



Theory to Practice: A Reflection on the Application of Engineering Education Coursework to New Course Development

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I. Introduction

One significant challenge for many students is translating theories learned in the classroom to real-world applications. In this paper I present a model for translating learning and pedagogical theories into practice through the development of a new online engineering course. As a second-semester student in an engineering education doctoral program I was given the opportunity to develop a new graduate-level course for an online Master of Civil Engineering (MCE) program. Concurrently, I was enrolled in an Engineering Education course, *Content, Assessment, and Pedagogy: An Integrated Engineering Design Approach* (CAP) and a Curriculum and Instruction course, *Advanced Issues in Distance Education* (AIDE). This combination of coursework and employment provided an ideal opportunity to immediately apply course concepts to a real-world problem.

The purpose of this paper is to reflect on the process of translating theoretical course concepts to a new curriculum development project. This reflection was guided by three overarching questions: 1) how were theoretical course concepts applied in the development of a new graduate-level online engineering course, 2) what were the challenges in developing this course, and 3) what lessons were learned that will aid in the development of future courses? These questions were answered by examining the contributions made by different bodies of literature, and how these were synthesized during the development project. This paper is intended to provide graduate students new to curriculum development with insights on the process and challenges of developing their first course.

II. Contributions of CAP Course and Literature

The CAP course was designed for first-year doctorate students with the overarching goal of providing a theoretical foundation for curriculum design within engineering education. The primary course objectives, as applicable to the scope of this paper, included:

1. To articulate an engineering design approach to curriculum development with strong alignment between content, assessment and pedagogy.
2. To apply the principles and theories of a backward design approach to a curricular development project.

The primary theme of this course can be summarized by one word, *alignment*; alignment between what students are expected to learn (objectives/content), how students are expected to demonstrate their learning (assessment), and how the learning environment should be designed to support student learning (pedagogy). In addition, alignment between program-level educational goals and course-level learning objectives; alignment between tacit assumptions of how students learn and acquire knowledge, how students produce evidence of knowledge, and how educators evaluate knowledge; and alignment between the teaching methodologies, the learning environment, and the intrinsic characteristics of the intended audience of the course were each important topics of discussion.

Throughout the CAP course, a rich body of literature was utilized to introduce a research-based, theoretical foundation of the course concepts. A list of example readings discussed throughout the course is provided in Table 1. In addition to the required reading, students were also encouraged to begin building a discipline-specific library that would support an individual engineering education curriculum development project. In my case, that project was the development of CE503, Fundamentals of Soil Mechanics and Foundation Engineering, an 11-week, 6-cr online course. The American Society of Civil Engineering Body of Knowledge Report, commonly referred to as the BOK2 Report, and publications within the Journal of Professional Issues in Engineering Education and Practice, and the Journal of Geotechnical and Environmental Engineering formed the foundation of my Civil Engineering-focus library.

Table 1. Selected Examples of CAP Required Reading

Topic	Examples of Required Reading
Content <i>What should students learn?</i>	Anderson, L. R., & Krathwohl, D. W. (Eds.). (2001). <i>A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives</i> (Complete edition). New York: Longman. Svinicki, M. D. (2004). <i>Learning and motivation in the postsecondary classroom</i> . Bolton, MA: Anker Publishing Company. Wiggins, G., & McTighe, J. (1998). <i>Understanding by Design</i> . Alexandria, VA: ASCD.
Assessment <i>How should we measure learning?</i>	Pellegrino, J. W. (2006). <i>Rethinking and redesigning curriculum, instruction, and assessment: What contemporary research and theory suggests</i> : Paper commissioned by the National Center of Education and the Economy for the New Commission on the Skills of the American Workforce. Pellegrino, J.W., Chudowsky, N., and Glaser, R. (Eds.). (2001). <i>Knowing what students know: The science and design of educational assessment</i> . Washington, DC: National Academy Press.
Pedagogy <i>How should the learning environment support learning?</i>	Perkins, D. N. (2009). <i>Making learning whole: How seven principles of teaching can transform education</i> . San Francisco, CA: Jossey-Bass. Smith, K., Sheppard, S., Johnson, D., & Johnson, R. 2005. Pedagogies of engagement: classroom-based practices. <i>Journal of Engineering Education</i> , 94(1), 87-101.

