, classifications, categories, and criteria |
| Comprehension | Ability to understand and grasp the meaning of material, but not necessarily to solve problems or relate 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. |

One of the issues involved with this assessment of individual course goals is centered on how material relating to site engineering was being presented to students, and what level of achievement should be expected from the students to meet intended ABET and BOK outcomes. The courses involved were further evaluated to see if, across the curriculum, the necessary subject matter was included, and that there was continuity and a proper sequencing of material between the freshman and senior level courses as indicated in Table 3.

**Table 3 Course goals and ASCE-BOK outcomes for various courses relating to site engineering.**

| Course No. | Course Title | Course Goals Relating to Site Engineering | ASCE- BOK Outcome |
|---|---|---|---|
| Civl 100 | Intro to Civil and Environ. Eng. | 3 | 1,3,4,5,6,11 |
| Civl 101 | Engineering Drawing | 4 | 5,7,11 |
| Civl 205 | Surveying | 5 | 1,2,5,6,11 |
| Civl 207 | Geomatics | 7 | 1,2,6,7,8,11 |
| Civl 235 | Surveying Laboratory | 5 | 1,2,6,7,11 |
| Civl 237 | Geomatics Laboratory | 5 | 1,2,4,8,11 |
| Civl 302 | Highway Engineering | 7 | 1,5,8,10,11,12,13 |
| Civl 305 | Transportation Engineering | 5 | 1,3,5,6,8,10,11,14 |
| Civl 312 | Intro to Environmental Eng. | 2 | 5,8,10,12 |
| Civl 313 | Hydrology and Water Resources | 9 | 1,3,5,8 |
| Civl 314 | Engineering Administration | 4 | 1,5,6 |
| Civl 315 | Fluid Mechanics | 7 | 1,5 |
| Civl 327 | Asphalt and Concrete Lab | 6 | 1,2,3,7,11 |
| Civl 408 | Water & Wastewater Systems | 4 | 1,2,5,10,11,12 |
| Civl 409 | Introduction to Geotechnical Eng. | 8 | 1,2,5,7,11 |
| Civl 410 | Geotechnical Engineering II | 4 | 1,3,5,11 |
| Civl 418 | Fluid Mechanics Laboratory | 9 | 1,2,5,7,11 |
| Civl 419 | Environmental Engineering Lab | 1 | 1,2,7,11,12 |
| Civl 421 | Subdivision Planning and Design | 6 | 1,3,5,6,7,8,10,11,12,13 |
| Civl 425 | Comprehensive Design Project in Engineering Practice | 6 | 1,3,4,5,6,7,8,9,11,12,13 |

Using the twenty courses involved with site engineering shown above, a further examination was made to determine the number of course goals that met each of the cognitive levels as outlined in Table 2. The findings are shown below in Table 4.

Further analysis using the goals from the courses depicted in Table 3 was made in Table 5 where each goal was mapped to its appropriate cognitive level as it was applied to the ASCE BOK outcomes matrix shown in Table 1. The order in which the BOK outcomes are shown along the abscissa conforms to that contained in the ASCE BOK.

**Table 4 Number of curriculum goals meeting various cognitive levels.**

| Bloom's Levels | Freshman | Sophomore | Junior | Senior |
|---|---|---|---|---|
| Knowledge | 2 | 4 | 8 | 4 |
| Comprehension | 5 | 7 | 6 | 5 |
| Application | | 10 | 19 | 16 |
| Analysis | | 1 | 7 | 8 |
| Synthesis | | | | 5 |
| Evaluation | | | | |

**Table 5 ASCE BOK outcomes matrix—site engineering curriculum threads.**

| | Technical Core | Experiments/analyze & interpret | Engineering problems | Engineering Tools | Specialized area of CE | Design | Multidisciplinary teams | Communication | Life-long learning | Professional & Ethical standards | Impact of engineering | Contemporary Issues | Project Management, etc. | Business & public policy | Leadership |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evaluation | | | | | | Experience | | | | Post-Licensure | | | | | |
| Synthesis | 4 | | 5 | 3 | 2 | 5 | | | | | | | | | |
| Analysis | 11 | 5 | 9 | 9 | 5 | 5 | | 4 | | | 1 | | Experience | | |
| Application | 37 | 16 | 31 | 21 | 1 | 6 | 1 | 13 | | 1 | 1 | 1 | 1 | | |
| Comprehension | 7 | 3 | 9 | 8 | 1 | 1 | 1 | 6 | | 3 | 4 | 1 | 2 | | |
| Knowledge | 4 | | 4 | 4 | 2 | 1 | 1 | 2 | 1 | 4 | 4 | 5 | | 1 | |

## Summary of Findings and Recommendations

Because site engineering cuts across the spectrum of non-structural practice areas within the umbrella of Civil Engineering, a variety of courses are required to adequately provide a foundation upon which an undergraduate student is able to acquire the necessary site engineering skills and knowledge. As a result, these courses cover various topics at different levels of complexity, making it imperative that they be structured in a manner to provide continuity throughout the curriculum. Beginning with freshman level introductory courses, each subsequent offering has to be properly sequenced so that students can incrementally build their knowledge and skill base throughout their four year undergraduate experience. Proper course sequencing must also consider the role that service courses (such as mathematics, physics, etc.) play in expanding a student's knowledge, where the timing of the introduction of certain site engineering topics must be coordinated with service course topics. For these reasons, the necessity for properly establishing pre-requisite and co-requisite course requirements is paramount to ensure that the “threads of knowledge” established by individual course goals provide curriculum continuity. A summary follows:

