AC 2009-438: A NEW APPROACH TO SOIL MECHANICS LABORATORY CURRICULA: INCORPORATING THE BOK INTO A WORKSHOP-ORIENTED LABORATORY

Laura Hernandez, Michigan Technological University

Laura Hernandez is a Civil Engineering (Geotechnical) Graduate Student at Michigan Tech. She obtained a BSE in Civil Engineering and a BS in Scientific and Technical Communication both from Tech. Laura is currently working on implementing the BOK into the Civil Engineering curriculum.

Stanley Vitton, Michigan Technological University

Dr. Vitton has been at Michigan Tech for 14 years. Prior to Michigan Tech he was an Assistant Professor at the University of Alabama. He spent eight years with the Shell Oil Company in their mining company. He was the Engineering Manager for Shell's R&F Coal Mine located in Cadiz, OH for approximately four years. His first four years at Shell were spent on the development of surface coal mines located in the Powder River Basin. Dr. Vitton's PhD is in Civil Engineering (geotechnical engineering) from the University of Michigan, his MSE is in mining engineering (rock mechanics) and his BSE is in geological engineering both from Michigan Tech.

A New Approach to Soil Mechanics Laboratory Curricula: Incorporating the BOK into a Workshop Orientated Laboratory

The American Society of Civil Engineers (ASCE) has recognized the need for change in how current undergraduate education is conducted to better prepare civil engineers for the 21st century. ASCE has developed an educational plan entitled, "Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future" (BOK) which encompasses twenty-four learning outcomes required for a civil engineer for professional licensure.

An educational model was developed to integrate twelve of the twenty-four BOK learning outcomes into the soil mechanics laboratory within the civil engineering curriculum. The model utilizes the cognitive domain of Bloom's Taxonomy to create a workshop-orientated laboratory that enhances student learning.

Current Teaching Strategies

Historically, soil mechanics has been taught through a lecture-laboratory approach since the introduction of the laboratory component during the 1930s. One of the first soil mechanics laboratory manuals published in 1939 by William S. Housel at the University of Michigan illustrated a systematic and discrete approach of teaching by introducing important test methods common to soil mechanics[1].

As the 1950s emerged authors developed manuals where there is little change to the overall structure and content in comparison to the first texts. Authors seem to have written these laboratory manuals to accommodate the teaching strategies desired at each institution or to include regional test methods and procedures. The laboratory manuals of this time period appear to establish the writing standards for manuals of latter years by way of content and formatting choice.

Authors continued writing new laboratory manuals throughout the 1970s and 1980s which show little indication of advancing engineering education. They followed the same format and content found in manuals from the 1930s.

Current soil mechanics laboratory manuals are stuck in the past. These laboratory manuals appear to be modified replicas of ASTM standards and contain no new material or teaching strategies.

Although soil mechanics testing procedures haven't changed significantly throughout the years, the path in which professional engineering practice has followed is changing significantly. Engineers of the 21st century now face challenges such as sustainability, global concerns and economic issues.[2] Current soil mechanics laboratory curriculum is outdated and does not reflect the need to transform civil engineering students of the 21st century into critical thinkers, problem solvers and technical communicators.

Wanted—Critical Thinkers

One deficiency commonly seen in current soil mechanics laboratory manuals is the neglect to prepare students to become critical thinkers. Critical thinking encompasses the ability to assess a given situation in a logical manner, to accept or reject a claim based upon reasonable conclusions about the situation. Brad Dowden, California State University, Sacramento sums it up nicely, *"A critical thinker has an attitude—an attitude of desiring to avoid nonsense, to find the truth and to discover the best action. It's an attitude that rejects "intuiting" the truth in favor of demanding reasons. To be a critical thinker you need to be fair and open-minded even with people you disagree with. You need to give them a fair hearing because your goal is the truth or the best action. Your goal isn't just to confirm what you already believe."*[3]

Soil mechanics is a unique field where much understanding of the field comes from empirical testing and past experience; yet, students must be provided the opportunity to develop and improve their critical thinking skills in the laboratory while performing standardized soil tests. Students must be given the ability to develop critical thinking skills by focusing on higher *"intellectual standards such as clarity, accuracy, precision, and logic, and to use analytic skills with a fundamental value orientation that emphasizes intellectual humility, intellectual integrity, and fair-mindedness."*[3]

