Creating a Library of Group Activities that Promote Active Learning in the Undergraduate Soil Mechanics Classroom

Dr. Gretchen Bohnhoff P.E., University of Wisconsin, Platteville

Dr. Gretchen Bohnhoff is an assistant professor in the Department of Civil and Environmental Engineering at the University of Wisconsin-Platteville. Her research interests have a common theme of sustainable and novel solutions to waste containment and the fate and transport of contaminants in the geoenvironment. Dr. Bohnhoff teaches a variety of undergraduate courses at UW-Platteville including Geotechnical Engineering, Environmental Engineering, Foundation Design, and Groundwater Hydrology.

Dr. Kristin M. Sample-Lord P.E., Villanova University

Dr. Kristin Sample-Lord is an assistant professor in the Department of Civil and Environmental Engineering at Villanova University, with expertise in geotechnical and geoenvironmental engineering. Her research focuses on soil barrier systems for protection of human health and the environment and geotechnical aspects of stormwater control measures. Dr. Sample-Lord teaches a number of undergraduate and graduate courses, including Geology for Engineers, Soil Mechanics and Geoenvironmental Processes.

Creating a Library of Group Activities that Promote Active Learning in the Undergraduate Soil Mechanics Classroom

Abstract:
A digital library of group activities that promote active learning in the undergraduate soil mechanics classroom was developed through a collaborative effort between Villanova University (VU) and the University of Wisconsin-Platteville (UW-Platteville). The intent was to develop multiple activities that could be shared with geotechnical faculty via dissemination through the United States Universities Council on Geotechnical Education and Research (USUCGER), which would be easy to implement in existing soil mechanics courses, with little to no preparation. Sixteen different activities were developed with the help of undergraduate and graduate students at both VU and UW-Platteville, and support from USUCGER. The materials for each activity include: (1) a summary sheet for the instructor with learning objectives and instructions; (2) the activity handout to provide to the students; (3) the solution set; (4) an example rubric for the activity; and (5) supplemental information, if applicable. The required in-class time for the activities ranges from as short as one to two minutes to 50 minutes, to allow for flexibility in implementing the activities in existing courses. All of the activities were created for small informal groups. The activities vary widely in their format (e.g. "typical" quantitative problems, group jigsaws, concept questions/discussion, group presentations, calculation QA/QC) to complement different teaching styles. All of the activities included in the library were reviewed by four other faculty members with experience teaching undergraduate geotechnical courses at a range of universities. Several of the activities also were piloted in an undergraduate soil mechanics class at UW-Platteville in spring 2017 and then most of the activities were implemented in fall 2017 and spring 2018. Scores from student evaluations from semesters before the activities were implemented were compared with student evaluations and surveys conducted after implementation of the new active learning format. The implementation of the activities showed improvement in student perception of the clear presentation of complex material, instructor confidence in course content, encouragement of questions, and instructor investment in student learning. In addition, students were more interested in geotechnical engineering, and felt the small group activities provided a real world context to the topics covered in geotechnical engineering.

Introduction and Background

Active learning may increase student engagement, performance, and retention [1]. One active learning technique is small group activities. Small group activities give students the opportunity to interact with their classmates, learn from others problem-solving techniques, and work in teams in non-stressful situations. In addition, small group activities provide an opportunity for the instructor to circulate around the room and provide feedback [2], [3]. Finally, small group activities are an opportunity to provide "real world" context to the topics covered in a course.

In order to attract the best and brightest students into the geotechnical field, geotechnical engineering needs to be shown to be challenging, interesting, and relevant; essentially we need to "sell" geotechnical engineering to undergraduate and graduate students [4]. Therefore, content with real world challenges and applications should be incorporated at the undergraduate level in the introductory geotechnical engineering course. Wirth et al. [5] recommend changes to undergraduate curriculum to reserve time for practical applications and modern developments in geotechnical engineering. These recommendations include keeping the fundamental topics (e.g., soil classification, seepage, mechanical behavior) but limiting the theoretical derivations to allow time to cover additional topics and incorporate active learning into the classroom. The overall goal of the small group activities created as part of this project are to expose students to real world concepts in geotechnical engineering and enhance student learning.

The authors have both taught geology for engineers courses at their respective universities and utilized the extensive resources available for geoscience educators through the Science Education Research Center (SERC website https://serc.carleton.edu/highered/index.html). In addition, the authors have used materials from the National Center for Case Study Teaching in Science (http://sciencecases.lib.buffalo.edu/cs/). The library created as part of the current project was modeled after the teaching materials available through these sites (i.e., classroom-ready, peer reviewed activities to use in existing courses).