CAP Course Themes

The backward design approach to course development outlined by Wiggins and McTighe¹ provided the structure of the CAP course. The backward design approach is described as beginning the course design process with the end in mind. For example, Wiggins & McTighe recommend that course development follow three stages:

- Stage 1: Identify desired outcomes and curricular priorities (content)
- Stage 2: Identify acceptable evidence of student learning (assessment)
- Stage 3: Plan and develop instructional strategies/learning experiences to support desired outcomes (pedagogy)

Content. The early stages of course design should begin with identifying desired outcomes and results, and articulating curricular priorities. Wiggins and McTighe¹ provide a framework for articulating curricular priorities, which organizes course content into three categories of *enduring understanding*, content that is *important to know*, and content that is *good to be familiar with*. Identifying the enduring understanding of a course is not a trivial task, and may vary a great deal depending on the nature of the content. In general, however, the enduring understanding should represent the lasting knowledge that is taken away from the course and remembered long after the course is completed. Alternatively, enduring understanding could also represent difficult to learn, abstract concepts, or central thematic concepts that help organize the content. Important-to-know content should provide direct support to the enduring understanding. Specifically, important to know content could include important gateway concepts (e.g., concepts that once learned make a variety of other concepts accessible), concepts that bridge major course themes together, or a combination of both. Finally, content that is good to be familiar with should include more peripheral concepts that add context to the bigger picture, but are too far removed from the central scope, or too advanced, for in-depth examination or deep understanding.

In preparation for selecting and articulating curricular priorities, concepts discussed by Svinicki² emphasize that factors such as students' intrinsic motivators (e.g., personal interests, career advancement, or professional licensure) will affect how students receive information and how easily it is assimilated into long term memory. In addition, understanding of how information is acquired, stored, and recalled will inform how students are expected to provide evidence of their learning.

Finally, once curricular priorities are established, course learning objectives should be generated. While there are several taxonomies available for organizing educational objectives, Bloom's Taxonomy of Education Objectives has perhaps the most widespread adoption in the U.S. Anderson and Krathwohl's³ revised Bloom's taxonomy organizes learning objectives within a continuum in the cognitive domain, ranging from low cognitive levels (e.g., remembering, understanding) to high cognitive levels (e.g., evaluating, creating); as well as a continuum in the knowledge domain, which takes into account the nature of the content by differentiating between different types of knowledge (e.g., factual, conceptual, procedural, and metacognitive). In general, the process of organizing content into clear and measurable learning objectives serves to bridge course content (i.e., what students are expected to learn) to course assessment (i.e., how students are expected to demonstrate their learning).

Assessment. Overall, the objective of course assessments is to make the implicit explicit, or in other words, using specific prompts as tools to elicit demonstrations of student learning, which are then interpreted by the instructor to determine if the learning goals have been met. The most substantial contribution on this topic came from Pellegrino's Assessment Triangle⁴⁻⁵, which provides a framework for aligning underlying theories of how people learn (cognition corner), to the type of evidence used to demonstrate student learning (observation corner), to the inferences made from that evidence regarding what students have or have not learned (interpretation corner). Pellegrino and others⁵ also emphasize the benefits of including formative assessments, which provide valuable feedback to both the students and instructor, in addition to traditional summative assessments. In addition, Wiggins and McTighe¹ provide a succinct outline of three different types of classroom assessments as they relate to curricular priorities (see Figure 1).

