122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #13380

Intra-Disciplinary Integration in Civil Engineering Education: An Approach to Integrate the Various Civil Engineering Disciplines with the Use of a Design Studio Lab

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Intra (Sub)-Disciplinary Integration in Civil Engineering Education: An Approach to Integrate the Various Civil Engineering Sub-Disciplines with the Use of a Design Studio Lab

Abstract

Typically, Civil Engineering education supplements an individual course lecture series with hands-on laboratory exercises. These laboratory exercises tend to deal solely with the material being addressed in the lectures for the particular course. Consequently, not only are these laboratories limited to one Civil Engineering sub-discipline but also limited to the material being taught in the specific course. The Civil Engineering Department at our Institute developed and implemented a Design Studio Lab (DSL) for use in the 2014-2015 school year. This experiential studio linked several of the Civil Engineering sub-disciplines in a series of two-two hour studios/labs and one lecture per week (three credits). Four Civil Engineering sub-disciplines participated in this experiential studio with the desired goals of; gaining additional knowledge in a specific Civil Engineering sub-discipline, performing experiments and exercises in a sequence that illustrate the multi-discipline interaction that typically occur on Civil Engineering projects, developing a better understanding of the role of each sub-discipline in the practice of Civil Engineering and emphasizing the need for communication, collaboration and cooperation between Civil Engineering sub-disciplines. This paper addresses the desired student objectives and an assessment of the achievement of these objectives. The successes of this course are discussed as well as the “lessons learned” from the first semester.

The experiential studio/laboratories are based on a known site and building. At the start of the design studio lab, the students are presented with the project information such as drawings, soil borings, and digital files. The faculty has the license to add underground tanks, contaminated soil and other Civil Engineering issues to the project data. The set-up of the design studio lab allows for significant change from semester to semester. Several of the intra (sub)-discipline experiential laboratories are discussed in the paper. As an example, the structural group interface with the geotechnical group in the development of building foundation loads, the performance of laboratory tests on the site soil to estimate differential settlement of the foundation and the input of this data into structural analysis software to determine the effect on the structural support moment frame. The results of the experiments/labs are captured in lab reports, papers and presentations. This design studio/lab is a prelude for a second more independent experiential studio which in turn leads to the comprehensive Capstone Design Course.

Keywords: Intra (Sub) Disciplinary, Civil Engineering, Experiential Studios

Background

When our program decided to switch from Civil Engineering Technology to Civil Engineering, the issue of having labs in several of the basic courses was hotly debated as the new curriculum was being developed. The technology program contained seven required courses with two or four hour lab segments, such as surveying, materials, fluid mechanics, structural analysis, soil mechanics, environmental engineering, and water and wastewater design. It was finally concluded that only the geomatics course in the new Civil Engineering program would have lab components. Labs were not included in any other course, in part because the courses were all to be just 3 credits, and including a lab would reduce class lecture time by a third. It was felt the labs were more appropriate for the hands-on technology program, but were not needed for a Civil Engineering curriculum, with the one exception. The geomatics course is taught for sophomores in the Fall, and contained a two hour, one credit labs, because after all, Civil Engineering graduates should know how to use surveying equipment.

Our Civil Engineering curriculum began for both the freshman and sophomore levels in the Fall of 2011. After the Fall semester in 2012, when the four fundamental Civil Engineering courses (fluid mechanics, soil mechanics, structural analysis and environmental engineering) were taught without labs, it became clear that the courses suffered from the lack of labs. The question became how to re-introduce the lab experiences, in a better way than as separate two-hour sessions directly attached to each course? Keenly debated issues were, what are the reasons that each lab is needed, how many labs are needed for each sub-discipline, and could the labs be delivered in a method other than in the traditional sense when attached to each course?

The valuable aspects of labs for each course were determined to be the following:

- Fluid Mechanics – labs are needed to demonstrate fundamental principles to enhance student understanding of buoyancy, friction losses, and laminar versus turbulent flow.
- Soil Mechanics – labs are needed so students experience the fundamental means by which soil properties are determined and to demonstrate behaviors of different soils. Lab testing is a fundamental means by which properties of soils are determined for geotechnical project sites.
- Structural Analysis – labs are needed to introduce students to building code requirements, sources of loadings applied in design (dead and live load, wind load, earthquake loading, etc.), and permit introduction of structural analysis software.
- Environmental Engineering – labs are needed to demonstrate methods of testing protocols to analyze for environmental contaminants such as volatile organic compounds (VOCs), light and dense non-aqueous phase liquids (LNAPL and DNAPL), mobility modeling and treatment strategies, determination of biological oxygen demand (BOD) and dissolved oxygen (DO) in water sources, sourcing information on site contamination and sustainable site design.

