Proceedings of the XVII ECSMGE-2019
Geotechnical Engineering foundation of the future
ISBN 978-9935-9436-1-3

doi: 10.32075/17ECSMGE-2019-0148

XVII European Conference
ECSMGE 2019
Reykjavik
on Soil Mechanics
and Geotechnical Engineering

Concept maps as a culminating experience in a design course

Cartes conceptuelles comme expérience culminante dans un cours de design

T. Kunberger / primary author
Florida Gulf Coast University, Fort Myers, USA

ABSTRACT: This paper discusses the application of concept maps in a senior level design course that is the second in a two course sequence in geotechnical engineering. A significant component of the course is an individual specialization project that requires students to research and investigate a topic related to geotechnical, geo-environmental, or geological engineering and synthesize the resulting information into a cohesive five thousand word paper and a five to seven minute multimedia presentation. The course culminates with each student being tasked with creating a concept map that ties their specialization topic to the course topics, previous course topics, specialization topics of other group members, and potentially to topics from other courses or personal experience. This paper presents an introduction to the benefits and limitations associated with concept map activities, an overview of the semester specialization project with a specific focus on the concept map activity, a discussion on the evolution of this activity, and an analysis of the developed concept maps. Concept maps are analyzed in both a qualitative manner with regards to themes developed in key concepts and connections and in a quantitative manner by considering the number of key concepts directly related to the course, the number of concepts related to other courses or outside topics, and the number of connections and cross-connections included.

RÉSUMÉ: Cet article traite de l'application de cartes conceptuelles dans un cours de conception de niveau supérieur qui est le deuxième d'une séquence de deux cours en génie géotechnique. Une composante importante du cours est un projet de spécialisation individuelle qui demande aux étudiants de rechercher et d'examiner un sujet lié au génie géotechnique, géo-environnemental ou géologique et de synthétiser les informations résultantes dans un document cohérent de cinq mille mots et un document multimédia de cinq à sept minutes présentation. Le cours se termine lorsque chaque étudiant est chargé de créer une carte conceptuelle liant son sujet de spécialisation aux sujets du cours, aux sujets de cours précédents, aux sujets de spécialisation d'autres membres du groupe et éventuellement à des sujets issus d'autres cours ou de l'expérience personnelle. Cet article présente une introduction aux avantages et limites associés aux activités de la carte conceptuelle, un aperçu du projet de spécialisation du semestre avec un accent particulier sur l'activité de la carte conceptuelle, une discussion sur l'évolution de cette activité et une analyse des cartes conceptuelles développées. Les cartes conceptuelles sont analysées de manière qualitative tant par rapport aux thèmes développés dans les concepts clés et les connexions que de manière quantitative en prenant en compte le nombre de concepts clés directement liés au cours, le nombre de concepts liés à d'autres cours ou à des sujets extérieurs, et le nombre de connexions et de connexions croisées inclus.

Keywords: Concept maps; information literacy; technical writing

1 INTRODUCTION

Students often struggle with recognizing links between different ideas, even those within the same course. This isolation of concepts can result in the overall reduction in comprehension of individual concepts as well as the likelihood of reduced synthesis of broader ideas. While identifying connections between key ideas may take more effort than rote memorization, it often results in richer and more comprehensive topical understanding (Brown, et al., 2014) and students reaching higher achievement levels on Bloom's revised taxonomy of learning (Anderson and Krathwohl, 2001).

Concept maps are a pedagogical tool which develops students' abilities to recognize these links, allowing greater connections to be identified and fostering a higher cognitive understanding. Built upon Ausubel's assimilation theory of cognitive learning (1968), the use of concept maps is also well-aligned with constructivist learning theories (Piaget, 1962, Vygotsky, 1978, Dewey, 1916). Preszler (2004) found increased student performance on exams when concept map instruction was integrated into the course while Novak and Musonda (1991) found increases in conceptual understanding on a longitudinal basis.

