Hands on Experiences in Civil Engineering

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Abstract

New "hands-on experiences" are being incorporated into the undergraduate civil engineering program at Rensselaer. The aim is to have students see real civil systems; better relate their classroom knowledge to the real world; tie their knowledge together, within and across the disciplines; and learn how to learn through experimental investigation and analysis. Various options are being explored ranging from three two-credit classes to a set of experience modules distributed across all four years. The areas being addressed are structural, geotechnical, transportation, and environmental engineering. The experiences will range from basic experiments to multi-disciplinary charettes. Some of the more advanced ones will emphasize simulation, where virtual systems are compared with their real-world counterparts. Others will tie together concepts from several disciplines. Some will be visits to construction sites, traffic management centers, and special lab facilities at other universities. This paper describes the experiences being devised, their potential packaging, and the findings from a pilot implementation. Overall, the experiences will help the students tie their classroom knowledge to the real world.

1.0 Introduction

There is a national trend to increase the amount of hand-on experiential learning seen by civil engineering undergraduates [1]. Educators are recognizing that classroom-based learning can benefit substantially from experiential learning wherein the students see how their classroom knowledge applies to real-world situations. Through these experiences, theory becomes real and reality adds depth to theoretical understanding.

This paper considers basic questions about these hands-on experiences. What kinds of experiences are important? How should they be integrated into the curriculum? Should they be independent or inter-related? What duration should they have? Should they be team efforts? Should they focus on individual disciplinary areas or integrate them together? Rensselaer's civil engineering program is used as a case study setting.

Building on prior efforts such as the Admiral Combs Design Retreat [12] and the required course in Sensors and Instrumentation [2], the Department of Civil and Environmental Engineering at Rensselaer is creating a suite of hands-on experiences that span the undergraduate program and tie closely to the sequence of courses being taken. The program also provides opportunities to show the students how information technology (IT) has become an integral part of civil engineering systems.

To start the discussion, in structural engineering students need to begin by seeing the properties of civil engineering materials. They need to see how these materials behave and how they take on special properties when formed into structural shapes, etc. They ought to see how sensors fit into these systems and how the resulting data are analyzed. They should learn about the ways in which such systems are modeled, especially through simulation. Finally, they should plan, design, and fabricate systems of their own, so they see whether the performance they predicted matches that which is observed.

The sections that follow present the plan that has been devised for Rensselaer and initial findings from a pilot implementation. Section 2 reviews similar efforts that have been undertaken at other institutions. Section 3 describes the plan that has been devised. Section 4 discusses initial findings from a pilot implementation and Section 5 presents plans for the expansion and implementation of the experiences.

2.0 Other Hands-On Initiatives

It is clear that many schools are embarking on efforts to introduce hands-on experiences. At Rensselaer, sophomores now participate in ENGR-2050 Introduction to Engineering Design [13]. In that class, multi-disciplinary teams of students design and build devices that meet a set of functional specifications (e.g., a robotic inspection device for I-beams). This course emphasizes creativity, teamwork, and communication. At the University of Oklahoma, a virtual space called Sooner City has been created to allow students to investigate design solutions to a wide variety of civil engineering problems [9]. Freshman take are plot of developable land and across their four undergraduate years turn it into a (partial) city that has sewer and water infrastructure, water supply, wastewater treatment, buildings, transportation systems. Thus, across their undergraduate years, students hone design skills as they create their virtual systems.

Other, similar programs have been created, at various scales. At Rensselaer, seniors in civil engineering take CIVL-4120 Civil Engineering Instrumentation and Sensors [13]. This course gives students hands-on exposure to data collection issues for real-world structural, geotechnical, transportation, and environmental systems. Teams of students learn how to monitor the behavior of in-lab and in-field systems using state-of-the-art instrumentation systems. The University of Colorado at Boulder has a hands-on introduction to engineering [7]. Interdisciplinary teams of students solve real world-like problems in hands-on experiments involving sensor, instrumentation, data collection, and data analysis concepts.