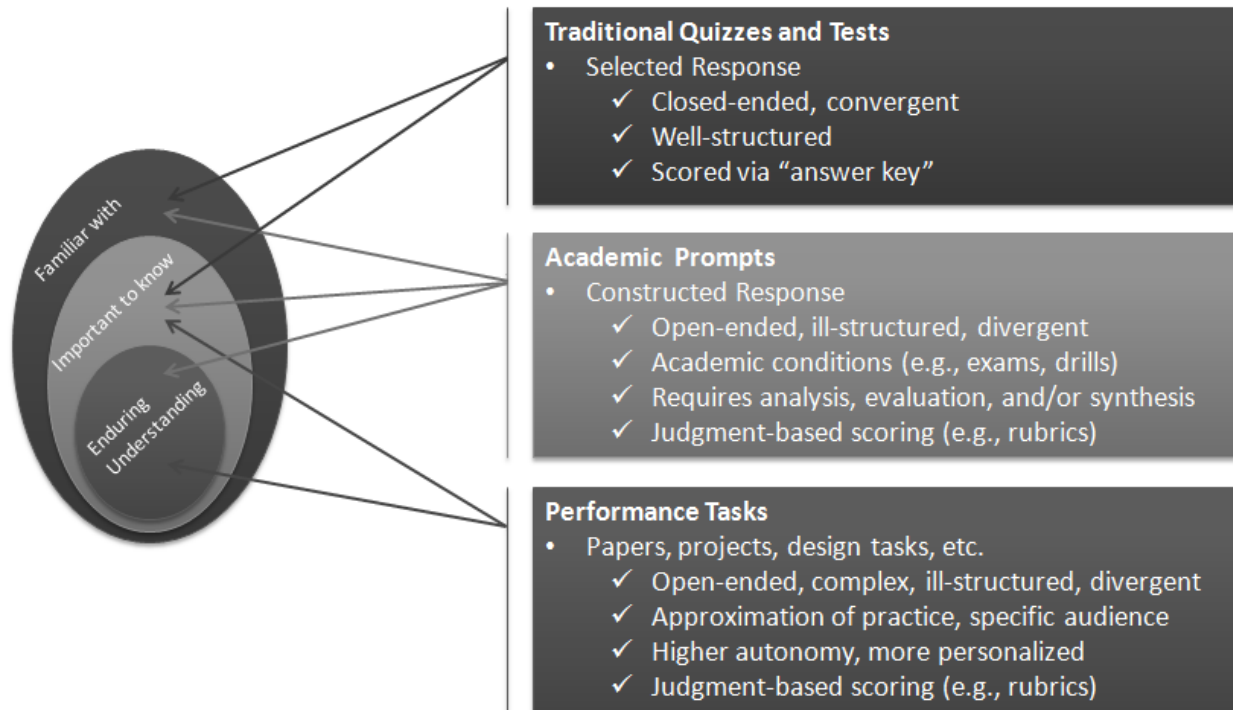


Figure 1. Classroom assessments (adapted from Wiggins & McTighe¹)

Pedagogy. In the discussion of pedagogy, Perkins’ *Seven Principles of Teaching*⁶ offered a unique and holistic framework for considering educational issues such as scaffolding, motivation, knowledge transfer, real-world applicability, collaboration, and building lifelong learning skills. The seven principles include 1) play the whole game, 2) make the game worth playing, 3) work on the hard parts, 4) play out of town, 5) uncover the hidden game, 6) learn from the team...and other teams, and 7) learn the game of learning. The work of Smith and his colleagues⁷ was also used as way to think about pedagogies specific to engineering classrooms, specifically active, problem-based approaches to teaching.

III. Contributions of AIDE Course and Literature

The AIDE course is designed for graduate students with the goal of preparing students to participate fully in distance education in terms of development, teaching, assessment, and evaluation in higher education, K-12, and business/industry environments. The primary course objectives, as applicable to the scope of this paper, included:

1. Discuss theoretical frameworks within distance education.
2. Compare and contrast instructional design methodologies.
3. Discuss common assessment and evaluation approaches used in distance education learning environments.
4. Apply course theories and frameworks to an online curricular development project.

This course was, by most definitions, a blended course. Several hours of “seat-time” were exchanged for guided, asynchronous online discussions. A completely separate body of literature was used to support the central topics of this course. A list of example readings discussed in the course is provided in Table 2.

Table 2. Selected Examples of AIDE Required Reading

Topic	Examples of Required Reading
Distance Ed. Theoretical Frameworks	Moore, M. (2007). <i>Handbook of distance of education</i> (2 nd ed). Mahwah, NJ: Lawrence Erlbaum Publishers. Simonson, M., Smaldino, S., Albright, M., & Zvacek, S. (2009). <i>Teaching and learning at a distance: Foundations of distance education</i> (4th ed.). Boston, MA: Pearson.
Instructional Design Strategies	Lehman, R. M., & Conceição, S. C. O. (2010). <i>Creating a sense of online presence in online teaching: How to "be there" for distance learners</i> . San Francisco, CA: Jossey Bass. Orellana, A., Hudgins, T. L., & Simonson, M. (Eds.). (2009). <i>The perfect online course: Best practices for designing and teaching</i> . Charlotte, NC: Information Age.
Assessment and Evaluation Strategies	Palloff, R. M., & Pratt, K. (2009). <i>Assessing the online learner: Resources and strategies for faculty</i> . San Francisco, CA: Jossey Bass.

AIDE Course Themes

Although presented differently, the AIDE course had similar curricular components as the CAP course. Instead of being organized by stages of the course design process, the content of AIDE course was grouped by a review of foundation theories, instructional strategies, and evaluation strategies. The following sections provide a summary of the three major themes of the AIDE course.

Theoretical Frameworks in Distance Education. One of the primary frameworks discussed in the AIDE course was the Community of Inquiry (CoI) framework⁸, which is among the more well-known and respected frameworks in the distance education field. The CoI framework was developed as process-framework for instructional design in text-based, asynchronous, online learning environments. In its original form, Garrison, Anderson, and Archer⁹ used the CoI framework to describe meaningful learning experiences as the intersection of three *presences* within the learning environment: *cognitive presence*, which represents students' interaction with the course content; *teaching presence*, which represents students' interaction with instructional tools and learning activities; and social presence, which represents students' interaction with other learners and cultural aspects of the learning environment. In 2010, Shea and Bidjerano¹⁰ proposed a fourth element to the framework: *learning presence*, which represents students' interaction with their own self-regulation and learning strategies. As previously mentioned, the CoI is a process-framework, which is primarily concerned with the process of developing the presences within the online learning environment, but is not explicitly concerned with student outcomes.

Instructional Design Strategies. This section of the AIDE course focused on using learning theories as a basis for instruction design and the development of strategies to engage students in online courses. For example, Sorensen and Baylen¹¹ present a concise guide to applying principle of seven widely accepted principles of good practice in teaching to web-based learning environments. Of note, there is a strong focus on developing student-to-student and student-to-instructor interactions and relationships. In addition, Lehman and Conceição¹² provide user-friendly development guides for incorporating group work, facilitating online discussion, and maintaining student engagement throughout various phases of the online course (e.g., before the course, during the course, and at the end of the course).

