Experiential Learning Exercised Through Project Based Instruction

Norman D. Dennis, University of Arkansas

Abstract

This paper describes the use of students with work experience as team leaders to promote peer-to-peer teaching and learning. This concept is employed in a senior-level design course titled Foundation Engineering. The course utilizes a scenario based semester-long design problem as the major learning vehicle. The design problem requires the development of a facility; typically a shopping mall, office complex or hospital, that is set on a real 100-acre agricultural site owned by the University. The scenario provides the basic functional requirements of the facility and a topographic map, which roughly delineates the property boundaries. Student teams are responsible for developing a functional site layout, planning a subsurface exploration program, selecting and designing shallow and deep foundations, locating and designing retaining walls, and synthesizing all activities into a comprehensive geotechnical report to a client. The problem is completely open-ended, allowing the students to use a substantial amount of individual creativity in their designs. However, the open nature can overwhelm students who have no exposure to land development activities. To combat this, design teams of 3 or 4 students are selected on the basis of pairing experienced students with non-experienced students. The results of this pairing activity have significantly improved the learning experience for all students. Evidence is presented that indicates design submissions have improved in content, accuracy and realism over submissions from teams that are randomly or self selected.

Introduction

While the concept of co-oping is not strong at the University of Arkansas (about one or two students per semester) the student population in the Civil Engineering Department at the University of Arkansas is composed of approximately 20 percent non-traditional students. These students are older than average, often support a family and typically have some previous work experience relating to the construction field or site development. An additional 10-15 percent of the students are employed as part-time quality control or CAD technicians at local engineering firms. This base of students with limited engineering experience forms a tremendous core of peer teachers who can significantly enhance the learning of their less experienced classmates.

This experience base is put to work in Foundation Engineering where these experienced students are used as peer teachers. Foundation Engineering, CVEG 4143, is normally taken by students in their senior year and is a required course in the civil engineering program. In accomplishing the major objectives of this course, students are required to produce an unconstrained site layout for some type of commercial facility, plan a subsurface exploration program for their site,
interpret raw field and laboratory soils data to extract design parameters and, finally, to complete designs for shallow and deep foundations as well as earth retaining structures. All of the objectives are accomplished through the execution of a semester long-scenario based design problem which requires the students to work in teams to complete each phase of the project. In addition to the actual design computations, each team submits a series of interim engineering reports to a client, documenting their findings and giving a recommendation for each phase. A final submission incorporates all of their findings for the semester into a well documented geotechnical report which communicates both pictorially and verbally the results of their investigation. The scenario changes from semester to semester, but its essence is to complete the geotechnical portion of a design for a major commercial facility such as a hospital complex or shopping mall. The facility is to be constructed on a real 100-acre parcel of undeveloped agricultural land owned by the university.

**Historical Group Assignment Procedures**

A portion of the first homework assignment, which is given on the first day of class, is to complete the student data sheet illustrated in Fig. 1. In addition to providing the typical student profile and contact information it also defines the student’s class and work schedule, work experience, calculator type, computer type, software literacy and topics of interest to the student. This data sheet is now used as the basis for assigning groups who will work together on the design project for the entire semester, however that was not always the case.

Historically, a variety of group assignment techniques have been used in this course, ranging from uniformly distributing GPAs to self-selection. In virtually every group assignment scenario there are drawbacks. When the instructor assigns the groups there tends to be problems with class and work schedule conflicts and sometimes with personalities. When the students self select there tends to be groups of “haves”, those students who are reasonably bright and in the mainstream cliques of the class, and groups of “have-nots”, those students who may not carry a high grade point or who are not in one of the cliques. The “have-nots” typically consist of the 10-15% of the class that is left over after all other groups are formed. These students then form a group or groups by default, which may or may not have any redeeming qualities. The author’s experience indicates that these groups also perform at lower levels than the “haves” groups. Pedagogically it is not sound to allow groups of “have-nots” to exist and the author is not a proponent of self-selection of groups for this reason. For several semesters the grouping procedure focused on equity in grade point, gender, and national origin. Every attempt was made to spread the wealth, while making sure that a minority group was not under represented in any design group.

For the first phase of the project student groups are given a brief description of the functional requirements of the facility, a topographic map similar to that illustrated in Fig. 2, and some brief guidance on what they might consider reporting. The first phase of the project requires students to actually walk the land to establish the requirement for utilities, internal and external road construction, any hydraulic improvements that may be necessary, requirements for earthmoving, and to actually site their buildings to produce a functional facility. Coupled with the first phase of the project is the requirement to plan a subsurface exploration program for the site. This program includes drilling and sampling as well as prescribing the necessary laboratory and field
tests. Historically, the site layout and subsurface exploration phase of this project has been a real struggle for some student groups because it required them to exercise judgment and employ concepts that had not been specifically addressed in the current class. Even though they are seniors, solving open-ended problems like this are very abstract to them. They have seen office complexes and shopping malls. They know how to perform earthwork calculations. They have seen pictures of drill rigs. They know what the sampling and testing equipment looks like and how it works. They have price lists from local consultants for sampling and testing. However, in many cases, their ability to put all the pieces together in a coherent fashion to produce a product that met all of the requirements and which could be completed within budgetary constraints was lacking.