Within other civil engineering programs, similar hands-on experiences have been developed. Kukreti [10] describes a set of experiences predicated on a table top, structural model-building set. In an “erector set” type fashion, one, two and three-dimensional models are fabricated, instrumented, and exercised to illustrate many different situations. Schmucker [14] has created physical models that he uses to teach structural engineering concepts. One is a girder and panel building set that helps students interpret structural drawings. Another is a structural engineering toolkit that can be used to create initial design examples, demonstrate truss behavior for moment resisting and braced frames, and similar systems. Raad, Aktan and Usmen [12] describe physical models they have devised to teach ideas related to the non-destructive evaluation of civil engineering structures. Their experiences introduce ideas like the mapping of rebar locations, the identification of corrosion, the profiling of chloride ion penetration, assessment of ion permeability, ultrasonic inspection, and health monitoring through acoustic emissions analysis. In a similar fashion, Bissey and Wipplinger [3] have devised physical models that can be used to teach structural analysis to architectural engineers.

Examples also exist in other areas. Fiegel and DeNatale [8] have created physical models that help teach basic geotechnical engineering concepts. Penumadu [11] has a trixial test set-up that lets students conduct experiments that demonstrate an engineering principle or to determine material characteristics. Brizendine [4] has a computer-controlled data acquisition laboratory where civil engineering technology students can learn how to acquire and process of geotechnical data.

Then there are hands-on experiences that use mathematical models to teach civil engineering concepts. Barton and Wallace [2] use MATLAB to help students gain an in-depth understanding of the behavior of composite materials-based structures. They have MATLAB generate a set of graphical outputs that show a composite beam's behavior under load.

Virtual (computer-based) environments have also been devised. Wyatt, Arduino, and Macari [20] have a virtual geotechnical testing laboratory that can duplicate a wide range of simple geotechnical labs. It has an extensive set of modular entities, including cameras, lights, and user-defined static, kinematic, and dynamic objects. Students can explore phenomenological issues in a highly controlled manner, varying one variable at a time. They can see things that are difficult to see with a real, physical model, such as phenomena occurring within the sample, because the virtual environment has no access restrictions, and they can monitor pressures, stresses, strains, etc., that are impossible to measure in real specimens because no reasonable physical way exists to obtain the measurement without compromising the experiment.

In a simpler, strictly multi-media sense, Baker and Chinowsky [1] use video clips to help explain hard to understand, essential, or visual concepts. The clips are tightly integrated with various learning modules so that the students can see visual illustrations of the concepts being covered.

In another type of experience, students compare and contrast the performance of a physical system (scale or full-scale) with the predictions of a computer-based model of that system. Sukumaran [16], for example, presents a hands-on experiment that combines a physical model of a sheet pile wall with a computerized model of that system. The students use the model to predict phenomena they ought to be able to observe and use the physical model to see if those phenomena can be observed. It is our opinion that this allows one to illustrate many important issues. Garbage-in / garbage out problems in modeling is one of them. And without being negative about computer modeling at all, the strengths and weaknesses of computer models is another. Wadia-Fascetti and Tarnowski [19] describe a series of experiences in which students are required both to observe the physical behavior of a structural system and verify the results with both theory and computer applications.

On a more comprehensive scale, Kolar *et al*. [9] have devised a virtual design space that students use to experiment with team-based design solutions to civil engineering problems. "Sooner City" lets the students "see" the real world setting in which the problem arises, identify constraints that define the solutions that might be possible, and observe the performance of the solutions they develop. Kolar *et al*. [9] indicate they wanted a virtual environment that could be a unifying theme for all the undergraduate civil engineering courses. They also wanted to use a format that mimics the dynamic setting that typifies highly complex civil engineering projects; employ a pedagogical paradigm that involves team-learning and 'just-in-time' knowledge acquisition; and use laptop PCs as the medium of instruction.