Within engineering education studies have shown concept maps to improve learning in both introductory and upper level courses (Roberts et al., 2014, Watson et al., 2014, Fang, 2015). Research has even expanded to the idea of amending concept map development to promote a more cohesive understanding of larger volumes of information (Williams et al., 2012), incorporating concept maps to personalize learning by aligning the learning environment with various student learning styles (Cartas, 2012), and considering how concept map scoring aligns with the demonstration of knowledge gains (Watson et al., 2016).

2 COURSE AND ASSIGNMENT LOGISTICS

As a senior-level design course, Geotechnical Engineering II is required of all students in the civil engineering program. Because the course is the second in a sequence, enrolled students have successfully completed the first geotechnical engineering course focused on fundamental soil mechanics concepts. This first course provides a reasonable foundation for integrated design work, but limited experience in addressing open-ended and ill-defined problems customary in an authentic design experience. The first course also emphasizes laboratory testing, data compilation and analysis of results focusing on soil characterization, while the impact of this characterization on soil behavior and the influence it exerts on design considerations is reserved for the second course (Kunberger and O’Neill, 2011).

2.1 General Course Information

The Geotechnical Engineering II course meets for four and a half hours once a week and is divided into three separate five-week modules. Module focus includes shallow foundation design, slope stability analysis, and retaining wall design, and each topic is paired with a related design project (Kunberger, 2013). Interwoven throughout all three modules are weekly discussions on historic to current articles on pertinent geotechnical engineering topics and an overarching individual semester project.

Module design projects are team-based group submissions each worth 20% (for a total of 60%) of the students’ final grades. Projects are evaluated against a standardized project rubric that is made available to students at the beginning of the course, and peer evaluation is incorporated to adjust a group grade to an individual grade based on individual team member contributions. Weekly discussions include expectations of completing either a written submission or brief quiz prior to the in-class discussion with the sum of these activities accounting for 10% of the overall course grade. The remaining 30% of the course grade is linked to the individual semester project. The most recent offering of the course deviated slightly from this grading breakdown: reducing each project to 17.5% each and shifting this 7.5% of the course to an individual in class design calculation (i.e. open book exam).

2.2 Semester Specializations

The individual project, or semester specialization, requires students to research and investigate a topic related to geotechnical, geo-environmental, or geological engineering and synthesize the resulting information into a cohesive five thousand word paper and a five – seven minute multimedia presentation. The project scaffolds with assignments throughout the semester that are designed to keep students on track and encourage revisions based on the feedback they receive. These assignments include an initial topic selection with a list of preliminary sources, an introduction and paper outline with an expanded reference list, and a 75% draft paper submission that receives feedback not only from the instructor, but also from another classmate.

Upon submission of the culminating paper and presentation, students are placed in groups of diverse topics and are required to view the multimedia presentations of their group members prior to the final exam period. Topic diversity is characterized by the combination of topics that at first glance may not have significantly overlapping concepts. Three examples of group topic diversity are presented in Table 1. Topic diversity is an intentional goal of group formation for several reasons. First, it allows students to serve as a nominal expert on their topic, as their familiarity with the subject is usually greater than that of their classmates. Second, it introduces students to the wide scope of applications of geotechnical engineering. Third, it requires students to correlate topics that initially appear only loosely related by utilizing core topics from both Geotechnical Engineering courses.

Table 1. Select Examples of Semester Specialization Diverse Grouping of Topics

Group	Topics
1	Soil Structure Interactions, Soft Ground Tunneling, Environmental Bioremediation, Biogrouting, and New Orleans Levee Failures
2	Soil Thermal Property Uses in Engineering, Soil Structure Interaction, Herbert Hoover Dike Restoration, Soil Creep Underlying Embankments, and Longterm Performance of Geosynthetics in Roadways
3	Hydraulic Fracturing, Fiber-Reinforced Soils, Haitian Geotechnical Concerns, Geosynthetics for Reducing Seismic Effects on Soils, and Underwater Tunnel Construction

The final exam time begins with brief group discussions of each presentation and culminates with each student being tasked with creating a concept map that ties their specialization topic to the course topics, topics in previous courses, specialization topics of other group members, and potentially topics from other courses or personal experience. The overarching goal is for students to recognize not only the diversity inherent in geotechnical engineering, but also the robust nature of the concepts covered in both classes and the integrative aspects of geotechnical engineering with respect to other branches of engineering.