Three questions had to be addressed in developing a course to deliver this content to the students. First, how much content would be delivered from each of the four technical sub-disciplines? Second, what form would the classroom and lab sessions take? Third, when in the student's curriculum would the course be positioned?

It was obvious the full content from the four labs previously offered in the Civil Engineering Technology program would not be provided, particularly since the new course would be three credits due to contact/credit hour restrictions imposed on curricula developed for the engineering program. This would limit the numbers of labs from the four sub-disciplines to just 5 to 8, depending on sub-discipline and the lab topics needed rather than the 12 labs per sub-discipline offered previously in the technology program. The thrust of the education objectives made it a natural to name the new course Design Studio Lab, or DSL.

The initial design of our new Civil Engineering curriculum provided a Civil Engineering technical elective course in the Fall of the junior year. However, without having taken the four fundamental Civil Engineering courses, the practical choices for such electives were rather limited (Geology for Civil Engineers and Sustainable Design were the only appropriate options at this point in the students' educational development). Therefore, it was decided that the Fall junior year semester would be a good place to position the DSL course; the students would be taking the four fundamental civil courses and now at the same time they would be receiving the lab-related DSL course.

The DSL course was structured to facilitate collaborative, experiential, interactive engagement, and peer learning through small-group and individual real world work assignments. The DSL faculty have used a variety of teaching styles including problem-based, project based, discovery and just in time teaching which have been indicated to enhance student problem solving abilities by many researchers [3,4,5]. Other research[3,4,5,6,7] indicates non-traditional courses such as DSL can increase students' overall academic performance, develop their interpersonal skills and develop their ability to frame and solve real world problems. Collaborative and integrative course environments have also been shown to reduce overall student attrition, increase retention of minorities and women, increase interest and understanding of students in STEM fields and increase students' pursuit of advanced degrees in STEM fields [3, 8, 9, 10, 11, 12]. These were all issues that the initial developers of the DSL course tried to incorporate in the individual lab components and the overall concept of the course.

Course structure, scope and schedule

The primary goal of the DSL course was to develop and perform Civil Engineering experiments to supplement lecture content in the individual fundamental engineering courses (structural analysis, soil mechanics, fluid mechanics, and environmental engineering) being taken simultaneously with the DSL course. The course uses site specific data (site plan and building) with the option for Civil Engineering faculty to add additional project features to the site to meet the students' learning objectives. The site, building, and some of the student learning objectives may vary each time the course is taught. Figure 1 below shows a plan of the building's roof used in the development of modules for the structural portion of the DSL course.

The desired student goals for this course are: (1) gaining additional knowledge in a specific Civil Engineering sub-discipline, (2) performing experiments and exercises in a sequence that illustrate the multi sub-disciplinary interaction that typically occurs on Civil Engineering projects, (3) developing a better understanding of the role of each Civil Engineering sub-discipline in the practice of Civil Engineering and (4) emphasizing the need for effective communication, collaboration, and coordination between Civil Engineering sub-disciplines.

The course format is two two-hour studio/labs and one – one hour lecture per week. The total credits assigned to this course are three. Instructions follow an integrated approach of independent reading, study and writing, discovery learning, experiments, labs, guided practice and independent practice.