Sun, Gramoll, and Mooney [18] have devised a series of virtual, hands-on experiences that use the Sooner City environment [9] to teach traffic engineering concepts. Students design solutions to specific problems and then use the Virtual City to see the implications of those designs. Definitions for concepts like level of service are presented through pictures, sounds, simulations, animations, and video in an integrated, web-based learning environment. Design variables include the traffic flow rate, the number of lanes, the length of the acceleration lane, and the on-ramp configuration.

Sun and Gramoll [17] have created a Virtual City, much like Sooner City, in which the highly-distributed database management features of the worldwide web are used to show how a geographically dispersed set of people can simultaneously collaborate on the development of civil engineering facilities and systems for a hypothetical urban area. In fact, their environment allows two designers to work on the same design project simultaneously. Chat rooms provide interaction capabilities among the designers. Specifically mentioned in the paper are the ability to address design issues related to buildings, steel structures, bridges, highways, and dams. A 3D virtual world ties all of these elements together in one environment.

Finally, there are real-world (living) laboratories where the students can see full-scale civil systems in operation. Chinowsky and Vanegas [6] describe how they used the 1996 Olympic Games to give students a "once-in-a-lifetime opportunity to study the expansion and redevelopment" of an urban center.

3.0 What to Include, When and How

The review of existing experiences presented above leads to the following questions: what hands-on experiences should be included in a given undergraduate curriculum, when should they take place, and how should they be conducted. Unquestionably, the answers to these questions are program dependent. That is, what is right for one curriculum may not be right for another. However, the logic by which the questions are answered may be transferable. That logic is the focus of this section.

To set the stage, we need to describe Rensselaer's civil engineering curriculum. That affects the decisions of what, when, and how. In Rensselaer's program, students focus on general engineering courses during the first two years and start discipline specific courses in the spring of the junior year. There is an elective one-credit optional course in the spring of the freshman year (introduction to civil & environmental engineering) and some of the early courses contain civil engineering topics (e.g., statics), but there are no required courses until the fall of the junior year.

Moreover, Rensselaer's program is quite flexible. There are only six discipline-specific courses that are named in the curriculum. Introductory courses in four civil engineering disciplines (structural, geotechnical, transportation, and environmental engineering) are taken in the fall of the junior year. A sensors and instrumentation course is taken in the fall semester of the senior year and a capstone design course is taken in the spring semester of the senior year. For all other requirements, options exist. The template that has to be satisfied is more categorical in nature: two design electives, one technical elective, and two multi-disciplinary electives [13]. The hands-on experiences fit into this flexible format.

3.1 Principles of Selection and Incorporation

Three fundamental principles were developed to guide decisions about what hands-on experiences to include, when and how. First, it was decided that the hands-on format should be used when it provided the best way to convey a particular piece of knowledge. Second, the experiences should take place when they best compliment and supplement class materials. Third and last, the hands-on experiences should have the students learn by discovery wherever possible, following a relatively risk-free sequence of steps (through a simple lab, a complex lab, a side-by-side comparison of physical and virtual systems, etc.) that reveal the set of concepts and ideas.

Two supplemental principles helped guide the choice of the initial experiences. One was that there should be an emphasis on data acquisition. Not only would this acquaint the students with high-tech civil engineering, it would also teach the students how to instrument civil systems with state-of-the-art sensors but it would also force them to think about how the systems should be instrumented: what should be measured, why and how; what results should be expected; what behavior should be expected. The fact that the students have to decide where sensors should be placed, and how, forces them to think about behavioral issues at a highly detailed level. Decisions about sensor choice and placement affect the extent to which the system's behavior can be discerned. The decision making process also highlights phenomena that are difficult to discern because the existing sensor technology does not permit it, as in the stress and strain distributions inside structural shapes. Using state-of-the art sensors to acquire this data also exposes the students to the best technology available. It helps them understand the limitations of more "primitive" options. Similarly, the analysis that supports these decisions helps students develop an "engineering" method of thinking.

Another guiding principle was that modeling and simulation should be stressed. With so much of today's design work being done by computer, it was decided that the students needed to see how various models work, what they predict, and how those predictions do and do not align with observable behavior. Seeing the differences lets them analyze the strengths and weaknesses of the computer models, find ways to work around those limitations, and think about ways they can enhance the models to eliminate those restrictions.