Wanted—Problem Solvers

Engineers typically collaborate to solve problems and *"tend to rely on conversations with internal colleagues and clients"*[4] in order to obtain adequate information about the problem. Engineers of the 21st century are faced with complex situations which require developed problem-solving skills many other disciplines lack. Problems can be solved in many ways and engineers typically have the freedom to determine how to go about the problem based upon their ability to obtain information about the situation.[4]

Students should be given greater opportunity to experience problem solving on a regular basis in the soils laboratory. Unfortunately, current soil mechanics laboratory manuals do not place students within a problem-based approach that limits the student's capacity to better develop their problem solving skills. Soil mechanics laboratory manuals should incorporate this critical aspect of civil engineering into the laboratory curricula.

Wanted—Technical Communicators

Technical communication is an important aspect of civil engineering, since all engineers must communicate with both engineers and non-engineers on a regular basis; however, *"much of the instruction provided in engineering schools is not clearly related to these practicing needs."*[5]

Research has shown the critical need for developing technical communicators within the engineering field. A survey of leading U.S. and Canadian programs revealed results which indicated technical communication skills are among the top 11 ranked engineering skills desired by professionals, even more desirable than *"the ability to design a product, system, or process."*[5]

Effective technical communication skills were determined *"second in importance"* compared to problem solving skills.[5] According to an industry survey communication skills ranked *"as one of the top five key success factors for engineers."*[5] Another survey showed engineers spent 64% of their time communicating by way of writing (32%), oral discussions (22%) and oral presentations (10%).[5]

Bloom's Taxonomy and Cognitive Learning

During the 1950s, Benjamin Bloom led a team of educational psychologists in the analysis of academic learning behaviors. The results of this team's research produced what is known today in the field of education as Bloom's Taxonomy. Cognitive learning is one of the three domains from Bloom's Taxonomy and emphasizes intellectual outcomes. *Cognitive* by definition is the mental process of perception, memory, judgment, and reasoning, as contrasted with emotional and volitional processes. Six levels of learning were defined within the cognitive domain: knowledge, comprehension, application, analysis, synthesis and evaluation. Students, starting with knowledge, must master each stage in order to advance onto the next level. The definition of each level within the cognitive domain is provided in Table 1.[6]

Table 1: Six Stages of Cognitive Development under Bloom's Taxonomy[6]

Stages	Name	Definition
1	Knowledge	Remembering or retrieving previously learned material.
2	Comprehension	The ability to grasp or construct meaning from material.
3	Application	The ability to use learned or implemented material in new and concrete situations.
4	Analysis	The ability to break down or distinguish the parts of material into its components so that its organizational structure may be better understood.
5	Synthesis	The ability to put parts together to form a coherent or unique new whole.
6	Evaluation	The ability to judge, check, and even critique the value of material for a given purpose.

What makes the cognitive domain useful in the establishment of engineering curriculum is how the use of action verbs can convey the desired outcome and goal. Table 2 illustrates common action verbs used to describe the outcomes associated with each of the six stages with the cognitive domain.

Table 2: Bloom's Taxonomy Cognitive Domain Action Verbs[6]

Stages	Name	Action Verbs
1	Knowledge	know, identify, relate, define, memorize, recognize, acquire
2	Comprehension	explain, discuss, restate, describe, represent, interpret
3	Application	apply, develop, use, employ, calculate, exhibit, practice
4	Analysis	compare, examine, differentiate, contrast
5	Synthesis	compose, produce, assemble, derive, originate, formulate
6	Evaluation	consider, appraise, criticize, choose, conclude

BOK Requirements

The BOK utilizes Bloom's Taxonomy to define what should be learned and achieved throughout undergraduate and graduate education. It contains twenty-four desired learning outcomes which are categorized into three groups: foundational, technical, and professional. Each learning outcome is assigned a minimal level of achievement corresponding to the cognitive domain of Bloom's Taxonomy.