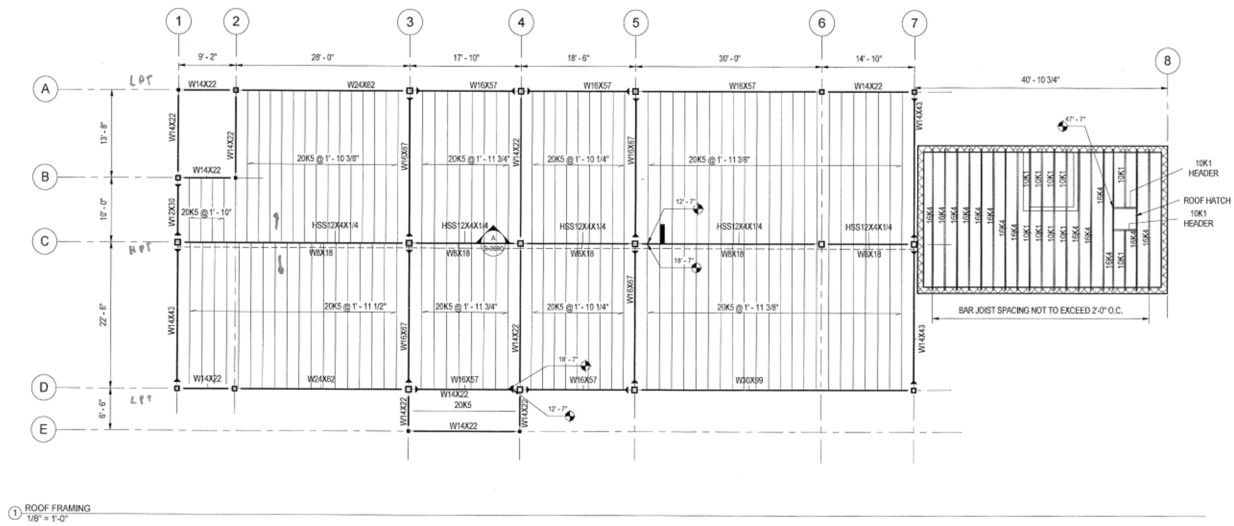

Figure 1-Building Floor Plan used in the development of Structural Assignment Modules

Lecture: The lecture period is used to review expectations for the upcoming week of studio/lab exercises and to discuss the specifics of any lab tests to be performed. The lecture period also demonstrates how the week's activities fit into the overall design sequence of the project. The requirements for the upcoming deliverables (submittal, presentations, and lab reports) are also discussed and questions answered.

Studio/Labs: The course consists of two studio / laboratory sessions per week, which include a variety of commonly performed laboratory testing experiments, application of standard codes, regulations and guidelines, use of computer software, and overlapping labs that illustrate the interaction between sub-disciplines of Civil Engineering.

The course content of the initial four weeks is shown below in Table 1.

Table 1-Schedule of weekly topics, labs and submittals (first four weeks)

Semester Outline			
Week	Lecture Topic(s)	Laboratory Topics	
1	Site & Project Overview Subsurface Exploration Program Layout	<u>Design Loading Criteria</u> -Structural Loading -Wind Pressure -Snow Loads -Building Codes (Mass, IBC)	

2	RISA-2D Lecture and Examples	Site Geology & Soil Identification -Boring Logs Use -Soil Classification -Soil Profile Development	Truss Analysis using Structural Analysis Software -RISA - 2D -Checking Output -'Reasonableness'
3	Site Soil and Environmental Characterization	Soil Gradation Testing -Sieve Analysis -Hydrometer Analysis Lab Testing-Soil	Site History and Conditions -Wetlands Conditions -Prior Use Environmental Concerns -Sources of Information
4	Site Soil Classification and Environmental Assessment	Soil Plasticity Testing -Water Content Atterberg Limit -Liquid Limit -Plastic Limit Lab Testing-Soil	Environmental Regulations -Soil Analysis -Jar Sample Headspace Analysis Lab Testing-Environmental

This course is scheduled to be taught in the Fall semester of student's junior year. Along with the DSL course, the student will have courses in the four Civil Engineering sub-disciplines offered by the Institute, Geotechnical, Structural, Fluid Mechanics, and Environmental Engineering. The design studio lab's goal is to tie all the separate engineering sub-disciplines together in one lab/studio experience. The Institute's Civil Engineering curriculum for the Fall semester of the Junior Year is shown below in Table 2.

Table 2-Institute's Civil Engineering Junior Year Fall Semester Curriculum

Junior Year Fall Semester				
Course	Title	Lecture	Lab	Course Credit Hours
CIVE 340	Fluid Mechanics	3	0	3
CIVE 372	Structural Analysis	3	0	3
CIVE 380	Soil Mechanics	3	0	3
CIVE 410	Environmental Engineering	3	0	0
CIVE 590	Design Studio Lab	1	4	3

A review of eight neighboring colleges and universities revealed very similar fundamental course requirements in the junior year of their Civil Engineering programs. All the programs had sub-disciplinary specific courses in environmental engineering, fluid mechanics, geotechnical engineering, and structural analysis. Also, most of these Civil Engineering programs have individual course specific laboratory requirements. None of the institutional programs reviewed had an intra (sub) disciplinary Civil Engineering laboratory requirement in their junior year. The curriculum with the DSL course lessens the student contact hours and credit hours as in this semester when compared to each individual course with one two-hour lab per week. Figure 2 depicts the students' credits and contact hours with and without the DSL course.