3.2 What topics?

From one perspective, the kinds of topics that we thought could be best learned through hands-on experiences fit into these categories:

1) *Material properties and behavior*: how materials behave that are part of civil engineering

systems: soils, steel, concrete, etc.;

2) *Subsystem properties and behavior*: how structural shapes (e.g., I-beams, C-channels) and other, similar civil engineering subsystems (e.g., footings, piles) behave and how this influences design options;
3) *Ways to see behavior*: the ways that are available to instrument civil engineering systems and develop information about their behavior;
4) *Computer models, their capabilities and limitations*: insights into the manner in which computer models predict the behavior of civil engineering systems, the difficulties they have in doing so, and the differences among models;
5) *Construction and construction staging issues*: the ways in which the process of planning, design, construction and testing of civil structures takes place; the sequencing issues that arise, the intermediate design problems that have to be solved, and how construction staging is handled;
6) *System behavior*: insights into the way in which real, full-size systems behave, how their behavior is affected by the inputs they see, and how that behavior is controlled and/or modified through various design options;
7) *Infrastructure management*: the issues that are important in managing the sequential investment in infrastructure to support societal development, the constraints that exist, the budgetary issues that are important, and how civil engineering systems are interdependent.

From a slightly different perspective, we can think about civil engineering systems (and concepts) as being categorized based on the subdiscipline to which they relate (e.g., structural, geotechnical, transportation, and environmental engineering). Then the hands-on experiences break down in a slightly different way:

- Behavioral examinations (by type of system, and further classified into basic, intermediate, and advanced, including taking systems to their design limits and the use of sensors and instrumentation to observe that behavior)
- Simulation and modeling experiences (by type of system, including models of full-scale and less-than-full-scale systems and comparisons of those models with the behavior of the real world systems they represent)
- Construction/fabrication experiences (including issues of site development, surveying, construction staging, and safety)
- Integrative experiences (experiences that look at the behavior of combinations of civil systems, such as water, sewer, and transportation)
- Asset management experiences (experiences that show the student how to create and maintain the built infrastructure of civil engineering systems that support societal activities, consistent with environmental goals, fiscal constraints, etc.)

3.3 What dependencies exist?

One more comment about the experiences is important. They need to be arranged in some logical fashion. Like a project schedule, each experience (task) relates to all other experiences (tasks) in some fashion. In some cases, precedence relationships pertain, in either a strict sense (A must be experienced before B) or an advisory sense (it is helpful / useful if A is experienced before B). For example, the more basic experiences should precede the intermediate experiences, which should precede the advanced experiences. The integrative experiences should take place after all other experiences have taken place. There will also be dependencies on modules that are part of the classes in the curriculum.

4.0 Initial Choices

Based on ideas from other programs, at Rensselaer and elsewhere, a list of hands-on experiences was created.

4.1 Disciplinary Experiences

The hands-on experiences can be categorized into those that are discipline specific and those that are cross cutting. For the four disciplines that are part of the Rensselaer undergraduate program, plus surveying, the hands on experiences are of the following types:

Structural Engineering

- Basic labs focused on the properties of structural materials
- Experiments that show the behavior of structural shapes when formed from various materials
- Experiences that show how structures can be instrumented and how the resulting data can be analyzed to learn about the structure's behavior
- Labs focused on the behavior of scale-model structures, such as scale-model bridges built for prior ASCE-sponsored steel bridge competitions
- Exercises that compare the predictions of computer models with the actual behavior of the physical structure being modeled
- Experiments that explore how full-scale structures, such as bridges and buildings, behave when subjected to various loaded conditions
- Hands-on activities related to earthquake engineering make use of 15 x 8-foot shaking table that has just recently been constructed and a desktop shaking table