3 CONCEPT MAP DEVELOPMENT

Informal polling in class indicates that only a handful of students are aware of what a concept map is designed to accomplish, and even fewer have actually developed a concept map in a formalized manner. The concept map assignment is posted on Canvas (the University's Learning Management System) at the start of the semester. This assignment includes not only assignment logistics such as due date, percent contribution to final grade and expectations for the deliverable, but also provides additional information including Novak and Cañas's (2008) article on the underlying theories of concept maps and brief instructional videos on constructing concept maps (Pohlman and Thomas, 2013, Pennsylvania State University Libraries, 2013).

During the final week of the semester the concept map assignment is formally introduced and discussed in class. Because of the relative unfamiliarity of students with concept maps in general, the instructor also provides a brief introduction to concept maps, a rationale for the incorporation of concept maps in the class, and the "real-time" development of an example concept map in addition to a general discussion of the assignment. The example concept map is created by the instructor on the white board in the classroom. While more limited in scope than the expected final student submission, concept map creation provides not only an example of a final product for the students, but also includes an example of the process, as the instructor verbally explains the applied thought process during concept map construction. Introducing the assignment prior to students viewing their group presentations also allows them to consider potential relationships between the topics while they are watching the videos.

4 ANALYSIS OF DEVELOPED CONCEPT MAPS

A subset of student work from a single semester was selected for in-depth analysis and discussion. Two sections of the course were offered in the semester under consideration, with a total of 56 enrolled students. Concept maps from ten students (18% of the overall course population) comprise the analyzed data set. The overall course average for all students was an 84.6%. The average for the selected subpopulation was 84.5%. Additionally, subpopulation selection included two students from each of the upper and lower quartiles of concept map grading and three from each of the middle quartiles. The class concept map average was 58.2/65 (89.5%) while the subpopulation average was 59/65 (90.8%). Both populations included a range of scores from 53/65 (81.5%) – 65/65 (100%). While the primary goal of subset selection focused on a representative grouping from the concept map assignment, the close comparison of final grade averages between the main and subset populations suggests that from an academic performance standpoint the subpopulation is a reasonable representation of the course population. Student concept maps were randomly assigned a number from 1 – 10 for discussion purposes.

Of the ten concept maps analyzed, six were from separate topic groups. The remaining four represented two additional topic groups. This resulted in the included maps comprising eight of the ten distinct groups created in this particular semester of the course.

4.1 Quantitative Concept Map Analysis

Quantitative concept map evaluation included counting the number of different concepts each student included, the number of hierarchies (branches) off of the main topic and the length of the longest chain starting from the main topic. Table 2 includes a summary of this information by student, as well as the range, mean, and median for each category.

With regards to the number of concepts, students included anywhere from 17 – 50 distinct ideas, with an average of 31.5 included concepts. Some variations in these numbers came from the specificity of concept labels (e.g. "soil testing" versus the inclusion of specific soil tests). The majority of the differences, however, came from the inclusion of a variety of concepts.

The number of hierarchies and length of the longest chain were both based off of the individual student's semester specialization topic. This means that even for students in the same topic group, hierarchy counts originated from different key terms. This "standard" counting approach, if considered in isolation, can result in an underestimation of the complexity of select student work. For example, Student 6 included only 3 branches off the main semester specialization topic, but had three concepts with 5 branches, and one topic with 7 branches.