Assessment and Evaluation Strategies. There is some overlap between the AIDE course and CAP course in discussion of assessment and evaluation. The assessment guide by Palloff and Pratt¹³ also emphasize the importance of communicating expectations through learning objectives that are clear and measureable and well-aligned to the curricular goals of the course. In addition, Palloff and Pratt discuss the importance of course evaluation as a means of continuous improvement.

IV. Merging CAP and AIDE in the Course Development Process

In late 2010, I was contracted by the School of Graduate and Continuing Studies of Norwich University to develop a graduate-level civil engineering course, *Fundamentals of Soil Mechanics and Foundation Engineering* (FSMFE). The course was 6 credit-hour seminar that was taught in an asynchronous, fully online format over 11 weeks, and a prerequisite in the Geotechnical track of the Master of Civil Engineering (MCE) program. The content of this course aligned well with both my professional background and my previous teaching experience with a traditional lecture and laboratory courses covering similar topics. At the time, however, I had never developed or taught an asynchronous online course and was eager to find out more about working within this medium. Therefore, for the 2011 spring semester I registered for both the CAP and AIDE courses, hoping that together they would provide a complementary foundation for the development of the new FSMFE course. While I was expecting the course development project to be a significant, time-intensive task, I was still taken aback by its overwhelming complexity at times. Using the FSMFE as the curricular development project for both the CAP and AIDE courses meant I was approaching the same project from many different perspectives, often before having a clear sense of the what the finished project or the "big picture" looked like. In the end I was fascinated by the way the concepts from the two courses came together; a patchwork of taxonomies and frameworks supported by common foundational learning theories.

The Content, Assessment, and Pedagogy of the New FSMFE Course

Content. As recommended by Wiggins and McTighe¹, I began the development process by identifying the curricular priorities (e.g., enduring understanding, important to know, and good to be familiar with) of the FSMFE course. To determine the enduring understanding, I conducted a literature review that focused on identifying specific criteria/objectives that should be addressed by graduate level engineering courses, and specifically concepts within Geotechnical Engineering that are central to the profession, abstract, and difficult to learn. My literature search focused on criteria for ABET accreditation of engineering programs¹⁴, and publications of the American Society of Civil Engineers (ASCE), particularly the *Body of Knowledge* report¹⁵, and articles from the *Journal of Professional Issues in Engineering Education and Practice*. From

this literature I identified three central themes of uncertainty in measurement, economical impact, and ethical decision-making as critical issues that are underrepresented in Civil Engineering, and particularly in Geotechnical Engineering curricula. In summary, I used the evidence shown in Figure 2 to select and justify the content for the new FSMFE course.

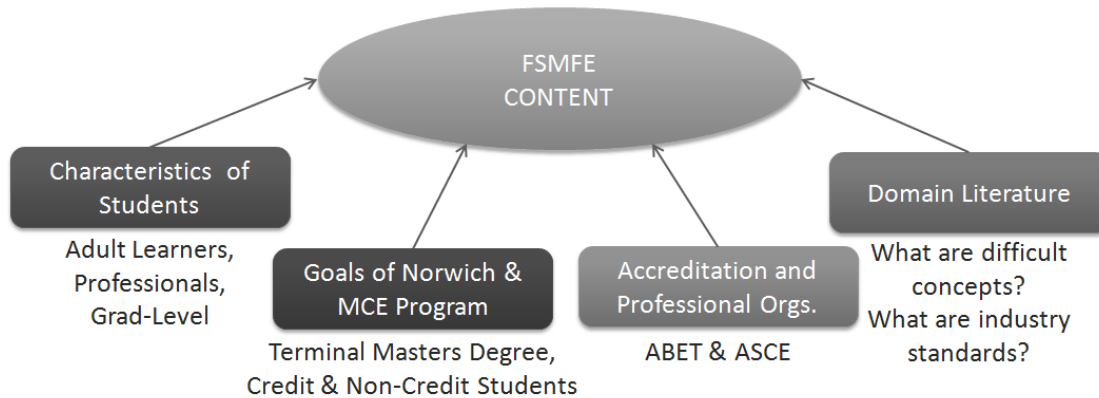


Figure 2. Evidence used to select and justify content for FSMFE course

Overall, I organized the enduring understanding into four primary learning objectives; students were expected to:

- describe how issues of uncertainty and ethical decision-making relate to soil mechanics and foundation design topics
- identify and describe geotechnical constructability factors that affect economical impacts of construction projects
- design a subsurface surface investigation plan
- generate foundation system recommendations for given soil conditions

The first two objects represent central themes that are difficult to learn, and the second two objectives represent concepts that require synthesis of course topics and bridge course themes together. The important to know content was selected to directly support the enduring understanding. To articulate the curricular priorities of the FSMFE course, I created a concept map that shows the structure of the enduring understanding and important to know content (Figure 3).

