Comparing Present Outcome Data to that Utilizing Bloom's Taxonomy

Enno "Ed" Koehn[1], and James Koehn[2]

***Abstract* - The American Society of Civil Engineers has adopted Policy Statement 465 which originally stated, in part, "ASCE supports the concept of the master's degree or equivalent (MOE) as a prerequisite for licensure and the practice of civil engineering at the professional level." This definition has been subsequently revised and today reads as follows, "the ASCE supports the attainment of a Body of Knowledge for entry into the practice of civil engineering at the professional level. This would be accomplished through adoption of appropriate engineering education and experience requirements as a prerequisite for licensure." The Body of Knowledge (BOK) required to support the policy statement is also being studied. Presently, the BOK recommendation includes 15 outcomes which are designed to broaden and deepen the 11 current outcomes required by the Accreditation Board for Engineering and Technology (ABET). This paper presents data that indicate civil/construction engineering programs at the bachelor's level may presently be satisfying, to some degree, 14 of the 15 BOK outcomes. An investigation was also conducted involving the fifteen ABET/BOK outcomes written in terms of action verbs recommended by Bloom's Taxonomy. Here, the expected level of achievement, or outcomes perceived by students are somewhat different than those using the original ABET/BOK language. Nevertheless, the maximum differences range from .5 to .8 out of a basic composite score of 5.**

Index Terms – Bloom's Taxonomy, Body of Knowledge, Civil Engineering, Construction Engineering, Educational Outcomes.

INTRODUCTION

In 1998 the American Society of Civil Engineers (ASCE) Board of Direction adopted Policy Statement 465 that reads, in part, as follows: [1] "ASCE supports the concept of the master's degree as the First Professional Degree (FPD) for the practice of civil engineering at the professional level." There was a great level of discussion and opposition to this approach by members of the society. [2,3,4] The perception was that outstanding practical experience may be just as or more important than advanced course work.

Upon reflection and after numerous discussions, Policy Statement 465 was amended in 2001 and 2004 and today reads: "the ASCE supports the attainment of a Body of Knowledge for entry into the practice of civil engineering at the professional level. This would be accomplished through the adoption of appropriate engineering education and experience requirements as a prerequisite for licensure". [5] In order to support Policy Statement 465, ASCE developed the body of knowledge (BOK) needed to enter the profession in the 21st century. Specifically, the BOK is defined as the knowledge, skills, and attitudes required to become a licensed professional engineer.

Today, some practitioners believe that graduates of engineering programs need greater knowledge of the design process, and increased understanding of business and management. For example, the National Research Council (NRC) has published a report concerning the following problems with students who hold the bachelors degree: [6]

- Lack of knowledge of the design process,
- Inadequate knowledge of the role of technology, and
- Minimum knowledge of business, economics, and management.

In this regard, the National Council of Examiners for Engineering and Surveying (NCEES) has recently voted to modify a section of its model law to require additional education beyond the bachelor's level in order to become a licensed professional engineer. [7] The new requirement is that an applicant must have either a master's degree in engineering or 30 additional credits in upper-level undergraduate or graduate courses in order to qualify. This action may be considered as offering strong support to ASCE's Policy 465.

The National Academy of Engineering has also studied this problem. [8,9] This group believes that, "engineers must be prepared to accommodate new social, economic, legal, and political constraints when planning projects. In addition, they recommend that the use of engineering case studies and interdisciplinary learning be introduced at four year institutions. Also, they believe domestic students should be encouraged to earn advanced degrees.

The Accreditation Board for Engineering and Technology (ABET) is also concerned with the particular knowledge and skills that the graduate of 2020 will need to enter professional practice. Meetings are being held to predict what must be included in the BOK required for future engineers. [10] It is hoped that the application of

[1] Enno "Ed" Koehn, Lamar University, USA, ed.koehn@lamar.edu

[2] James Koehn, Chadron State College, USA, jkoehn@csc.edu

ASCE Policy Statement 465 will assist in solving the perceived problems in engineering education.

ENGINEERING EDUCATION

Recently, there have been recommendations from educators and technical/professional societies such as ASCE and NRC, as indicated in the previous sections, to revise the engineering curriculum that is being required in accredited institutions. [2,3,4] Partially in response to these recommendations and the recognition that the traditional program must include more information, the Accreditation Board for Engineering and Technology (ABET) has revised the criteria for accrediting engineering programs. [11] To assist in implementing the revised criteria, numerous conferences have been held and papers published involving the topics of accreditation and the curriculum.