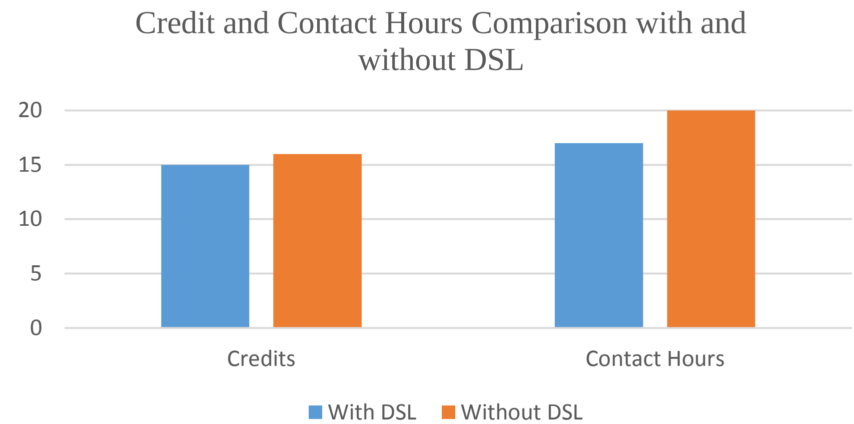

Figure 2-Comparison of Credits and Contact Hours with and without DSL

The reduction of one credit and three contact hours from the curriculum by using the DSL course instead of the individual courses' laboratories is a worthwhile advantage as it aids in the "curriculum time budget" of the student and potentially allows the student an addition course elective. However, the real advantage is the laboratory experience in four sub-disciplines of Civil Engineering coupled with the added benefit of demonstrating the interface, coordination, collaboration and communication required between the sub-disciplines of Civil Engineering in the execution of a project.

Intra-Discipline (Sub-Discipline) Nature of Course

A trend in education is to stress external, interdisciplinary project based learning. This approach to education changes the delivery method from the standard lecture approach utilizing a "learn to do" approach to one that is project based using a "do to learn" approach. The project based aspect stresses the need to coordinate, collaborate and communicate with the members of the project to have a global understanding of the many attributes necessary for the project to be successful. The sub-disciplines of Civil Engineering are a subset of an interdisciplinary project. The same attributes needed for success in the overall project must be exhibited by the sub-disciplines of Civil Engineering. Consequently, a goal in our DSL course was to demonstrate how inputs from one sub-discipline of Civil Engineering are used by another sub-discipline of Civil Engineering to produce its deliverables. These interfaces between sub-disciplines also help to demonstrate the sequence of tasks on a project.

Examples of Intra-Discipline (Sub-Discipline) Experiments

As an example of the interface between the geotechnical and structural sub-disciplines, the students used the current building codes to establish structural design loadings for the DSL project building in the first structural module assigned. The students then determined a load path for the applied vertical loadings, which in turn enabled the students to determine foundation loads for selected columns (Structural Modular #4). The foundation loads developed by the structural sub-discipline were used by the geotechnical sub-discipline in Geotechnical Labs #7 and #8 to estimate foundation settlement using soil properties determined from the soil consolidation test experiments. The estimated differential settlement calculated in Geotechnical Labs #7 and #8 were then used as input into a RISA-2D computer model for the structure's moment frame in Structural Module #5 to analyze for the effect on building frame loads caused by the estimated differential settlement. Several lectures supplemented these assignments including a lecture on the effect of differential settlement on different types of structures.

Another example of sub-discipline interface occurs in the removal of an underground fuel oil tank and replacement with a new underground fuel oil tank in the 100-year flood zone of the site. This series of labs required the use of all four sub-disciplines associated with this course, geotechnical, structural, fluid mechanics, and environmental engineering.