In August 2016, Villanova University (VU) received grant funding from the United States Universities Council on Geotechnical Education and Research (USUCGER) to develop a digital library of group activities that promote active learning in the undergraduate soil mechanics classroom. The project was a collaborative effort with UW-Platteville. The goal of the project was to create a digital library of short (< 50 min) group activities that promote active learning in the undergraduate soil mechanics classroom and are easy for faculty to implement in their own courses with little to no preparation. The following guidelines were used to develop the library:

- The final product must be a useful resource for geotechnical educators and support the mission of USUCGER to further geotechnical engineering education.
- The primary purpose of all activities must be to enhance student learning.
- The activities should be for a range of in-class times (1 – 50 minutes) to allow for flexibility in implementing the activities in existing courses.
- The activities should be for a range of small, informal group sizes (2 – 5 students) to allow for use in a range of class sizes.
- The activities should be a range of formats (e.g. "typical" quantitative problems, group jigsaws, concept questions/discussion, group presentations), to allow for different classroom types, student learning styles, and teaching methods.
- The library should include activities for most major topics covered in a typical undergraduate soil mechanics course, and must include a minimum of 15 activities total.
- The project must provide a valuable learning experience for the undergraduate students assisting with organizing and developing the materials.

The time required to create active learning curriculum can be prohibitive, especially for new faculty members. Therefore, this format of sharing resources is innovative in that it will help new faculty members become more effective and efficient teachers. Many faculty members hesitate to employ new teaching strategies due to the perceived effort required to implement them. Preparing resources such as those described in this paper can help faculty become better, more effective educators with the ultimate goal of improving student learning. Similar strategies can be used by faculty in other engineering disciplines to create libraries of classroom materials that can be shared with their colleagues to support active learning in their discipline areas. Finally, implementing these active learning techniques into engineering education has the potential to improve the overall quality of engineering education and thereby increase participation in the field.

Method and Timeline

Project contributors included USUCGER members representing a wide range of institutions, who have experience teaching undergraduate level soil mechanics courses. The authors were responsible for leading solicitation, collection and development of the group activities and associated materials. Project contributors were asked to share successful small group activities they have used in previous semesters and/or propose ideas for developing new activities. All USUCGER members were welcome to contribute activities by contacting the authors directly.

Examples of successful group activities were collected from the authors and project contributors and further developed during the fall of 2016. The teaching materials were refined and organized into the project deliverables during the spring of 2017. The authors worked with two undergraduate students (one at each university) and one graduate student to develop, test, and improve the teaching materials. During the spring of 2017, several of the activities were also piloted at UW-Platteville. During the summer of 2017 the activities were re-reviewed and finalized for dissemination.

Four USUCGER members volunteered their time to review the activities, prior to submitting the final digital package. The reviewers were faculty members from a range of universities (1 primarily undergraduate institution, 1 Moderate Research Doctoral University (R3), 1 Higher Research Doctoral University (R2), and 1 Highest Research Doctoral University (R1)) with experience teaching undergraduate soil mechanics. Their comments were helpful and improved the overall quality of the teaching materials.

Library Created

Sixteen different activities were developed, as summarized in Table 1. The library includes activities for most major topics covered in a typical junior level undergraduate soil mechanics course and a comprehensive final activity. The activities are meant for group sizes of two to five students, and range from short introductory concept questions that require two to five minutes of class time (e.g. #6) to a competitive problem solving “horse race” activity (#4) that requires from 25 minutes to an entire class period The materials for each activity include: (1) a summary sheet for the instructor with learning objectives and instructions; (2) the activity handout to provide to the students; (3) the solution set; (4) an example rubric for the activity; and (5) supplemental information, if applicable. All files were provided in Microsoft Word, Excel, Powerpoint and/or PDF formats to allow for easy editing.

Dissemination

The goal of the library was for geotechnical faculty members to be able to "grab-and-go" the activity of their choice and use the materials immediately in their classes. Therefore, the primary mode of dissemination is a downloadable zip file, with sub-folders for each activity. Each sub-folder includes the individual Word/PDF/Excel files for the activity to allow for instructor editing, as well as a single PDF of the complete activity. There also is a front-matter file describing the contents of the library and acknowledging contributors. The password-protected zip folder is available for download on the USUCGER website (http://www.usucger.org), on the

Teaching Aids page. The files are password protected to limit student access to solutions. The password is available from the authors via e-mail request. In addition, Dr. Kristin Sample-Lord and Dr. Gretchen Bohnhoff presented their project at the USUCGER 2017 Annual Meeting. During this presentation, they summarized the materials that had been created, shared an example activity, and described how to navigate the documents and access the activities.