Geotechnical Engineering

- Basic labs focused on fundamental geotechnical concepts
- Labs that address the behavior of foundation systems
- Analysis of basic geotechnical data, such as boring logs
- Tests of small-scale earth structures, like retaining walls, using the 10 G-ton centrifuge
- Computer modeling of geotechnical systems and comparisons with the actual performance of real systems
- Experiments with full-scale, instrumented foundations

Transportation Engineering

- Basic labs focused on traffic flow phenomena (gaps, headways, flow rates, traffic stream composition, delays) and the instrumentation technologies whereby such information can be collected
- Experiments with highly advanced data collection technologies such as machine vision and two-way, GPS-equipped two-way transponders.
- Exercises that compare computer model predictions of performance with field measurements

- Experiments focused on the techniques used to control traffic flow in signalized networks, such as changes in signal timings

Environmental Engineering

- Basic labs focused on environmental phenomena (diffusion of water through soil, filtration, adsorption)
- Experimentation with small scale environmental systems (e.g., bench top soil model, scale-model filtration plant)
- Exercises that compare simulation model predictions of system performance with the actual performance of the physical system
- Experiments in which the parameters of a real water / wastewater treatment facility are adjusted (e.g., chemistry and/or filtration) to achieve specific objectives

Surveying

- Basic surveying concepts learned on campus by checking landmarks on campus
- Exercises involving a real world site, where the site chosen for that experience is one that has recently been surveyed, so the students can compare their results with those obtained by the professional surveyors

4.2 Culminating Disciplinary Experiences

The more advanced hands-on experiences described above can also be categorized as Culminating Disciplinary Experiences. Much like a charette, these are events of short duration and high intensity. The students are immersed in a real world situation and they devote a high proportion of their time to the activities of the experience. Their other activities and coursework are largely put on hold.

Current ideas for culminating disciplinary experiences include the following.

Structural Engineering: The culminating experience in structural engineering is presently a trip to the Fritz Laboratory at Lehigh University. The students are given a description about a set of tests that are currently underway, they see and work with the test set-up, collect data, analyze the data, and develop insights about the phenomena that have been observed.

Geotechnical Engineering: The current culminating experience in geotechnical engineering is an experimental analysis predicated on the in-situ soil-testing laboratory at the University of Massachusetts, Amherst. The students go see the testing facilities, the instrumentation employed, the cyclic testing strategies used, and are given a briefing about a current project. They then analyze data recently collected and strive to discern trends in parameter values and/or relationships between independent and dependent variables.

Transportation Engineering: The present culminating experience in transportation engineering is an experiment in real-time control of a signalized network predicated on the traffic control system in White Plains, NY. The students visit the system, see it work, and make changes to certain parameters so that the network's performance can be enhanced in light of current maintenance activities underway within the network and changing trends in economic activity and land use.

Environmental Engineering: The culminating experience in environmental engineering is currently a full-scale experiment in water and/or wastewater treatment utilizing a plant at a nearby city. The testing lab for New York City is the current venue. The students learn about problems associated with operating the plant and experiment with adjustments in chemical treatment and filtration to ensure that effluent standards are met.

Construction: The culminating experience in construction is a series of day trips to local construction sites. More than one site is visited so that construction projects can be seen at various stages of completion.

4.3 Cross-cutting, Integrative Experiences

Some of the integrative experiences are cross cutting. They pertain to all disciplines and/or tie the disciplines together. Three have been identified. They either already exist in the program or will be added.

Capstone Design: The first is the senior level capstone design course. It offers students an opportunity to focus on a full-scale design project. The course ties each of the civil engineering concentrations together and provides student an opportunity to apply their coursework in to a "real world" problem. Students must form an imaginary company, prepare a project proposal in response to a request for proposals, prepare design submittals in accordance with a written statement of work, and make presentations to practicing engineers, faculty, and other students about the work that they have done on their design project.

Admiral Combs Design Retreat: The civil engineering students at Rensselaer also have the opportunity to attend the Admiral Lewis B. Combs Design Retreat. An elective opportunity, the retreat is an annual, one-week event where students can experience a variety of civil engineering concepts in a "real world" situation. Students take up residence in the offices of a design firm, they visit projects in the immediate vicinity, work on large-scale design tasks, and make presentations about the results of their efforts on those tasks.