It is believed that twelve of the twenty-four learning outcomes within the BOK can be incorporated into the soil mechanics laboratory curricula through a workshop orientated approach. The twelve learning outcomes include:

1. Materials Science (L3)
2. Experiments (L4)
3. Problem Recognition and Solving (L3)
4. Design (L4)
5. Sustainability (L3)
6. Risk and Uncertainty (L3)
7. Project Management (L3)
8. Communication (L4)
9. Leadership (L3)
10. Teamwork (L3)
11. Attitudes (L2)
12. Professional & Ethical Responsibility (L2)

This structure utilizes the cognitive domain of Bloom's Taxonomy to enable students who comprehend the fundamental concepts of soil mechanics. Each laboratory workshop will guide students through the cycle of learning by starting at stage 1, knowledge, where students begin to explore the concepts of the topic and building up to stage 6, evaluation, where students are able to grasp the larger picture by being able to communicate what they have learned.

A Proposed Workshop Model

The issue of what should or should not be included in the soil mechanics curriculum (including the lab portion) has long been debated. Karl Terzaghi's[7] opening comments to the First International Conference of Soil Mechanics and Foundation Design contained a number of important and challenging statements dealing with the teaching of soil mechanics—many of these issues are relevant today as they were in 1936.

While it is beyond the scope of this paper to address these issues, it might be sufficient to quote J. B. Burland[8] from his Nash lecture on his personal view on the teaching of soil mechanics who strongly suggested that the profession reread Terzaghi's comments on the teaching of soil mechanics and cited two factors that caused him to drastically revise his views as to what should be taught in soil mechanics. These two factors are (1) there is never enough time to teach everything and (2) "*that it is all too easy to underestimate the difficulties faced by students, and* *indeed by the majority of civil engineers in general practice, in tackling the fundamental concepts of soil mechanics*." The proposed workshop model will address these two factors in addition to the task of incorporating the BOK requirements into the soil mechanics laboratory.

Laboratory Workshop

The workshop model follows the six stages of learning in the cognitive domain. Table 3 illustrates the correlation between the cognitive domain and the six stages of the proposed laboratory workshop as well as action verbs describing both models.

Table 3: Six Stages of the Laboratory Workshop

Correlation Between Bloom's Taxonomy and the Laboratory Workshop		
Bloom's Taxonomy Stages of Learning	**Workshop Phases**	**Action Verbs Describing Both Models**
Knowledge	Introduction	identify, relate, define, memorize, recognize, acquire
Comprehension	Hands-on-Demonstration	explain, discuss, restate, describe, represent, interpret
Application	Hands-on-Application	apply, develop, use, employ, calculate, exhibit, practice
Analysis	Engineering Analysis	compare, examine, differentiate, contrast
Synthesis	Design Practical	produce, derive, originate, formulate
Evaluation	Group Discussion	consider, appraise, criticize, choose, conclude

A fifteen week semester course will have the following four workshops consisting of approximately three weeks: (1) soil classification, (2) soil properties, (3) soil-hydrologic interactions and (4) soil settlement and strength; consisting of approximately three weeks. In order to fulfill ABET's requirement of providing students "*an ability to design and conduct experiments, as well as to analyze and interpret data*" [9], the final portion consists a student laboratory-design experience. Each of the four workshops is outlined below.

Workshop 1 – Soil Classification

The objective of workshop # 1 is to introduce the fundamental characteristics of soil. The BOK requirements addressed in workshop # 1 consist of: (5) materials science, (7) experiments, (8) problem recognition and solving, (9) design, (10) sustainability, (12) risk and uncertainty, (13) project management, (16) communication, (20) leadership, (21) teamwork, (22) attitudes and (24) professional and ethical responsibility. [2]

Workshop #1 will cover classification of soil and include tests such as visual identification, sampling, mechanical sieving and hydrometer analysis. Table 4 illustrates the BOK requirements and corresponding levels of achievement fulfilled by workshop #1.