For example, this is the sixth paper in a series published by the principal author designed to study the engineering curriculum and accreditation criteria. In the first publication, respondents were requested to indicate whether credit hours allocated to various courses should be revised. [12] The findings show, in part, that (1) practitioners recommend an increase in credits in the English literature and composition, especially technical writing, areas; (2) older graduates recommend greater academic emphasis in law, accounting, construction estimating and specifications, oral communications, and personnel management.

The second paper was designed to investigate the recommendations included in the updated Engineering Criteria. Specifically, knowledge of professional practice issues and the ability to perform engineering design utilizing realistic design constraints was studied. [13] Here, the findings suggest, in part, that both undergraduate and graduate students as well as practitioners perceive that engineering codes/standards and constructability constraints presently have been and are recommended to be incorporated into the engineering design program at a high level.

The third paper in the series, involves the perception of students and practitioners concerning the *Program Criteria for Civil and Similarly Named Engineering Programs* which is included in the ABET criteria. [11] The findings suggest that practicing engineers as well as undergraduate and graduate students, perceive that a major design experience or course should receive a high level of coverage in the civil engineering curriculum. [14]

"Practitioner and Employer Assessment of Accreditation Board for Engineering and Technology Outcome Criteria" is the fourth paper. [15] Here, civil engineering alumni and their employers rate "The broad education necessary to understand the impact of engineering solutions in a global/societal context" at a level lower than the ten other subject areas under consideration.

The fifth paper, investigates, according to civil engineering students at Lamar University, the level at which their understanding of various subject areas required by *Engineering Criteria 2000*, and specifically listed in the *Program Criteria for Civil and Similarly Named Engineering Programs* and the *General Criteria* (Professional Component) may have been enhanced by being involved with the steel bridge and concrete canoe projects. [16] The following were determined to be greatly enhanced: project management/scheduling and estimating, team work, and constructability.

Overall, it appears that the foregoing five papers support the present educational concerns of the NRC, NCEES, ABET and ASCE. In addition, the papers present, in part, the concept that the traditional four year engineering degree is no longer enough to practice as a professional engineer.

BODY OF KNOWLEDGE (BOK)

In order to determine the BOK required for civil engineers, ASCE proposes to utilize outcomes that are nominally similar to the eleven (a-k) Accreditation Board for Engineering and Technology (ABET) outcomes in addition to the specific program criteria required for civil engineering students. In order to totally satisfy BOK specifications, a single depth outcome, and three breadth outcomes were also added to the basic ABET requirements. These are listed as 12-15 in the tabulation below. The depth outcome includes knowledge in a specialized technical area. The three breadth outcomes include project management, construction, and asset management; business and public policy, and administration and leadership. [1]

Specifically, according to the new criteria, the 21st century civil engineer must demonstrate the following: [1]

1. An ability to apply knowledge of mathematics, science, and engineering. (ABET a)
2. An ability to design and conduct experiments, as well as analyze and interpret data. (ABET b)
3. An ability to design a system, component, or process to meet desired needs. (ABET c)
4. An ability to function on multi-disciplinary teams. (ABET d)
5. An ability to identify, formulate and solve engineering problems. (ABET e)
6. An understanding of professional and ethical responsibility. (ABET f)
7. An ability to communicate effectively. (ABET g)
8. The broad education necessary to understand the impact of engineering solutions in a global and societal context. (ABET h)
9. A recognition of the need for, and an ability to engage in, life-long learning. (ABET i)
10. A knowledge of contemporary issues. (ABET j)
11. An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. (ABET k)
12. An ability to apply knowledge in a specialized area related to civil engineering. (Added BOK requirement.)

13. An understanding of the elements of project management, construction, and asset management. (Added BOK requirement.)

14. An understanding of business and public policy and administration fundamentals. (Added BOK requirement.)

15. An understanding of the role of the leader and leadership principles and attitudes. (Added BOK requirement.)

A BOK committee recommends that ABET refine the outcomes previously listed. They are still somewhat similar; however, action verbs are utilized to describe the expected level of achievement.

PERCEPTIONS OF REQUIRED ABET OUTCOMES

In order to satisfy ABET requirements, a survey instrument was distributed to seniors of the Civil Engineering Department at Lamar University. The questionnaire listed the eleven required educational outcomes (a)-(k) and requested that respondents indicate at which level – strongly agree, agree, neither disagree nor agree, disagree or strongly disagree – each outcome has been incorporated into the curriculum. [15] As shown in Table I, ABET requirements 1-11 are well satisfied. The scores range from 4.4 – 4.7.