I used the revised Bloom's taxonomy³ to generate and organize learning objectives for the FSMFE course. I used a matrix of the cognitive domain versus the knowledge domain as a visual tool to display weekly learning objectives. The purpose of this tool was to make the alignment between the learning objectives and curricular priorities explicit. For example, I reviewed the matrix of weekly learning objectives to ensure that a) the number of objectives was appropriate and represented a reasonable workload for students (e.g., typically 5-8 objectives each week); and b) learning objectives relating to enduring understanding and important to know content were written to appropriate levels in the cognitive domain.

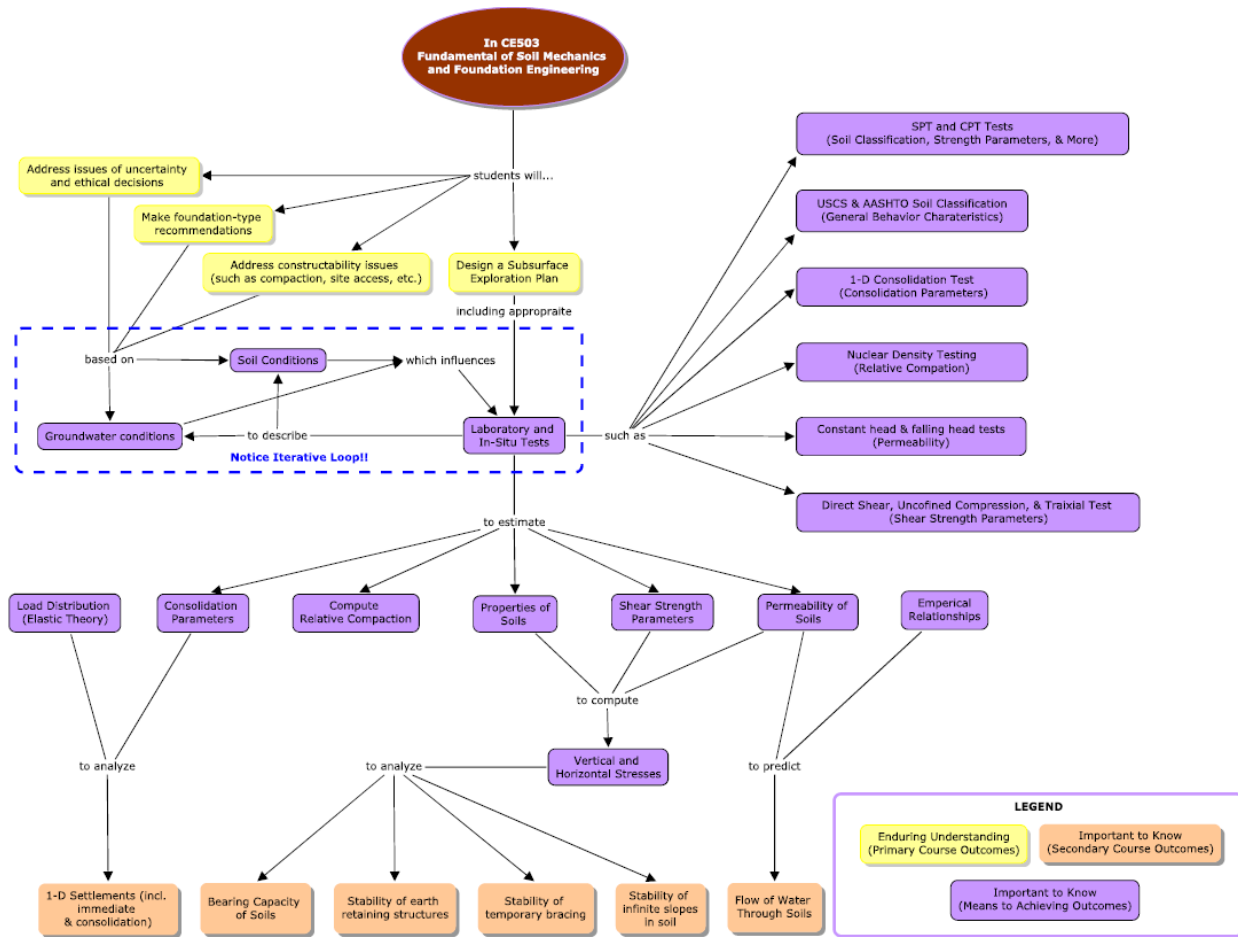


Figure 3. Concept map of FSMFE course

Assessment. Overall, combinations of formative and summative assessments were designed for this course. Two oral exams were used primarily as formative assessments. The primary purpose of the exam was to provide the students an opportunity to verbally articulate their understanding of geotechnical concepts and receive instructor feedback. In addition, students' responses were used to determine if instructional materials were effective or if additional materials were needed to clarify difficult concepts. A rubric was generated to explain the criteria for the exam. The exam was pass/fail, however, the only consequence of not passing is that the student would need repeat the exam.