Table 4: Workshop #1 BOK Requirements Fulfilled

BOK Outcome	Workshop #1 Bloom's Taxonomy Level of Achievement					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
5. Materials Science	x	x	x			
7. Experiments	x	x	x	x		
8. Problem Recog. & Solving	x	x	x			
9. Design	x	x	x	x		
10. Sustainability	x	x	x			
12. Risk & Uncertainty	x	x	x			
13. Project Management	x	x	x			
16. Communication	x	x	x	x		
20. Leadership	x	x	x			
21. Teamwork	x	x	x			
22. Attitudes	x	x				
24. Professional & Ethical Responsibility	x	x				

Workshop 2 – Soil Properties

The objective of workshop #2 is to introduce an understanding of the engineering behaviors and properties soils exhibit while promoting professional mindset development. The BOK requirements addressed in workshop #2 consist of: (5) materials science, (7) experiments, (8) problem recognition and solving, (9) design, (10) sustainability, (13) project management, (16) communication, (20) leadership, (21) teamwork, (22) attitudes.

Workshop #2 will cover properties of soil and include tests such as: moisture content, Atterberg limits, specific gravity and relative density. Table 5 illustrates the BOK requirements and corresponding levels of achievement fulfilled by workshop #2.

Table 5: Workshop #2 BOK Requirements Fulfilled

BOK Outcome	Workshop #2 Bloom's Taxonomy Level of Achievement					
	Knowledge	**Comprehension**	**Application**	**Analysis**	**Synthesis**	**Evaluation**
5. Materials Science	x	x	x			
7. Experiments	x	x	x	x		
8. Problem Recog. & Solving	x	x	x			
9. Design	x	x	x	x		
10. Sustainability	x	x	x			
12. Risk & Uncertainty						
13. Project Management	x	x	x			
16. Communication	x	x	x	x		
20. Leadership	x	x	x			
21. Teamwork	x	x	x			
22. Attitudes	x	x				
24. Professional & Ethical Responsibility						

Workshop 3 – Soil-Hydrologic Interactions

The objective of workshop #3 is to introduce the effects water flow on soil behavior while promoting professional mindset development. BOK requirements addressed in workshop # 3 consist of: (5) materials science, (7) experiments, (8) problem recognition and solving, (9) design, (10) sustainability, (13) project management, (16) communication, (20) leadership, (21) teamwork, (22) attitudes.

Workshop #3 will cover hydrological interactions of soil and include tests such as: constant head and falling head permeability. Table 6 illustrates the BOK requirements and corresponding levels of achievement fulfilled throughout workshop #3.

Table 6: Workshop #3 BOK Requirements Fulfilled

BOK Outcome	Workshop #3 Bloom's Taxonomy Level of Achievement					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
5. Materials Science	x	x	x			
7. Experiments	x	x	x	x		
8. Problem Recog. & Solving	x	x	x			
9. Design	x	x	x	x		
10. Sustainability	x	x	x			
12. Risk & Uncertainty						
13. Project Management	x	x	x			
16. Communication	x	x	x	x		
20. Leadership	x	x	x			
21. Teamwork	x	x	x			
22. Attitudes	x	x				
24. Professional & Ethical Responsibility						

Workshop 4: Settlement and Strength

The objective of workshop #4 is to introduce strength in correlation to soil behavior while enforcing professional mindset development. BOK requirements addressed in workshop #4 consist of: (5) materials science, (7) experiments, (8) problem recognition and solving, (9) design, (10) sustainability, (13) project management, (16) communication, (20) leadership, (21) teamwork, (22) attitudes.

Workshop #4 will cover settlement and strength of soil and include tests such as: consolidation, direct shear and unconfined compression. Table 7 illustrates the BOK requirements and corresponding levels of achievement fulfilled throughout workshop #4.

Table 7: Workshop #4 BOK Requirements Fulfilled

BOK Outcome	Workshop #4 Bloom's Taxonomy Level of Achievement					
	Knowledge	Comprehension	Application	Analysis	Synthesis	Evaluation
5. Materials Science	x	x	x			
7. Experiments	x	x	x	x		
8. Problem Recog. & Solving	x	x	x			
9. Design	x	x	x	x		
10. Sustainability	x	x	x			
12. Risk & Uncertainty						
13. Project Management	x	x	x			
16. Communication	x	x	x	x		
20. Leadership	x	x	x			
21. Teamwork	x	x	x			
22. Attitudes	x	x				
24. Professional & Ethical Responsibility						

By following the purposed workshop model the twelve BOK requirements can be satisfied as illustrated in Table 8.