These findings suggest that civil/construction engineering students believe they have received a good background in the various aspects of civil engineering and satisfy requirements 1-11. However, the results are based upon the perceptions of students. It must be recognized that, at times, student opinions of their own level of knowledge may yield results that are at variance with that of university facility and other professionals.

A statistical analysis of the data listed in column 4 of Table I was also conducted. The findings indicate that the standard deviation of the fifteen items vary from .416 to .807. The mean is .628. These results illustrate that there is a central tendency of the values contained in the spread of the distribution for each of the fifteen items.

PERCEPTIONS OF BOK OUTCOMES

The data in Table I, concerning outcomes 13-15 related to the additional BOK requirements were extracted from investigations conducted by the Department of Civil Engineering at Lamar University that were published in various journals. [14,15,16] As illustrated, BOK 13 (an understanding of the elements of project management, construction and asset management), is perceived by the students to earn a 4.2 score. This places it in the “agree” range.

BOK 14, an understanding of business and public policy and administration fundamentals, received a rating of 3.7 which places it in the agree/disagree category.

BOK outcome 15; an understanding of the role of the leader and leadership principles and attitude, was supported by a score of 3.9, slightly lower than the agree range.

In review, the BOK data obtained from various investigations conducted over a number of years, indicate that undergraduate students in a civil engineering program generally believe they satisfy, in their program of study, BOK 13 – 15 at reasonable levels.

TABLE I
OUTCOMES

Fulfillment of Outcomes Utilizing Various Terms*			
Educational Outcome (1)	ABET (2)	BOK (3)	Bloom’s Taxonomy (4)
1. Technical Core	4.6	---	4.1
2. Experiment	4.5	---	4.2
3. Design	4.4	---	4.2
4. Multi-disciplinary	4.4	---	4.7
5. Engineering problems	4.6	---	4.3
6. Prof/ethical	4.6	---	3.8
7. Communications	4.7	---	4.4
8. Engineering impact	4.4	---	4.1
9. Life-long leaning	4.7	---	4.4
10. Contemporary issues	4.4	---	4.1
11. Engineering tools	4.4	---	4.4
12. Specialized area	---	---	4.0
13. Proj. mgmt., const., and asset mgmt.	---	4.2	4.3
14. Business and public admin.	---	3.7	4.2
15. Leadership	---	3.9	4.2
* Composite score based upon 5.0= strongly agree; 4.0=agree; 3.0=neither agree nor disagree;2.0=disagree; 1.0=strongly disagree			

PERCEPTIONS UTILIZING BLOOM’S TAXONOMY

As mentioned in a previous section, a BOK committee recommends that ABET refine the outcomes previously listed. They are still somewhat similar; however, using Bloom’s Taxonomy, action verbs are utilized to describe the expected level of achievement. The updated version shown in Table II demonstrates the academic prerequisites required for professional practice. [17] More detailed information concerning Bloom’s Taxonomy is located in the next section.

In order to determine the perceptions of senior students as related to satisfying the criteria utilizing Bloom’s Taxonomy, a survey instrument was utilized as illustrated in Figure 1.

As shown in Table I, using Bloom’s terminology, nine scores are less than the ABET and BOK values. However, five scores are identical to or greater than those obtained for ABET and BOK criteria. The largest difference, (.8), is in the professional/ethical areas. Here Bloom’s Taxonomy Terminology states, “Analyze a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action.”

This is considerably more complex than the ABET criteria, “An understanding of professional and ethical responsibility.” It is understandable that the student’s knowledge would be lower utilizing Bloom’s requirement.

Item number one, “Technical Core”, exhibits a difference of .5. The ABET requirement is, “An ability to apply knowledge of mathematics, science, and engineering.” Bloom’s description is, “Solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science." Bloom's terminology is a bit more complex than that of ABET. The students appear to recognize this change.

In 14 and 15 Bloom's approach uses the word "explain". In comparison, ABET and BOK emphasize "understanding". Here, it appears that students perceive that Bloom's criteria may be less rigorous than that presently being utilized.