Assessment Tools

The Civil Engineering Department has a number of assessment tools to ensure the ABET – General Criterion 3 - Student Outcomes (a-k)[1] and student learning objectives are evaluated and assessed every time a course is taught. Following is a list of several of the assessment tools:

- Start and End of Semester Student Surveys-The students complete a pre and post-course survey addressing their perception of each student learning objective before the start of the course and at the completion of the course. The survey response choices for each student learning objective is 'strongly agree', 'agree', 'uncertain', 'disagree', and 'strongly disagree'. The faculty uses the students' perception of the learning objective by taking the number of 'strongly agree' and 'agree' responses to the survey and dividing by the total number of students responding to the survey question. The changes in students' 'strongly agree' and 'agree' responses from the beginning of the semester to the end of the semester are used as one measure of the knowledge gained.

- Institute Course Survey-The Institute survey gives the students a chance to evaluate the professors teaching the course, make assessment of the importance of this course in respect to several student outcomes mirroring the ABET student outcomes (a-k), and make comments for improvement of the course.

- Course Quality Improvement Report (CQI Report) - This document is part of the regular course, curriculum, and program review process. The primary instructor for the course completes the CQI report within one month of the end of the semester. The instructor indicates how course Goals and Learning Objectives were delivered to the students, and how the students' learning was assessed. The instructor reports on how well the course goals and learning objectives were achieved using grade data from the course, the student's start and end class surveys, and the Institute's survey. In this document, the instructor assesses the students' perception of learning by comparing the end class survey against an assignment(s) that demonstrates the student learning objective being assessed. In addition, the instructor makes suggestions and recommendations for future changes to the course and/or curriculum that could improve Learning Objective achievement or enhance the course. The CQI is therefore a resource for course data and instructor assessment that can be used for departmental assessment of Program Educational Objectives. The completed CQI report forms a starting point for consideration of course modifications the next time the course is offered, and can provide valuable information on prerequisites, course sequencing, and overall curriculum effectiveness.

- Student Outcome Report (SO Report) - This document is created as an assessment tool and used for identifying and measuring ABET Student Outcomes (SOs) linked to this course. The primary instructor for a course is expected to complete this report within one month of the end of the semester. When completed, this Report is used to consider whether this course and its assessment measures are effective in meeting the specific ABET a-k Student Outcomes (SOs) which have been linked to the course by Department Faculty. Results and recommendations included in this document are used in the Department's program assessment evaluation process and may serve as the justification for minor or major modifications the next time the course is offered, reconsideration of SOs linked to the course, and/or identification of the need to change other coursework in the civil curriculum.

Student Learning Objectives

Fourteen learning objectives (LOs) were identified for the DSL course, as follows:

LO1-Work cooperatively as a member of a group to make analyses and assessments, to perform lab tests and evaluate results, to derive appropriate conclusions, and prepare summary reports for project design aspects in Civil Engineering sub-disciplines involved (environmental, geotechnical, structural or fluid mechanics).

LO2-Assess load development on buildings, evaluate building code structural requirements, determine load path through a building system by hand and by using RISA-2D computer analysis software.

LO3-Characterize site soil stratification and classify the soils, and perform the commonly performed soil identification lab tests (visual-manual, sieve and hydrometer, and Atterberg limits).

LO4-Assess the important environmental character site soils by investigating; current site conditions and uses, wetlands conditions and results of site survey, and historical site uses and

potential for remnant environmental contamination, and performing soil sample testing that includes jar sample headspace analysis.
LO5-Develop proportions for concrete mix needed to provide specific strength and site environmental resistance, make concrete cylinders, perform wet concrete slump test, air content tests, cure concrete cylinders, determine breaking stress of the concrete cylinders, and then optimize concrete mix design based on results of initial batch preparation.

LO6-Perform a consolidation test on clay soil and use the results to evaluate appropriate soil parameters needed to determine foundation settlements due to consolidation of underlying clay stratum, and make the necessary foundation settlement calculations.

LO7-Determine the changes in column load distribution that would occur as result of differential settlement of building foundations.

LO8-Develop experiments that use the PASCO structure modelling system to assess load paths through a structure to determine expected foundation loads, and use appropriate computer/hand analysis to calculate foundation loads for selected columns associated with the project structure.

LO9-Determine appropriate site zoning regulations and restrictions on land development, and incorporate these restrictions into a sustainable design for aspects of site design, including; grading, parking, roadway layout, and drainage and run-off detention.

LO10-Design and perform a laboratory experiment to confirm the theory of buoyancy force acting on a submerged object, use the results to determine groundwater buoyancy force that would act on an underground tank at the project site, and determine methods to properly anchor the tank to prevent flotation for the site high groundwater (100-year flood).