Asset Management: The third cross-cutting, intergrative experience focuses on asset management, in the context of a metropolitan area. SimCity is used as the experiential environment. Scenarios are developed by the teaching team that represent challenges to the students in terms of anticipating the demand for system expansion, the need for fiscal management, compliance with changing environmental regulations, and natural calamities.

All three of these experiences provide the students with a look into the industry and allow the students to apply the theories of the classroom to "real world" problems.

4.4 Courses or Checklists?

At least three options exist for scheduling the hands-on experiences. One is to attach them to existing courses (like required labs), determining what experiences work best with what courses. The second is to create separate classes that progress through the hands-on experiences (across all the disciplines) in a logical manner. The third is to conduct the hands-on experiences as stand-alone events in which students must participate (effectively earning “points” for their completion) as they progress through their studies. In this latter case, the students are responsible for ensuring that they determine when to sign-up for the events and for ensuring that prerequisites are met.

Not any one of these three options is right for all the experiences. It makes sense to make all or most of the basic and intermediate disciplinary experiences part of formal courses in those areas (e.g., basic structures labs should be part of the introduction to structural engineering course). The culminating disciplinary experiences, on the other hand, could be part of a separate class. Other experiences, like surveying, could stand alone and simply be a milestone that must be met before graduation.

In Rensselear’s case, the present idea is to have four hands-on courses. Two will be scheduled during the junior year, one each in the fall and spring semesters.

Because of the timing of the introductory courses, the basic and intermediate structural and geotechnical hands-on experiences will be placed in a single two-credit class and be coordinated schedule-wise with the structural and geotechnical engineering classes that are offered in the fall term. The transportation and environmental engineering basic and intermediate experiences will be packaged into a two-credit class offered in the spring semester since the long-term plan is to move the associated introductory classes to the spring semester anyhow.

The culminating disciplinary experiences will be stand-alone events that students must sign up for and complete sometime during their undergraduate studies. They must have completed the basic and intermediate labs before these experiences can be undertaken. The structural and geotechnical experiences will be held in the spring semester so they follow the basic and intermediate experiences. Similarly, the transportation and environmental culminating experiences will be scheduled in the fall semester so that students who do the basic and intermediate experiences in the preceding spring semester can participate.

The surveying and construction experiences will stand alone. The surveying experience will be scheduled for both fall and spring semesters. The same is true for the construction experience. These will not be credit bearing, but their completion will be required before graduation.

The Asset Management hands-on experience will be a one-credit requirement and it will be scheduled for both fall and spring semesters. Students are required to complete the experience before graduation. This means students in all four years can take it when it fits their schedule.

5.0 Pilot Testing

The Hands on Experience has been a product of several steps. It started out as a vision and moved toward a reality. A set of goals and objectives had been defined and the initial concepts of the Hands on Experience were developed. The next step would be implementation. In order to implement the courses, the curriculum would need to endure intense changes. The existing curriculum needed to be examined and new experiences needed to be researched. It was these thoughts that lead to the pilot test.

Several seniors registered for a course call "Hands on Experience" in the 2001-2002 academic year. Although the course was quite different from the "Hands on Experience" courses that will be offered in the future the course provide students a wonderful opportunity to reflect on what they had learned in the previous year and allowed them to explore new opportunities for learning. In order to ensure that the Hands on Experience courses in the future would be seen as valuable to the students, the students were asked to play a key role in its design.

The objective of the course was to review the labs/experiences that they had taken as juniors, assess their value, develop new lab/experiences and strive toward creating a program which could serve as a stepping stone in the development of the "Hands on" courses in the future.

The students' first task the students encountered was to develop a good definition of what the "Hands on Experience" was supposed to accomplish. The guidelines directed them toward a course in which student could participate in real life applications of civil engineering course material. They determined the course should consist of a number of integrative experiences that could be used to support/promote the students understanding of classroom material and provide opportunities to explore pieces of civil engineering which go unseen in typical classroom. Through these experiences, the course should provide high-quality preparation for working in industry.