Table 1. Activities and associated teaching materials in the library of small group activities for the undergraduate soil mechanics classroom.

#	Topic	Activity	Teaching Materials Included				
			Summary	Handout	Solution	Example Rubric	Supple-mental
1	Soil classification	Failed raingarden case study	✓	✓	✓	✓	✓
2	Site investigation	Boring log jigsaw	✓	✓	✓	✓	✓
3	Weight-volume relationships	Porosity demo & activity	✓	✓	✓	N/A	N/A
4		Problem-solving horse race	✓	✓	✓	N/A	✓
5	Soil compaction	Acceptable zone case study	✓	✓	✓	✓	✓
6	Hydraulic conductivity & 1-D seepage	Introductory concept questions	✓	✓	✓	N/A	N/A
7	2-D seepage	Flow nets	✓	✓	✓	✓	N/A
8	Total & effective stresses	Geotech. engineering in the news	✓	✓	N/A	N/A	N/A
9	Load-induced stresses	Group Calculation	✓	✓	✓	✓	N/A
10	Settlement	Millennium Tower case study	✓	✓	✓	✓	N/A
11	Shear strength	Interpreting lab data	✓	✓	✓	✓	N/A
12	Lateral earth pressures	PE practice problem	✓	✓	✓	✓	N/A
13	Bearing capacity	Calculations & Quality Control process	✓	✓	✓	✓	N/A
14	Slope stability	Evaluation of existing slope	✓	✓	✓	✓	N/A
15	Geosynthetics	Categorizing geosynthetic samples	✓	✓	✓	N/A	N/A
16	Comprehensive: site investigation, classification, compaction, geostatic & load-induced stress, settlement and time-rate of consolidation, shear strength, bearing capacity		✓	✓	✓	✓	✓

Implementation

Several of the activities were piloted in an undergraduate soil mechanics class at UW-Platteville in spring 2017 (while the library was still under development), and then most of the finalized activities were implemented in fall 2017 and spring 2018 in the same course. The course was taught by the same instructor each semester described. This instructor had taught soil mechanics for five years before implementing the activities. During spring 2017, draft versions of activities 1, 4, 5, 8, 10, and 16 were implemented at UW-Platteville. Fourteen activities were implemented in fall 2017 and spring 2018. The two activities that were not implemented (e.g., 3 and 15) are included in other upper-level courses at UW-Platteville. The activity worksheets were collected, graded for completion, and recorded as part of attendance/participation grade. Traditional classrooms with individual desks were used for this course as active learning classrooms are generally not available. During the small group activities, students rearranged desks into circles to facilitate discussion. These small-group activities were included in addition to example problems in some cases (e.g., 1, 3, 5, 8) and were used as replacement for example problems in other scenarios (e.g., 11, 12, 13).

Feedback on Small Group Activities

Student feedback

Student feedback regarding the course format with the small group activities at UW-Platteville has been positive. Similar to the work by [7], an anonymous survey was administered on the last day of class in fall 2017 and spring 2018. The purpose of the survey was to ask students about their learning experience and their perceived effectiveness of the course format. The survey questions are provided in Table 2. The answer choices were: strongly disagree (1), mildly disagree (2), neutral (3), mildly agree (4), and strongly agree (5). A total of 37 and 34 students completed the surveys (100 % and 89 % response rates, respectively). Data was not collected on individual activities.

Table 2. Summary of student survey results collected on the last day of the course in 2017 and 2018 at UW-Platteville.

Survey Question	**Average Score (out of 5)**		**% that Responded Mildly or Strongly *Agree***	
	Fall 2017	Spring 2018	Fall 2017	Spring 2018
1. The format of this course improved my overall learning over a classical in-class lecture only format.	4.6	4.6	97.3	91.2
2. The format of this course improved my conceptual understanding of soil mechanics/geotechnical engineering over a classical in-class lecture only format.	4.6	4.6	97.3	94.1
3. The format of this course improved my ability to apply knowledge in solving basic geotechnical design problems over a classical in-class lecture only format.	4.7	4.5	94.6	94.1
4. Solving problems in class helped me prepare for solving problems on my own.	4.7	4.8	94.6	97.1
5. The format of this course allowed me to interact directly with the instructor more than a classical in-class lecture only format.	4.5	4.6	94.6	94.1
6. The activities completed as part of this course provided a real world context to topics covered in this course.	4.7	4.6	100	91.2
7. I am more interested in geotechnical engineering after taking this course.	4.0	4.1	67.6	70.6
8. Activities completed as part of this course were appropriate and helpful.	4.6	4.8	94.6	97.1
Total Number of Survey Responses Received	37 (100 %)	34 (89 %)	37 (100 %)	34 (89 %)