LO11-Perform tests to determine soil shear strength, soil compaction characteristics and soil permeability, and relate soil properties derived from these tests to geotechnical design parameters and soil characterization/classification parameters.

LO12-Perform tests to determine various environmental characteristics of groundwater present in the soils beneath the site (hardness, chlorides, sulfates, BOD, DO) and assess suitability of water from site dewatering for discharge into nearby stream or storm drains.

LO13-Assess the potential impacts that could result if site soils are determined to contain LNAPL and DNAPL contamination, and understand potential remediation scenarios that may be needed.

LO14-Understand and experience the interaction and overlap of various Civil Engineering sub-disciplines on a typical building project, and value the importance of using the results obtained from one Civil Engineering sub-discipline’s tasks as input to another Civil Engineering sub-discipline’s tasks.

Assessment results

The primary assessment tools used for this DSL course were the students' perception of their mastery of each learning objective at the start and end of the course, and the graded assignment(s) showing percent of students passing the assignment(s) associated with each learning objective. The results of this assessment for each learning objective is shown in Figure 3.

With the exception of student learning objective L13, all assessed learning objectives were satisfied in the DSL course. For student learning objective L13, a lecture was given but there was no lab or experiment performed by the students; therefore, there was no graded work to assess. The total results for this course totaling 32 students are shown in Figure 3. The stated outcome for this course is to have 60 percent of all students achieve a passing grade in each learning objective. As previously stated, the students' perception of the course goals and learning objectives were measured by the start of class survey and the end of class survey percentages using the combined agree and strongly agrees options. The results demonstrated that the students' perception of learning has increased significantly for each question of the survey. It was only in learning objectives 9, 12, and 13 that the students reported less than full understanding of the concept. In these three learning objectives, the students reported at 83% understanding which is still very positive. The students' assessment of the goals and learning objectives of the course were generally in line with the results registered by the graded experimental, research and laboratory reports. Therefore, there were no significant discrepancies between the students' perception and the results demonstrated by the graded assignment(s). Based on these results, the course student learning objectives were achieved.

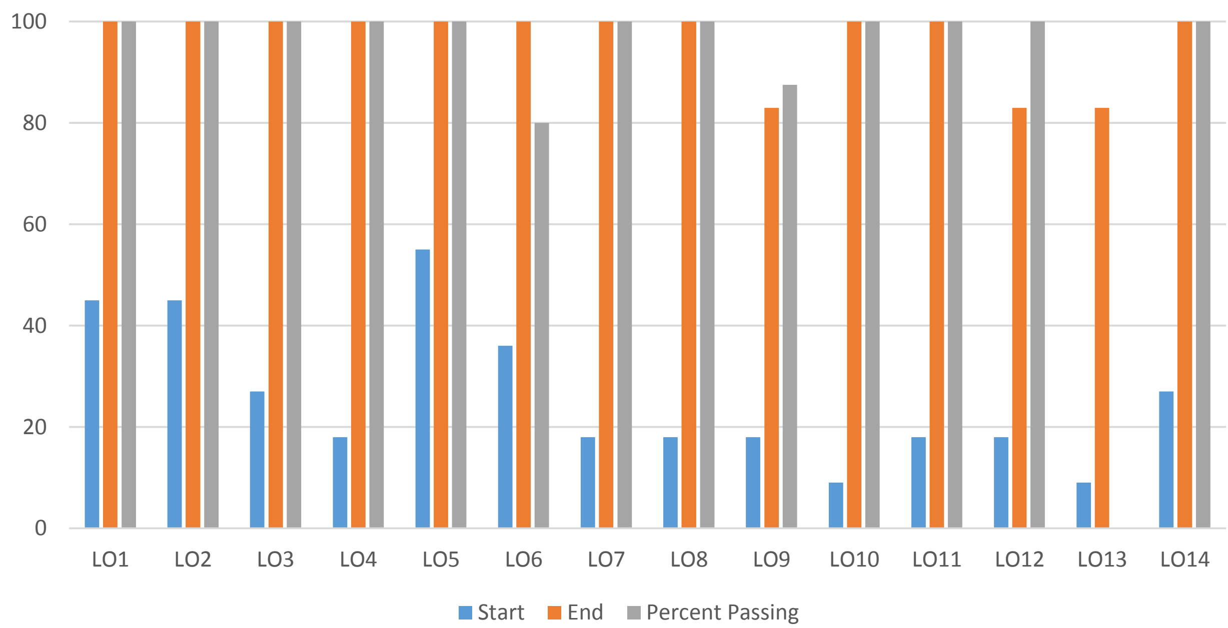

Figure 3 – Assessment Results of Student Learning Objectives

SO Report

The following results are used to measure achievement of the specific ABET Student Outcomes for this course. The data and resulting Instructor recommendations are used by Department faculty to evaluate the effectiveness of the course as delivered in meeting Student Outcomes.