Table 2. Number of concepts, branches, and chain length by student

Student / Summary Category	Number of Concepts	# of Branches off main concept	Length of longest chain
1	38	7	4
2	20	5	4
3	17	3	5
4	19	6	6
5	23	9	9
6	46	3	7
7	36	12	6
8	50	6	6
9	48	9	8
10	18	4	8
Range	17 – 50	3 – 12	4 – 9
Mean	31.5	6.4	6.3
Median	33.5	7	6.5

4.2 Qualitative Concept Map Analysis

Qualitative concept map analysis was conducted to identify overarching themes in all concept maps. In addition, special focus was placed on concept maps from two students within the same group to ascertain theming similarities for similar topics. Themes from a majority of the concept maps fell into two distinct categories. The first category was terms common to both geotechnical engineering courses, while the second was design or group specific terms. Common course terms included themes such as water (pore water pressure, groundwater flow, etc.) and soil types (sands, clays, etc.). These terms appeared most often as connections between multiple semester specialization topics and demonstrated how students were able to relate multiple specific geotechnical ideas and innovations to the broader concepts that serve as focus areas of the course.

The second theme that arose fell into a category that can be described as more design and/or group specific ideas. Design concepts such as stability, safety, settlement, and bearing capacity were applicable to multiple semester specialization topics and thus it was not surprising for them to appear on concept maps – even when topic areas exhibited limited overlap. Group specific ideas including erosion, liquefaction, various geosynthetics, and earthquakes / natural disasters also appeared on a majority of maps. The frequency of these concepts was likely due less to them being common design ideas and more due to the fact that a vast majority of the created groups had at least one semester specialization topic focused on earthquakes, geosynthetic applications, and geotechnical design failures (e.g. levees during Hurricane Katrina, Herbert Hoover Dike, Mexico City geotechnical challenges).

When assessing two concept maps from separate students within the same group, additional term similarities were apparent. As students were asked to include all five topics as concept map terms, these similarities were ignored during comparisons. The first group duplicates were students #2 and #5 (group 1 from Table 1). Three terms (Finite Element Modeling, micro-organisms, and tunnel walls) were duplicated in these concept maps. In all three cases these terms were used as intermediate points between the same semester specialization topics for each map. While terms were duplicated, verbiage on the connecting arrows was individualized. Even with these similarities student maps exhibited several unique terms and concept correlations that distinguished one map from the other. The second duplicate group concept maps included students #7 and #8. As these concept maps both included a greater number of concepts than the previous two discussed, it is somewhat expected that the number of duplicate terms was also greater. In this case ten terms fell into the duplicate list and while several of these were employed for semester specialization topic connection purposes, the majority served as additional details for extended / more complex concept mapping.

5 EXPANSION OF WORK

After two years of conducting concept map activities with the Geotechnical Engineering II course, a version of the activities was introduced into the Geotechnical Engineering I course (Kunberger, 2018). The specific focus of the concept maps in the first course is slightly different, as the primary purpose is to help students link core course concepts to one another, resulting in greater similarities in key terms across individual maps and a greater repetition in relationships between terms than what is seen in this second course, which contains more diverse and personalized topics. Future research will consider whether or not greater experience with / earlier exposure to concept maps results in more robust and complex maps in the second course.

6 CONCLUSIONS

In an effort to demonstrate both the complexity and interconnectivity of diverse geotechnical, geo-environmental, and geological engineering topics, concept maps were introduced into a senior level geotechnical design course. Results show students are able to identify connections within the broader realms of geotechnical engineering even when tasked with developing relationships between intentionally differentiated ideas. These links are constructed both from personal experiences as well as from foundational knowledge provided in the two course sequence. While students created concept maps of differing complexities, some general overarching themes of foundational knowledge and design concepts could be identified in all maps, and specific ideas were utilized by multiple individuals to link topics within the same groups.

The next step will be a focus on the impact multiple exposures to concept map activities has on individuals' abilities to develop meaningful concept maps and the student perception of concept map development on the value of geotechnical engineering.

7 REFERENCES

Anderson, L. and Krathwohl, D. eds. 2001. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, Longman, New York, NY, USA, 352 p.