- ♦ Twenty courses offered within the department’s thirty-one course curriculum contain goals that are congruent with the subject matter associated with the practice of site engineering. Table 3 indicates that throughout a student’s undergraduate experience, the number and complexity of courses increases as one progresses from year to year. In addition, Table 3 depicts a fairly balanced distribution of one hundred and seven course goals. When comparing individual courses, a fairly uniform learning environment throughout the curriculum is achieved with an average of around five goals being targeted by each course. This helps avoid having the student learn everything during the last semester before graduation. Table 3 also provides insight on progress being made to achieve the ASCE BOK outcomes. As illustrated, a fairly uniform distribution of these outcomes are targeted by each course, when considering the overall curriculum.

- ♦ When assessing the site engineering curriculum for evidence of increasing complexity in learned knowledge and skills, Table 4 is useful. The one hundred and seven goals are shown to map in a pattern that indicates increased complexity using Bloom’s taxonomy. The seven course goals associated with freshman year courses need to be at the Knowledge and Comprehension levels as one embarks on his or her graduation plan. Table 4 nicely depicts that the course goals, as currently structured, do provide an opportunity for students to incrementally increase their knowledge and skills level throughout the curriculum.

- ♦ When examining site engineering “threads of knowledge” throughout the curriculum, the use of Table 5 is helpful. The number of threads measured against ASCE’s BOK (1) technical core, (5) engineering problems, (11) engineering tools, (12) specialized area of civil engineering, and (3) design indicate numerous measurements that are well distributed from basic knowledge to the ability to synthesize in these various areas. BOK outcome (2)—the ability to design experiments and analyze/interpret data—sets forth a standard of “Ability” for student competency. Table 5 indicates that students currently interested in the site engineering track only target a cognitive achievement level of “Analysis”, which is slightly below BOK standards. BOK outcome (4), “Multi-disciplinary teams” indicates that students currently achieve a cognitive level of “application” as shown on Table 5. In the area of “Communication skills”, BOK outcome (7), students currently have a good progression of activity where they have the opportunity to achieve at the “ability” level, which is satisfactory. In the areas of “Professional and Ethical standards, BOK outcome (6), the “Impact of engineering”, BOK outcome (8), “Contemporary issues”, BOK outcome (10), and “Project Management”, BOK outcome (13), students are afforded cognitive experiences at the “Application” level, or above, which satisfies BOK’s stipulated “Recognition” level of achievement. “Business and public policy”, BOK outcome (14) is measured at the “knowledge” level, which meets the BOK criterion of “Recognition. In the area of “Lifelong learning”, BOK outcome (9), only one measure currently exists at the knowledge level within the site engineering sequence—which is at a level lower than the stipulated level of “understanding”. Finally, “Leadership”, BOK outcome (15) is not currently included as a curriculum thread.

**Recommendations**

Table 5 indicates various areas of weakness in meeting all of the ASCE BOK outcomes and levels of competence when considering the selected collection of twenty courses outlined in Table 3. A proposed course of action to correct these deficiencies is outlined below:

- ♦ **BOK Outcome 2—An ability to design experiments and analyze/interpret data**: The BOK indicates that students should achieve this outcome at the “ability” level. Currently, the site engineering track indicates activity at Bloom’s “analysis” level, and not at the desired “Synthesis” level. To improve this outcome, an initiative is underway to try to address this in the Civl 330, Measurements, Analysis and Modeling Course, which is not currently grouped with site engineering.

- **BOK Outcome 9—Lifelong Learning:** Additional improvement must be achieved with reference to this outcome, because only one measure exists at the Capstone Course level. Possibly additional measures using both the technical elective (Civl 421) and the Capstone Course could be achieved by tying in student attendance to monthly ASCE Branch meetings where technical presentations are offered to Branch members for continuing education credit (professional development hours). Having students write a **Memorandum of Record** summary of the technical presentation, coupled with their thoughts on its impact on the attending practitioners, might be a way to package a process that promotes an "Introduction to Lifelong Learning" .
- **BOK Outcome 14—Business and Public Policy:** This outcome currently is measured in Civl 305—Transportation Engineering. In order to strengthen this measure, the authors intend to explore the possibility of incorporating another measure into the Capstone Courses (i.e. Civl 425) by coupling this outcome with NEPA (the National Environmental Policy Act).
- **BOK Outcome 15—Leadership:** Although not specifically addressed as a curriculum matter when considering the site engineering coursework, student involvement in the ASCE Student Chapter as well as within the Corps of Cadets provides many opportunities to develop positive leadership skills.

## CONCLUSION

In summary, this paper delineates the activities associated with the practice of site engineering and the knowledge and skill base needed to prepare one for this endeavor. The sequencing of material relating to site engineering and at what level of achievement the students should meet are also considered. An example curriculum is mapped to the various ABET and BOK outcomes, along with the desired cognitive knowledge and skill levels. As a result, several weaknesses in the example curriculum are revealed, and various proposed options are presented for further perusal as part of the ongoing departmental assessment process curriculum. It is hoped that the reader is able to gain some new ideas on ways to assess and improve curriculum matters that will ultimately benefit students and the profession.

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