Student Outcome "b" – Ability to design and conduct experiments, as well as to analyze and interpret data.

Geotechnical Labs No. 2 and 3 are used to measure Student Outcome "b" relative to conducting experiments (hydrometer test for soil grain size and Atterberg limits test for clay soil plasticity). These test results were then used by the students in preparing their site characterization reports, which also included the soil profiles. Most student groups did quite well on this report, receiving scores of 10 (out of 10). All of the student groups (4 to a group) received at least a score of 9, indicating successful achievement of the "b" student outcome goal.

Student Outcome "k" – Ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Structural Module #2 demonstrates the use of modern engineering tools (i.e., RISA 2D2 structural analysis program) to distribute the loads on a selected part of the structure to selected columns. Loads such as dead load, wind load, snow load including snow drift, live loads and contingency loads are distributed to the selected columns. Loads are distributed through joist, W-shape beams and a truss. The truss is model in RISA 2D and member forces and deflections are calculated with the software. Most student groups did quite well on this report, receiving scores of 9 out of 10 or better. All of the student groups (4 to a group) received at least a score of 6, with an average grade of 8.6 indicating successful achievement of the "k" student outcome goal.

Other ABET's a – k Student Outcomes could also be achieved through the teaching of the DSL course depending on the deliverables of the course and instructor's sub-discipline expertise.

'Lessons Learned' and Challenges

After teaching the DSL course, it is evident the theoretical utopian envisioned structure as a laboratory contribution to the core engineering classes requires further modification. Several barriers in the simultaneous implementation of DSL with the four Civil Engineering fundamental courses were observed:

- Students' perception of the course: It was expected that students would perceive DSL as a laboratory extension of the other four core courses. If the core courses included separate lab components, the students would be performing four separate labs per week. Under the DSL course structure, they performed two different sub-discipline specific labs per week, which is an overall reduction in their workload. However, because DSL was packaged and implemented as a separate course, the students did not view it as an extension of the four core courses and a reduction in their workload. Instead the students viewed the course as a fifth new topic area/course in conjunction to their already rigorous junior Fall semester. Consequently, there was a disconnect in the vision of the course by the faculty and the students. The students felt overwhelmed and overworked by this fifth course.

- The students felt the schedule of labs was not well organized because they had to alternate between multiple Civil Engineering sub-disciplines each week. Often times they commented the material would have been easier to digest if they finished a series of sub-discipline specific labs and related assignments first before they moved on to other sub-discipline specific series of labs and assignments.

- DSL's team teaching approach: At our Institute, most courses are taught by a single faculty member and students are accustomed to this approach. The DSL course had to adopt a team teaching approach due to the different sub-disciplines, but such team teaching was unfamiliar and unconventional to students. Even though the course professors had clear communication between themselves as to the labs to be performed and assignments, the students' perception of the organization was that the course was mismanaged, leadership unclear and the syllabus schedule unorganized.

- Those teaching the course need to have intimate knowledge of the topics they are responsible for to be able to lead students through the different laboratory exercises. Dependence on the lab technician to instruct the students in the details of different experiments leads to a disconnect between the instructor and the professor.

- Going beyond laboratory work: Even though the DSL course is comprised of the laboratory extensions of the fundamental courses, it does require students to take a "leap" and showcase their ability to collect, analyze, interpret, present and communicate data effectively just like in 'real world' projects. This leap requires a further extension from simply carrying out a lab and writing a lab report. Because some DSL intra-disciplinary assignments require interaction between sub-disciplines, as noted in the earlier examples, they are perceived as complex and the students were required to deliver project solutions that linked the sub-disciplines, like 'real world' consultants have to do. Teaching DSL in the junior Fall semester before students have had their first coop work-education semester makes it more challenging for students to make the "real-world" linkages and truly understand the importance of the interaction of the sub-disciplines and methods for compiling such linked sub-discipline deliverables.