Summative assessments included homework assignments, quizzes, and group discussion questions that were generally assigned on a weekly basis. The homework assignments consisted of two parts. Part one contained academic prompts, which were open-ended constructed-response problems. Even in cases where computational problems were given, there were still multiple solutions, depending on how assumptions were made, that were considered correct. Part two consisted of one or two performance tasks that generally required higher levels of cognition to complete. For example, performance tasks included a) describe and respond to ethical scenarios relating to geotechnical issues, b) providing theoretical/conceptual justification

for assumptions commonly made in geotechnical analyses, or c) locating and interpreting scholarly research publications. In general, the second task was designed to encourage students to apply course concepts in a less structured assignment. The discussion questions were typically used as a group reflection forum. Guiding questions were used to prompt student to explain how course concepts were relevant to their personal experience, or to explain how course concepts were related to one another. In an asynchronous online course, the threaded discussions were the primary mode of communication between the course participants. As a reflection of that central role, discussion was worth approximately one-third of the final course grade.

Pedagogy. The pedagogy portion of the course is where I drew the most from the distance education literature, particularly the CoI literature and readings such as Bonk and Dennen¹⁶ that give broad overviews of activities to consider that suit a variety of learning goals. The learning management system (LMS) used by Norwich University was Angel. Several features of the LMS included an integrated grade book and calendar tool, and redundancy features that allowed users to search through course material by aggregated menus showing all course items, or by organized tabs. Links to all discussion forums and graded assignments were found in more than one location. Pedagogical tools that I chose to integrate specifically for the asynchronous online learning environment included weekly podcasts that provide an overview of each week, as well as narrated examples for problems that were difficult or confusing. In addition, I used a digital pen to write and narrate solutions to part one of the written assignments. Students were provided a static pdf of the solution as well as a link to the narrated solution. Students could go directly any part of the narration by clicking on the text. More broadly, I choose examples, tables, and problem solving tools to be pragmatic and immediately relevant to students who are also professionals in the field.

Bumps in the Road

The Instructional Team. The instructional team for this project included the following personnel:

- course developer (myself), responsible for selecting/generating all course content, assessments, rubrics, and learning materials;
- instructional design expert, responsible for putting all course content into the LMS;
- instructional design manager, responsible for managing the instructional design process; and
- assistant program director, responsible for managing the course development process.

I found working with such an extensive instructional team to be both helpful and frustrating. In my own previous experience I had free reign to organize content and upload content to the LMS in whatever manner I chose. This was good in that I had a lot of creative license, but restrictive when I ran into limitations of the LMS or my own technological expertise. The development of the FSMFE course was my first experience working with a large instructional team. There were some cases where I assumed I could structure an assignment in a certain way, and it would not take much planning beyond uploading a file or two into the LMS classroom, which actually caused significant challenges for the instruction design expert. For example, my decision to allow students to have two attempts to pass a quiz presented the instructional team with a hurdle

they had not faced before. Since every graded assignment is automatically linked to the grade book, having two quizzes, when only one will be graded, created some complications with the grade book that took some creativity to work around. Ultimately, every time a challenge like this occurred, it forced me to further articulate pedagogical decisions to justify the time spent by the instructional design team to find solutions to these problems.

Time Management. In any course development project, time is usually a significant limitation. In teaching an asynchronous online course, it is generally helpful for students if the complete course is available at start of the course. Otherwise, students can become confused and overwhelmed if content is frequently added or reorganized. Overall, I spent approximately 120 hours on the development of the FSMFE course. I also used this course as the final term project in two courses, which justified spending some extra time above and beyond what I would have done if I designed independently. The development of the course was very time intensive, but there were some trade-offs. For example, I spent three to four weeks exclusively on course planning. During this time I generated the course concept map, drafted course learning objectives, organized learning objectives by week, and outlined major assessments. Taking this time upfront made developing course materials easier for the rest of the project. In addition, by developing all of the material before the start of the course, the instruction of the course was much easier. For example, I felt like I was able to focus more on providing detailed feedback on course assignments (i.e., written assignments, discussion, and oral exam) rather than needing to develop the content for the next week.

Adapting to Changes. Traditionally there is a minimum of eight students required for a course to be offered in the MCE program. Knowing this, I designed the course assuming there would be approximately eight to 12 students. The FSMFE course, however, is a prerequisite that not all students are required to take, and the geotechnical track is new to the MCE program. Two weeks before the course completion deadline I discovered that only two students would be taking the course. Nearly 50 percent of the course grade was collaborative work (e.g., peer review, discussion, and a collaborative group project). With this new information, I did not feel like the course structure would work with only two students. To adapt, I revised some discussion questions to be reflections that did not require back and forth discussion, and I changed the course project to be a self-selected individual project. The main lesson I took from this was that careful planning made the course development process go smoothly, but being able to adapt to changes is still very important.