Table 8: BOK requirements fulfilled by workshops #1-4

BOK Outcome	Workshops (WS) #1-4 Level of Achievement																							
	Level 1				Level 2				Level 3				Level 4				Level 5				Level 6			
	WS 1	WS 2	WS 3	WS 4	WS 1	WS 2	WS 3	WS 4	WS 1	WS 2	WS 3	WS 4	WS 1	WS 2	WS 3	WS 4	WS 1	WS 2	WS 3	WS 4	WS 1	WS 2	WS 3	WS 4
5. Materials Science	x	x	x	x	x	x	x	x	x	x	x	x												
7. Experiments	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
8. Problem Recognition & Solving	x	x	x	x	x	x	x	x	x	x	x	x												
9. Design	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
10. Sustainability	x	x	x	x	x	x	x	x	x	x	x	x												
12. Risk & Uncertainty	x				x				x															
13. Project Management	x	x	x	x	x	x	x	x	x	x	x	x												
16. Communication	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x								
20. Leadership	x	x	x	x	x	x	x	x	x	x	x	x												
21. Teamwork	x	x	x	x	x	x	x	x	x	x	x	x												
22. Attitudes	x	x	x	x	x	x	x	x																
24. Professional & Ethical Responsibility	x				x																			

Summary

The ASCE has recognized the need to change how current undergraduate education is conducted. To accomplish this they have identified twenty-four learning outcomes known as the BOK that civil engineers must possess to become professional engineers. It is expected that many of these outcomes will be learned throughout undergraduate and post-graduate education. To assist in this effort a laboratory workshop model following Bloom's Taxonomy has been proposed for the soil mechanics laboratory within the civil engineering curriculum. The proposed laboratory workshop model integrates twelve of the twenty-four learning outcomes desired within the BOK.

A fifteen week semester course will consist of four laboratory workshops followed by an ABET laboratory experience. Each workshop will consist of six stages: introduction, hands-on demonstration, hands-on application, engineering analysis, practical design and group discussion. It is anticipated that within the workshop model the twelve BOK learning outcomes can be incorporated. The current teaching structure of the laboratory is underutilized and lacks many of the desired BOK outcomes. This is obvious since minimal changes have been made in teaching the soil mechanics laboratory since the 1930s. This workshop model will equip engineering students with the critical thinking, problem solving and technical communication skills needed in the 21st century.

References

[1] Housel, W.S., 1939. *Applied Soil Mechanics: Laboratory Manual of Soil Testing Procedures*. Ann Arbor, Michigan: University of Michigan.

[2] ASCE: *Civil Engineering Body of Knowledge for the 21st Century: Preparing the Civil Engineer for the Future, 2nd edition*, prepared by the BOK committee of the Committee on Academic Prerequisites for Professional Practice. 2008. www.asce.org.

[3] Dowden, B. California State University. Sacramento, CA. www.csus.edu/indiv/d/dowdenb/4/ct-def/def-of-ct.htm. Accessed January 1, 2009.

[4] Tenopir C., and D.W. King. 2004. *Communication Patterns of Engineers*. IEE Press: Wiley Interscience.

[5] Reave L. 2004. University of Western Ontario, Technical Communication Instruction in Engineering Schools A Survey of Top-Ranked U.S. and Canadian Programs. *Journal of Business and Technical Communication*, 18 (4) October 2004.

[6] Bloom, B.S. and D.R. Krathwohl. 1956. *Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain by a committee of college and university examiners.* New York: David McKay Company, Inc..

[7] Terzahgi, K. 1936. Discussion on instruction in soil mechanics. *Proceedings of the International Conference on Soil Mechanics and Foundation Engineering*. Harvard University, (3): 261-64.

[8] Burland, J.B., 1987. The teaching of soil mechanics: a personal view. *Proceedings of the 9th European conference on soil mechanics and foundation engineering*. Dublin, (3): 1427-47.

[9] ABET: *Criteria for Accrediting Engineering Programs*. 2008-09. www.abet.org.