The students then examined the existing civil engineering curriculum, focusing on the four main concentrations (Environmental, Geotechnical, Structural, Transportation). Each lab/experience that is assigned in the current curriculum was reviewed, judging its value and quality. They questioned the departments faculty looking for their opinions of the existing labs/experiences and incites into what additional experiences they would like to see incorporated into the program. The students then went in search of new lab/experiences. Teams of two were given a specific concentration, which they were to research. The students developed a long list of high-quality experiences they felt would greatly enhance the civil engineering program at Rensselaer.

The labs/experiences are of two main types, ex-situ and in-situ. Further, the ex-situ experiences tended to consist of basic labs and modeling (virtual) labs. The in-situ experiences included integrative field visits and large scale "real-world scenario" labs. The students had completed the majority of the basic labs in the past and their value was easy to assess. The student spent a large amount of time working with a program called SimCity and trying to determine it value. They experimented with its capabilities to create/develop scenarios and its uses to teach Asset Management, Infrastructure Management, and City Planning.

The students also explored three integrative field experiences. The first was a trip to Lehigh University, where students visited two large structural labs. They were amazed by the facilities and found the visit to be a very valuable experience. They witnessed fatigue testing on large corrugated beams as well as half of a full-scale bridge. They did stress and strain calculations, which were then matched to the tests being conducted in the labs. The second field experience the students explored was to the White Plains Traffic Management Center. Here students saw how the traffic network was set up, the operations behind the traffic controls and how minor changes to a single network component could greatly impact the system. The third field experience was a trip to the geotechnical facilities of the University of Massachusetts, Amherst. The students visited the NGES in-situ soil testing facilities, where they witnessed full scale loading on several foundation types. They also toured the laboratory observing various instruments and witnessing the analyses of a variety of soil types.

With a large number of possible labs/experiences, the students once again went back to the current curriculum, this time examining its overlying structure. The curriculum is devised in such a manor that for the first two years students take core-engineering courses and in the junior year they start taking civil engineering courses. The students were looking for a ways to integrate the new “Hands on” course into the curriculum. The difficulty they encountered was coordinating the labs in such a manor that the material would be covered in the corresponding introductory course before the students were presented with a lab. Several options were developed. These included options in which the “Hands on Experience” was comprised of two courses offered in the junior year, to an option in which there was a series of five courses spread across all four years. In each scenario, the students arranged the labs/experiences in a way such that the courses would offer the optimal value to the students as well as align with the material of the other courses. Finally, the students presented their findings and ideas to a handful of the department’s faculty, who then asked numerous questions about how the course would affect their own courses. In addition to this presentation, two of the students also presented the materials to the departmental advisory board. The advisory board was very receptive of the ideas and offered valuable feedback and additional experiences, which could be considered for the course. The results of these efforts are reflected in the ideas about scheduling the hands-on experiences presented in Section 4 above.

6.0 Conclusions and Next Steps

Our work to date in developing the hands-on experiences convinces us they have great value. The students that have helped explore the concepts and ideas have all praised the initiative. Some of them participated in the pilot experience without registering for credit. They all participated in the development of the materials that undergird the ideas presented here.

Many reasons can be seen for creating such experiences, only some of which are pedagogical. The experiences can be a hallmark of distinction for the program. They provide a source of motivation for the students as they deal with the “drudgery” of the more conventional classroom-based classes. They also provide a way to connect with freshmen and sophomores who are interested in pursuing civil engineering as a career.

Long term, the challenges are finding the personnel to manage the experiences, the resources (funding, etc.) to make them possible, and scheduling. The latter may be the most significant.

Ideally, one would like to create scheduling windows for the culminating experiences, adjusting other aspects of the semester schedules to accommodate. This would mean creating windows during the academic year when charettes could take place. It would also mean taking greater control of the course sequences followed by the students, and creating agreements with other academic units across campus (e.g., other schools) so that the students can take part in such events. Architectural departments do this regularly.

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