TABLE II
FORMAL EDUCATION

		Formal Education
	Outcome	To satisfy the academic prerequisites for the professional practice of civil engineering, an individual must be able to:
1	Technical Core	Solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science.
2	Experiment	Design a civil engineering experiment to meet a need; conduct the experiment, and analyze and interpret the resulting data.
3	Design	Design a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
4	Multi-disciplinary	Function effectively as a member of a multi-disciplinary team.
5	Engineering problems	Solve well-defined engineering problems in four technical areas appropriate to civil engineering.
6	Prof./ethical	Analyze a complex situation involving multiple conflicting professional and ethical interest, to determine an appropriate course of action.
7	Communication	Organize and deliver effective verbal, written, and graphical communications.
8	Engineering impact	Determine the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution.
9	Life-long learning	Demonstrate the ability to learn on their own, without the aid of formal instruction.
10	Contemporary issues	Incorporate specific contemporary issues into the identification, formulation, and solution of a specific engineering problem.
11	Engineering tools	Apply relevant techniques, skills, and modern engineering tools to solve a simple problem.
12	Specialized area	Evaluate the design of a complex system or process, or evaluate the validity of newly created knowledge within a specialized area of civil engineering.
13	Proj. mgmt, const., and asset mgmt.	Explain key concepts and problem-solving processes used in management.
14	Business and public admin.	Explain key concepts and problem-solving processes used in business, public policy, and public administration.
15	Leadership	Explain the role of the leader, leadership principles, and attitudes conductive to effective professional practice of civil engineering.

BLOOM'S TAXONOMY

Bloom's Taxonomy is a long established model for defining educational objects and levels of achievement. [18] Bloom's various levels of development are as follows: [17]

- Knowledge (Level 1)
- Comprehension (Level 2)
- Application (Level 3)
- Analysis (Level 4)
- Synthesis (Level 5)
- Evaluation (Level 6)

Each level represents a progressively higher level form of thinking.

The terms recognition, understanding, and ability used by ABET have been found, by some, difficult to measure. Therefore, it is recommended by a BOK committee that they should be replaced by appropriate Bloom levels. In translating from the old to new levels the following may be utilized: [18]

- Recognition; Knowledge (Level 1) and Comprehension (Level 2)
- Understanding; Application (Level 3) and Analysis (Level 4)
- Ability; Synthesis (Level 5) and Evaluation (Level 6)

The specific levels of achievement in terms of Bloom's Cognitive Domain are shown in Table III. [17] As shown, the level of achievement is defined using action words such as determine, solve, design, organize, analyze, demonstrate, incorporate, develop, explain and evaluate. These are taken from Bloom's taxonomy for cognitive development.

EDUCATION REQUIREMENTS FOR CERTIFIED PUBLIC ACCOUNTANTS

As in civil engineering, the educational component of the BOK required for accountants recently joining the profession is tending to increase. Nevertheless, for both new and older practitioners, being designated as a Certified Public Accountant is the most prestigious credential an accountant can achieve. However, for an individual to become a Certified Public Accountant, a candidate must comply, as in engineering, with the requirements of the state in which the individual wishes to practice. The general components of the initial licensing requirement include passing the Uniform CPA Exam, work experience and educational requirements. Each state specifies the education requirements of a certain number of accounting hours and other business credits. In addition, candidates are required (or shortly will be required) by 45 states to have completed 150 semester hours of coursework. [19] As part of the 150 hours, a candidate must have earned either a bachelor's or a master's degree. [20] There is no requirement for a master degree and the entire 150 hours can be composed of undergraduate coursework. [20] Previously only a bachelor's degree with certain specific coursework was the requirement. The idea of additional education was endorsed by the American Institute of Certified Public Accountants governing council in 1959 and approved by the general membership in 1988, nearly 30 years later. [21] The recommended

Please indicate your preferred response to the statements below using the following scale:

Strongly Agree (5)	Agree (4)	Neither Agree nor Disagree (3)	Disagree (2)	Strongly Disagree (1)

Draw a line through any statement for which you lack sufficient knowledge to make a judgment.