Conclusions

Since teaching this course, I now act as a mentor to other course developers in the MCE program, many of whom are professionals with limited or no educational training. The role has helped me generate some planning tools that can be used to streamline the development process. In particular, the following three planning guides have been useful planning guides and communication tools.

Educational Priorities. One of the most difficult steps of the process is selecting content, and in particularly articulating education priorities. A useful guide is shown in Figure 3.

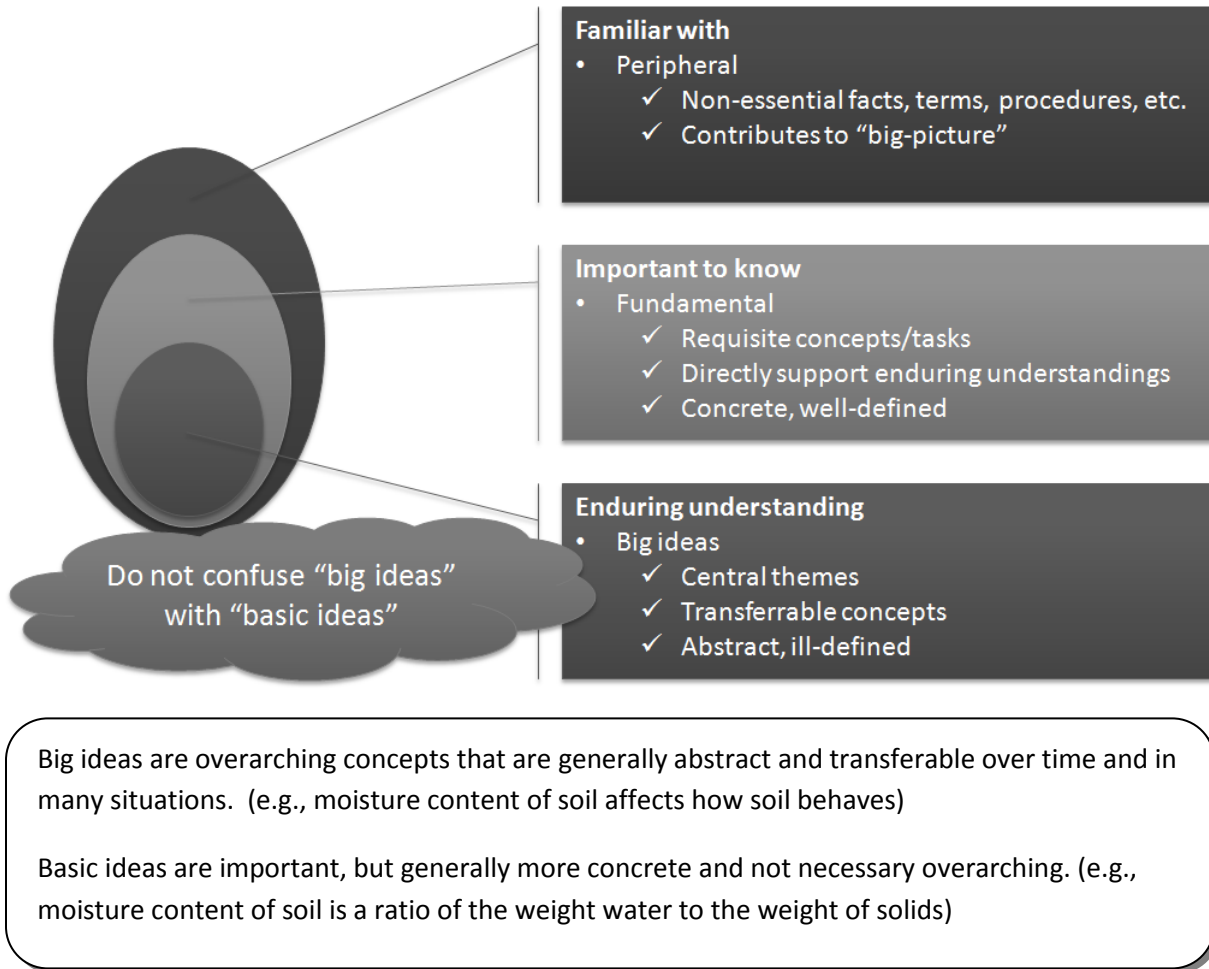


Figure 3. A framework for curricular priorities (adapted from Wiggins and McTighe¹)

Backward Design CAP Framework. Explaining the alignment between course content, assessment, and pedagogy can be difficult, especially to an audience with limited educational training. I developed Figure 4 to illustrate the big picture of the backward design process and overall CAP framework.