As shown in Table 2, the feedback regarding the course format that includes the new active learning activities using small groups was overwhelmingly positive. The average score for all questions was greater than 4 (out of 5). In addition, greater than 90 % responded mildly or strongly agree for all questions except for question #7 (which had 67.6 % and 70.6 % mildly or strongly agree for fall 2017 and spring 2018, respectively). These results indicate that the course format improved the students' perception of overall learning, conceptual understanding of the material, and ability to apply knowledge and solve basic geotechnical engineering problems. In addition, students believed that the format allowed additional interaction with the instructor. The authors believe the real world context for the topics (question #6) also affected the increased interest in geotechnical engineering after taking the course (question #7). Finally, students indicated that the activities included in the course were appropriate and helpful (question #8) and helped them be able to solve problems on their own outside of class (question #4).

Scores from official student course evaluations from semesters before the activities were implemented were compared with student evaluations conducted after implementation of the new in-class activities (for the same course and instructor). A total of 22 questions are included on the student course evaluations at UW-Platteville, which are distributed during the last two weeks of class each semester. For this paper, seven of these questions were selected as relevant to active learning and their learning experience. Answer choices ranged from: Never, ~0 to 10 % of the time (score of 1), to Always, ~90 to 100 % of the time (score of 5). Table 3 summarizes the questions and results for three different periods: (1) before the activities were implemented in spring 2016, (2) when some of the activities were piloted in spring 2017, and (3) when most of the activities were implemented (fall 2017 and spring 2018). Data from other semesters are not included because different instructors taught the class.

As indicated in Table 3, after implementing the small group activities, students reported that the instructor was better able to organize and present complex material (question #2; scores increased 5 %), explain how different concepts relate (question #4, scores increased 3 %), and cares about their understanding of the material (question #7, scores increased 5 %). In addition, the students feel that the instructor is confident in course material and encourages questions from the students. Surprisingly, implementation of small group activities did not change students' perception of a class period (question #3) in a positive way (scores decreased 6 %). Perhaps this was a result of the students being accustomed to active learning. The traditional lecture portion of the class may have seemed to drag on compared to the small group activities.

Table 3. Comparison of relevant questions from student evaluation scores for soil mechanics course at UW-Platteville prior to (spring 2016) and after (spring 2017, fall 2017 and spring 2018) implementing the small group activities.

Question	Course Mean				Change from Spring 2016 to Spring 2018 (%)[1]
	Before Adding New Activities	With 6 of the Small Group Activities	With Most (14) of the Small Group Activities		
	Spring 2016	Spring 2017	Fall 2017	Spring 2018	
1. My instructor enjoys teaching.	4.76	4.90	4.83	4.82	+ 1
2. My teacher organizes and presents complex material in simple and clear ways.	4.16	4.29	4.25	4.36	+ 5
3. I am surprised that the class period has ended, because the time has passed quickly.	3.60	3.61	3.50	3.39	- 6
4. My teacher explains how different concepts relate to each other.	4.52	4.52	4.47	4.67	+ 3
5. My teacher is confident about the course content.	4.44	4.71	4.78	4.82	+ 9
6. My teacher encourages questions from us.	4.60	4.71	4.72	4.70	+ 2
7. My teachers cares about our understanding of the material.	4.56	4.73	4.75	4.79	+ 5

[1]Calculated as: 100 % x (Spring 2018 score – Spring 2016 score) / Spring 2016 score

Faculty feedback

A faculty survey was created by the authors and posted with the library on the USUCGER website to solicit feedback about the materials and faculty and student experiences at other institutions. There was limited participation in the survey (4 responses). However, the authors are aware (via word of mouth and e-mail) of many additional faculty that have implemented portions of the library in their courses. The survey questions are included in Table 4. Because of the limited responses, the survey results are not summarized in Table 4. In retrospect, the authors would have placed a requirement or an agreement to complete the survey in order to access the active learning library materials.

Those faculty that completed the survey indicated that they enjoyed using the activities, would use them again, and had increased interactions and a positive response from the students. In addition, faculty that took the survey increased the frequency of incorporating active learning in their courses compared to previous quarters or semesters.