With the assistance of the Civil Engineering coursework, faculty and curriculum at Lamar University, my engineering thought process has developed such that I am able to:

(1) Solve problems in mathematics through differential equations, calculus-based physics, chemistry, and one additional area of science.
5 4 3 2 1

(2) Design a civil engineering experiment to meet a need; conduct the experiment, and analyze and interpret the resulting data.
5 4 3 2 1

(3) Design a complex system or process to meet desired needs, within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
5 4 3 2 1

(4) Function effectively as a member of a multi-disciplinary team.
5 4 3 2 1

(5) Solve well-defined engineering problems in four technical areas appropriate to civil engineering. 5 4 3 2 1

(6) Analyze a complex situation involving multiple conflicting professional and ethical interests, to determine an appropriate course of action. 5 4 3 2 1

(7) Organize and deliver effective verbal, written, and graphical communications. 5 4 3 2 1

(8) Determine the global, economic, environmental, and societal impacts of a specific, relatively constrained engineering solution.
5 4 3 2 1

(9) Demonstrate the ability to learn on my own, without the aid of formal instruction. 5 4 3 2 1

(10) Incorporate specific contemporary issues into the identification, formulation, and solution of a specific engineering problem. 5 4 3 2 1

(11) Apply relevant techniques, skills, and modern engineering tools to solve a simple problem. 5 4 3 2 1

(12) Evaluate the design of a complex system or process, or evaluate the validity of newly created knowledge within a specialized area of civil engineering. 5 4 3 2 1

(13) Explain key concepts and problem-solving processes used in management. 5 4 3 2 1

(14) Explain key concepts and problem-solving processes used in business, public policy, and public administration. 5 4 3 2 1

(15) Explain the role of the leader, leadership principles, and attitudes conductive to effective professional practice of civil engineering.
5 4 3 2 1

Please provide any comments you wish on the reverse side of this page:

FIGURE 1
QUESTIONNAIRE

implementation date was set for sometime after the year 2000. This time span required to change educational requirements is similar to that in civil engineering

Over approximately the last fifteen years, the number of accounting graduates has declined as well as the number of candidates sitting for the CPA exam. [22] During the 1990-91 academic year the total number of accounting graduates (both undergraduate and master's degree) was 59,140. This total declined to 46,555 for the year 2000-01 academic year and recovered somewhat by the 2003-04 academic year to 53,760.19 The recent uptick in graduates is attributed to the increase in exposure to and interest in accounting due to business scandals such as the failure of Enron and Worldcom. Over the same time period, the composition of the accounting graduates has shifted from being about 9% master's degree graduates in 1990-91 to 19% in 2000-01 and 25% in 2003-04. [19] The increase in the relative position of master's level graduates is attributed to the 150 hour requirement. However, over the same fifteen year period, the number of candidates sitting for the CPA exam has dropped from 143,572 in 1990 to 115,493 in 2000 and to 109,872 in 2003. [22] It will be interesting to see if civil engineering experiences similar change, increase in master's degrees and decrease in numbers sitting for the professional practice exam, over the next twenty years.

SUMMARY AND CONCLUSION

For the 21st century civil engineer, broad and/or specific knowledge in numerous areas will be necessary to practice as a professional engineer. To gain this knowledge it is recommended that he/she will need a master's degree or equivalent practical experience. ASCE developed a set of criteria called BOK, for future engineers to satisfy to become licensed professional engineers. The BOK consists of the existing 11 ABET outcomes, plus four new additional criteria. This investigation indicates that almost all the ABET/BOK outcomes tend to be perceived by the respondents as being satisfied in the currently existing undergraduate curriculum, except outcome 12, specialized knowledge. Obtaining knowledge in a specialized area is found to be difficult to accomplish in an undergraduate program utilizing this approach. Nevertheless, using Bloom's Terminology, seniors rate outcome 12 in the "agree range".

The findings of the paper have been obtained by using data collected from various studies published in different journals. In particular; feedback from students was utilized. The results which are presented in Table I, indicate that the present curriculum generally satisfies, as perceived by the respondents, the ABET/BOK criteria. The findings also suggest that, overall, the program satisfies the criteria when Bloom's Taxonomy is utilized.

TABLE III
BLOOM'S LEVELS

Bloom's Levels	Bloom Verbs	ABET Terms	Summary Levels
6. Evaluation	Appraise, criticize, justify, support		III
5. Syntheses	Design, develop, create, compose, reconstruct	Design, proficiency	III
4. Analysis	Analyze, break down, present, interpret, organize, formulate, subdivide	Identify, formulate	II
3. Application	Apply, conduct, solve, demonstrate, compute, relate, use	Apply, conduct, solve, function, use	II
2. Comprehension	Explain, distinguish, paraphrase, summarize, generalize	Understanding	I
1. Knowledge	Define, label, list, recite, select	Knowledge, familiarity, recognition	I

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