Successes

Clearly, some aspects of the initial DSL were successful, as illustrated by the following student learning assessment and their comments:

- Student Learning: All of the student learning outcomes assessed were achieved.

- Student Comments: Many of the student comments in the end of semester surveys showed that the class clearly demonstrated to them the intra (sub) disciplinary nature of Civil Engineering projects. They also commented that DSL helped prepare them for their co-op work-education semester, mostly by teaching them effective ways to communicate their findings in an engineering context, and by having collaborated on multi sub-disciplinary teams. Many students have also indicated that they used their completed assignments to successfully secure cooperative work positions. They noted that since the class assignments were modeled on a ‘real world’ project, it was a great exercise for them to continue to develop critical thinking skills and provide practical knowledge of working on complex Civil Engineering projects.

Future

Based on our “lesson learned”, the various faculty who have taught the DSL course have recommended several modifications be made to the theoretical structure of the DSL course to increase its academic impact. The proposals are as follows:

- It was proposed to restructure the syllabus to compartmentalize and segment the introduction of knowledge in the various sub-disciplines. An example would be to carry out all soil mechanics lab related activities then move on to the structural components and so on, to allow students sufficient time to digest the material. This change would steer students in a more focused, topic-specific manner and avoid some of the complexities inherent of Civil Engineering projects. Such re-organization would greatly suffer in the junior Fall semester because the course would not be coordinated with the core courses topic presentations, resulting in either some labs being performed a month to six weeks before the topic was introduced in the core course, or too late to supplement the topic in the core course. In addition, the sub-discipline sequence and interface would be lost and the student’s comments on the successes of the course would be diminished. On the other hand, such repackaging could be very effective if the DSL course were moved to a later semester, after the students had taken the four core courses (see further discussion in final comment below).

- It is clear if the course is to survive in its current format and location in the Fall semester of the junior year as a companion course to fluid mechanics, soil mechanics, structural analysis and environmental engineering, then the following modifications to the DSL course are needed:

    - Introduce the Course – An introduction segment is required in the course to explain the intent and functioning of the course. It will illustrate the workload reduction of this course as opposed to a separate labs in each core course and point out the advantage of the course in terms of interface and sequencing of the civil-engineering sub-disciplines on real projects. The students need to be apprised of the advantages of this concept, as supported by the student comments previously discussed, at the beginning of the course.

    - Lead Instructor – The Lead Instructor function would be to coordinate the content of the four sub-disciplines. This is no small task but was lacking in the initial delivery of the course. The Lead Instructor duties would include consistency of format and coordination with the core course instructors in the timing of the sub-disciplines labs.

- Lab Instructors – Lab Instructors must be experienced and qualified in the subject matter and experiments they oversee.

- Repositioning the DSL class to the senior year after students have taken their four fundamental classes and two other civil engineering technical electives, and have cooperative work knowledge, would increase DSL's academic impact on students. Students in their senior year already have a strong foundation of fundamentals. Additionally, their cooperative work experience fortifies their understanding of the theory; hence, grasping DSL concepts would be easier, and more effective. It would increase the value of the content taught in DSL and enhance their critical thinking skills in linking the intra (sub) disciplinary nature of Civil Engineering projects, because the students will have a different perspective. The repositioning of DSL in their senior year would also help them in further sharpening their skills to undertake the more rigorous and comprehensive Capstone Course in their final senior semester. If placed in the first semester of the senior year, it would have a significant disadvantage in that it would not serve its intended purpose of directly supplementing the four Civil Engineering core courses taken by the students a year later in the Fall semester of their junior year.

Conclusion

The integrated flavor of the DSL course does require further adjustment to ensure that the expectations of the students are in line with those of the department. It is not surprising the vision of DSL is met with student resistance. Florida Gulf Coast University implemented a similar course that also met with resistance from students[13]. It is evident students learn more when they are given the opportunity to apply theory to practical applications in collaborative settings, which mimic the real world working environments [14]. Even though the DSL course requires further fine tuning, the student skill-set development and benefits it offers make DSL a worthwhile concept. Based on the discussions on the future of this course, it is apparent that there is disagreement among the initial instructors as to its format and location in the curriculum. The challenge is to package and staff this course correctly. Based on the initial results, it certainly seems that it has significant value in our students' educational experience.

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