Table 4. Faculty survey questions included in on-line Qualtrics Survey

Survey Question
1. How many activities did you implement in your course this semester? (type in answer)
2. Which activities did you implement? (bulleted list included for selection)
3. In general, students responded to these activities a. Positively b. Mixed c. Negatively
4. If you have taught soil mechanics before, the frequency at which you previously incorporated active learning was: a. Never b. In some classes c. In about half of the classes d. In most of the classes e. In every class f. This is my first time teaching soil mechanics
5. This past semester or quarter, the frequency at which you incorporated active learning was: a. In some classes b. In about half of the classes c. In most of the classes d. In every class
6. Using the active learning modules increased my interaction with students. (Agree/Disagree)
7. I enjoyed using these activities. (Agree/Disagree)
8. I would use these activities again. (Agree/Disagree)
9. What is the current Carnegie Classification for your institution? a. Doctoral - R1 b. Doctoral - R2 c. Doctoral - R3 d. Masters – M1 e. Masters – M2 f. Masters – M3 g. Baccalaureate (Primarily undergraduate) h. Other
10. What is the typical size of your soil mechanics course?
11. What is your title (e.g., Assistant Professor, Associate Professor)?
12. Additional comments (type in)
13. Please provide any feedback on specific activities (e.g., typos, errors, suggestions, comments).

Summary
A digital library of sixteen small group activities was created by geotechnical engineering faculty at Villanova University and the University of Wisconsin-Platteville, with the support of the USUCGER Special Projects program. The goal was to create a library of group activities that would promote active learning in the undergraduate soil mechanics classroom. The format of this library was such that it would be easy for faculty at other institutions to implement the new activities in their own courses with little to no preparation. The materials for each activity include: (1) a summary sheet for the instructor with learning objectives and instructions; (2) the activity handout to provide to the students; (3) the solution set; (4) an example rubric for the activity; and (5) supplemental information, if applicable. The required in-class time and format of the activities varied to allow for flexibility in implementation in existing courses and to complement different teaching styles. Initial student feedback was positive and indicated improved perception of overall learning, conceptual understanding of the material, and ability to apply knowledge and solve basic geotechnical engineering problems. In addition, students believed that the format allowed additional interaction with the instructor. The authors believe that this active format and activities with real world context increased undergraduate student interest in geotechnical engineering, and that similar strategies could be utilized to develop shareable activity libraries for other engineering disciplines.

Acknowledgements
Financial support for this project was provided by the United States Universities Council on Geotechnical Education and Research (USUCGER), as a 2017 Special Projects grant. The opinions expressed in this paper are solely those of the authors and are not necessarily consistent with the policies or opinions of the USUCGER. The authors would like to thank the following undergraduate and graduate students who helped to develop the activity library: Kurtis Johnson at UW-Platteville, Philip Armstrong at Villanova University, and Mustaki Ahmed at Villanova University. In addition, the authors are thankful for the helpful feedback about the activities provided by Dr. Patricia Gallagher (Drexel University), Dr. Andrea Welker (Villanova University), Dr. Christina Curras (UW-Platteville), and Dr. Joseph Scalia IV (Colorado State University).

References

[1] J. Schultz, J. Wilson, and K. Hess, "Team-based classroom pedagogy reframed: the student perspective," *American Journal of Business Education*, vol. 3, no. 7, pp. 17-24, 2010.

[2] S. P. Sternberg, “Small Group, In Class Problem Solving Exercises,” in *Proceeding of the 1997 Annual Conference*, Milwaukee, WI, USA, June 15 -18, 1997.

[3] H. G. Murzi, “Team-Based Learning Theory Applied to Engineering Education: A Systematic Review of Literature,” in *Proceedings of the American Society of Engineering Education Annual Conference & Exposition*, Indianapolis, IN, June 15-18, 2014.

[4] Townsend, F. (2005). “Challenges for geotechnical engineering graduate education.” J. Prof. Issues Eng. Educ. Pract., 10.1061/(ASCE)1052-3928(2005)131:3(163), 163–16

[5] Wirth, X., Jiang, N-J, da Silva, T., Della Vecchia, G., Evans, J., Romero, E., Bhatia, S.K. (2017) “Undergraduate geotechnical engineering education of the 21st century.” J. Prof. Eng., Educ. Pract. 143(3): 02516002.

[6] K. Sample-Lord and G. Bohnhoff, “Final Report: Creation of a library of group activities that promote active learning in the undergraduate soil mechanics classroom,” 2016-2017

Special Grants Program, United States Universities Council on Geotechnical Education and Research (USUCGER), 2017.

[7] K. Sample-Lord, A. Welker, A., and Gallagher, P., “Strategies for Flipping Geology for Engineers with Limited Time and Resources,” in *Proceedings of the ASEE Annual Conference*, Salt Lake City, Utah, June 24-27, 2018