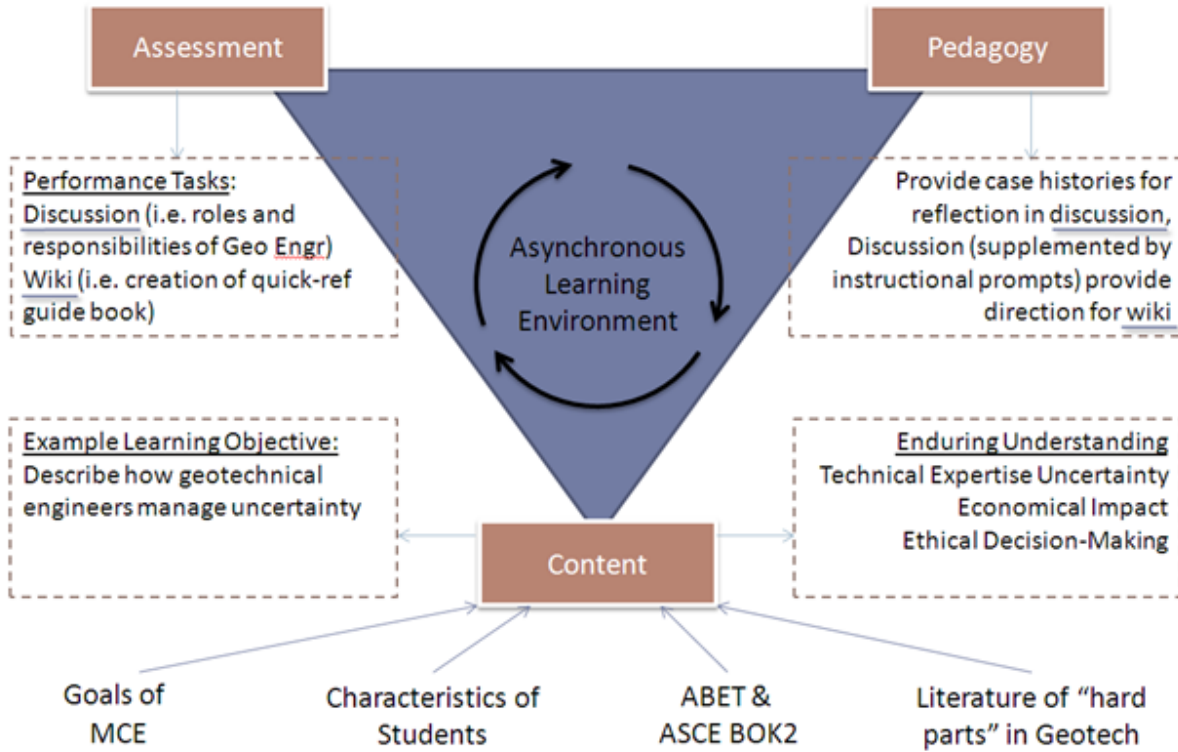


Figure 4. Content, assessment, and pedagogy course development framework

Weekly Planning Guide. To facilitate course planning, I developed a CAP worksheet that served as weekly outline to explicitly articulate weekly learning objectives (content), how each learning objective would be assessed (assessment), and the learning materials that support the content for that week. An example of this worksheet is show in Figure 5.

Map of Week 2 Learning Objectives		Cognitive Process Dimension					
		1 Remember	2 Understand	3 Apply	4 Analyze	5 Evaluate	6 Create
Knowledge Dimension	A. Factual Knowledge	L1-IK			L4-EU		
	B. Conceptual Knowledge		L2-EU				
	C. Procedural Knowledge			L5-EU L6-EU			
	D. Metacognitive Knowledge			L3-IK			

(Framework: Anderson & Krathwohl, 2001)

Content:

- [L1] Define basic rock and soil formation terminology.
- [L2] Explain the how geologic site descriptions are relevant to geotechnical projects.
- [L3] Write a geologic description for a given project site.
- [L4] Compare and contrast main characteristics of granular soil structure and clay soil structure.
- [L5] Manipulate basic weight-volume relationships to identify needed soil properties.
- [L6] Classify soil using AASHTO and USCS systems.

Assessment:

- Written Assignment
 - o Task 1 - Academic Prompts (AP)
 - Problem 1 = L1, L2
 - Problem 2 = L4
 - Problem 3 = L5
 - Problem 4 = L6
 - o Task 2 - Performance Tasks (PT)
 - Task 1 = L3
- Discussion D2 = L1, L2
- Quiz Q2 = L3, L4, L5, L6

Pedagogy:

- Lecture Notes
 - o 2.0 Soil Deposition
 - o 2.1 Soil Structure
 - o 2.2 Soil Composition
 - o 2.3 Soil Classification
- Multimedia
 - o Podcast: Week 2 Overview
 - o Lecture 2.2 Examples (Narrated PPT)
 - o Lecture 2.3 Examples (Narrated PPT)

Figure 5. Example CAP worksheet

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I would like to thank my professors of the CAP course, Drs. Ruth Streveler and Karl Smith, and the AIDE course, Dr. Jennifer Richardson. Their courses were expertly designed and provided valuable learning experiences that led to the successful completion of this project.

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