Current Group Assignment Procedures
Not all groups suffered from the problems described above. In fact, some groups did exceptionally well on this portion of the project. It took several semesters, however, for the author to discern that the groups who performed well on this phase of the project were those who
were made up predominately of students with prior or current work experience in this area. The groups who performed well understood, either through training or common sense, some of the nuances of siting a facility; taking into account drainage features, minimizing earthwork requirements, recognizing the need for utility and external infrastructure improvements. They were also more likely to create a subsurface exploration program that would produce acceptable data for the design of foundations at a manageable cost.

Figure 2. Guidance given for phase 1 of the project and the USGS Topographic map showing location of project site.

As a result of this revelation recent group assignment procedures have been based primarily on distributing the experience assets among groups and only secondarily on ensuring equity.
between GPA, gender and national origin. Newly formed groups must establish a CEO and develop a work plan, which insures an equitable distribution of work between members. Peer reviews are conducted twice during the semester do determine if each member is contributing to the project. Students know that their grade is based not only on group work but also on their individual contribution to the project. As the client, the instructor can fire members from groups and cause them to become a group of one if peer evaluations indicate that there is a severe problem and that they are not pulling their load.

**Advantages of Experienced Groups**

Often, but not always, the more experienced members of the group became the CEOs. Whether the experienced student became the CEO or not the groups formed based on experience seemed to develop more complete workplans than had been created with previous inexperienced groups. Mechanisms were put into place for one group member to review another member’s work prior to submission of the report, a common event in engineering practice, but one rarely accomplished by students in academia. As a result of this seemingly obvious practice and easily employed activity the numbers of foolish mistakes in design submissions dropped dramatically. An additional benefit of the review process was that calculations were laced with commentary and engineering sketches to better explain the solution process. Without a review process it was not apparent to the student that his or her calculations could not be followed or well understood unless some documentation accompanied them. This review practice also ensured that more than one individual understood the analytical process. It was clear in most submissions that some discussion of the integration of individual work pieces had occurred before the report was assembled and submitted. In previous semesters with inexperienced groups this integration process sometimes appeared to be the result of attaching a staple to several independent efforts.

The overall quality of reports was also improved. For example, phase-one submissions would often include only crudely drawn pencil sketches of the facility layout and site plan when groups were assign without regard to experience. However, when experienced individuals were included in every group the drawings were much more likely to be produced on a CAD program of some sort. Experienced individuals knew what the standards for reports were in engineering practice and they typically made sure that their group adhered to those standards. Reports were much more likely to come with a letter of transmittal and an executive summary that clearly communicated the outcome of the design and directed the reader to the appropriate appendix to review design calculations.

Experienced groups were also far more conscious of costs. For example, even though rule-of-thumb cost figures for sub-surface exploration were given in class, some subsurface exploration proposals coming from inexperienced groups would often approach 15 to 20% of the estimated construction costs of the entire facility. This problem rarely occurred with the experienced groups. Designs that were not easily constructed were less likely to be submitted by an experienced group. For example no experienced group has yet submitted a design for a shallow foundation that is built below the ground water table. On the other hand this was a routine problem with inexperienced groups. In general the inclusion of an experienced individual in each group increased the amount of class time the instructor spent discussing issues related to costs, ethics, and constructibility. Students seemed to be less preoccupied with memorizing an analysis procedures that they could reproduce by rote on an exam and more worried about big
picture issues. The direction of learning has clearly shifted from the compartmentalized application of design concepts learned only in the foundations course to integration of topics learned throughout the curriculum. The author ascribes this change to the inclusion of experienced students in each group. The experienced individuals have ignited the thought process of their less experienced peers. In addition to better designs and better design reports the average on examinations in the course has risen by about 3 to 5 percent since the shift to experienced design teams occurred.

**Course Assessment**
Students complain bitterly about the workload this design problem represents during the entire semester. However, on the course end assessment they rate it as the most important aspect of their education in the geotechnical engineering sub-discipline. They specifically point out that the complexity of the problem should not be reduced for future groups. They cite their interaction with peers during the creation of their designs as being extremely valuable in internalizing the design process. In response to the question, “What would you change about the design problem?” Comments like, “Don’t change a thing, this was the best learning experience I have had in five years at this University.” are common. External evaluation data provided by the discipline specific Fundamentals of Engineering Exam suggests that students are in fact well prepared in this sub discipline. Since instituting this scenario based design students have scored between 10 and 20% above the national average on the geotechnical portion of the exam.

**Conclusions**
External evaluation data suggests that project based design promotes critical thinking and better prepares students to understand the importance of issues aside from analysis. Historical data from this course suggests that the quality of design submissions is enhanced when each team has a member who has been exposed to the standards of practice of the profession. Exam data also suggests the learning has been positively affected by the inclusion of experienced individuals in the design teams.

**Norman D. Dennis, Jr.**
Norman D. Dennis, Jr., P.E., is an Associate Professor in the Department of Civil Engineering at the University of Arkansas-Fayetteville. His research interests are related to the deformation characteristics of soils used in transportation applications and the use of geographical information systems in the geotechnical arena. Dennis has been actively engaged in faculty development activities for over a decade. He is the director for one of ASCE’s ExCEEd teaching workshops and sits on the ASCE Committee for Faculty Development. Dennis holds BS and MS degrees in Civil Engineering from the University of Missouri-Rolla, an MBA from Boston University, and a Ph.D. from the University of Texas-Austin.