Ausubel, D. P. 1968. *Educational Psychology: A Cognitive View*, 2nd ed., Holt, Rinehart and Winston, New York,, NY, USA, 733 p.

Brown, P. C., Roediger, H. L., and McDaniel, M. A. 2014. *Make It Stick: The Science of Successful Learning*, Harvard University Press, Cambridge, MA, USA, 313 p.

Cartas, M. L. 2012. Using an Improved Virtual Learning Environment for Engineering Students, *European Journal of Engineering Education*, **37**, 3, 229 – 241.

Dewey, J. 1916. *Democracy and Education: An Introduction to the Philosophy of Education*, The Macmillan Company, New York, NY, USA, 358 p.

Fang, N. 2015. Using Student-Generated Concept Maps to Assess Students' Conceptual Understanding in a Foundational Engineering Course, *Proceedings of the 122nd ASEE Annual Conference and Exposition*, Seattle, Washington.

Kunberger, T. and O'Neill, R. 2011. Evaluation of Teaching a Two Course Sequence in Geotechnical Engineering in an Integrated Lecture – Lab Environment, *5th Pan-American Conference on Teaching and Learning of Geotechnical Engineering*, Toronto, Ontario, Canada, CD-ROM.

Kunberger, T. 2013. Revising a Design Course from a Lecture Approach to a Project Based

Learning Approach, *European Journal of Engineering Education*, **38**, 3, 254 – 267.

Kunberger, T. 2018. The Impact of Concept Map Development on Student Synthesis of Course Information, *Proceedings of the 2018 ASEE Southeastern Section Conference*, Daytona Beach, Florida.

Novak, J.D. and Musonda, D. 1991. A Twelve-Year Longitudinal Student of Science Concept Learning, *American Educational Research Journal*, **28**, 1, 117 – 153.

Novak, J. D., and Cañas, A. J. 2008. The Theory Underlying Concept Maps and How to Construct and Use Them, *Technical Report IHMC CmapTools 2006-01, rev 2008-01*.

Pennsylvania State University Libraries. 2013. How to Create a Concept Map, *YouTube*, https://www.youtube.com/watch?v=eYto-ZRmWLBc.

Piaget, J. 1962. *The Language and Thought of the Child*, 3rd ed., Routledge & Kegan Paul, London, England, 288 p.

Pohlman, C. and Thomson, B. 2013. The Mind Matters Show – Becky on the Concept Map, *YouTube*, https://www.youtube.com/watch?v=bmncg-Kzhq8.

Preszler, R. 2004. Cooperative Concept Mapping: Improving Performance in Undergraduate Biology, *Journal of College Science Teaching*, **33**, 6, 30 – 35.

Roberts, M. W., Haden, C., Thompson, M. K., and Parker, P. J. 2014. Assessment of Systems Learning in an Undergraduate Civil Engineering Course Using Concept Maps, *Proceedings of the 121st ASEE Annual Conference and Exposition*, Indianapolis, Indiana.

Vygotsky, L. S. 1978. *Mind in Society: the Development of Higher Psychological Processes*, Harvard University Press, Cambridge, MA, USA, 159 p.

Watson, M. K., Pelkey, J., Noyes, C. R., and Rodgers, M. O. 2014. Use of Concept Maps to Assess Student Sustainability Knowledge, *Proceedings of the 121st ASEE Annual Conference and Exposition*, Indianapolis, Indiana.

Watson, M. K., Pelkey, J., Noyes, C. R., and Rodgers, M. O. 2016. Assessing Conceptual Knowledge Using Three Concept Map Scoring Methods, *Journal of Engineering Education*, **105**, 1, 118 – 146.

Williams, C. B., Johri, A., Pierce, R. S., and North, C. 2012. Advancing Personalized Engineering Learning Via an Adaptive Concept Map, *Proceedings of the 119th ASEE Annual Conference and Exposition*, San Antonio, Texas.