

# Multi-Disciplinary Capstone Design Class: Integrating Specific Civil Disciplines, Teaching Styles, and Teaching Effectiveness to Meet ABET Criteria

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**Abstract** – The CEE department developed an artificial project that incorporated a real world feel. The combined course structure was designed to provide an environment consistent with a small-to-medium size consulting firm. Meanwhile, the individual classes were taught in a variety of different styles. Local professionals were used to play the role of clients and meetings were arranged with actual local regulatory agencies to discuss the design alternatives and submittal deadlines. The class project resulted in comprehensive sets of plans, specifications, and cost estimates along with other discipline specific deliverables. This paper describes the type of project used, how the Army Corps of Engineers and local professionals were incorporated into the class structure, the level and type of involvement between the three civil specific disciplines, and provides the results of course feedback from the students. In addition, problems encountered during the semester and plans on addressing them during the following year are provided.

*Keywords:* Capstone, real world problem, multi-disciplinary design team.

## INTRODUCTION/BACKGROUND

The Citadel's Department of Civil and Environmental Engineering (CEE) recently abandoned its senior research project in lieu of a comprehensive multi-disciplinary capstone class. The addition of ABET Criterion 3d requiring students to work in multi-disciplinary teams and ABET Criterion 4 (the professional component) which requires students to participate in a major design experience utilizing knowledge obtained from previous classes make the capstone class an attractive alternative to meet the assessment criteria in these areas. Based on input from the Department's Advisory Council and the results of a survey conducted on senior design experiences at other institutions [1], the CEE Department decided to integrate the three disciplines of environmental, structural, and site development into one unified design team.

The first obstacle was to develop a project that would be both engaging for the student and meet the learning requirements of the diverse subject matter covered in the three different classes. Literature supports the notion that embellished or contextualized problems can increase student's motivation to learn and be engaged in the subject. Ideally the faculty would want a class that would result in activation of the students intrinsic motivation to learn and engage the subject. Intrinsic motivation is defined by Alderman [2] as the students' engagement in learning for

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satisfaction, interest, or challenge of the subject matter. Extrinsic motivation differs because students are doing the work only for the grade or special privilege. Lepper and Cardova [4] showed that when assignments were embellished, students were at first more motivated to learn; however, this did not permanently improve or effect their intrinsic motivation. It seemed that a problem contextualized in a real world situation would result in a more engaging situation, but would not take care of all the motivational issues.

Once the structure of a real world approach was adopted, the issue of how the class should be taught was tackled. The faculty members involved had very different teaching styles. In addition, students were at different places in the curriculum in different subjects. For example, the site development class has a whole elective prerequisite on site development prior to the capstone class while the structures students are enrolled in steel design at the same time as the capstone course is taken. The question arose: Should the faculty try to teach the class with the same classroom pedagogy or could the faculty make it work with different approaches to teaching and learning?

Literature supports the notion that students have different learning styles and therefore benefit differently to different classroom pedagogy. Atkins et al. [5] outlines the main learning style theories focusing on the three different layers of Curry's Onion Model. The theories outline many different parameters that can positively and negatively affect a student's ability and motivation to learn. By providing three different classroom pedagogies to the students, they can select a capstone class that caters to their general learning preferences. Based on this information, it was determined that the capstone class would be taught with different classroom pedagogies, while at the same time still trying to bring the classes together as one unified design team.

Thus, during the spring semester of the 2003-2004 school year, the Civil & Environmental Engineering (CEE) senior class participated in a multi-disciplinary capstone course. The students were enrolled in independent classes, but each of the three separate courses worked together toward the completion of a common real world problem.

## **PROJECT DESCRIPTION**

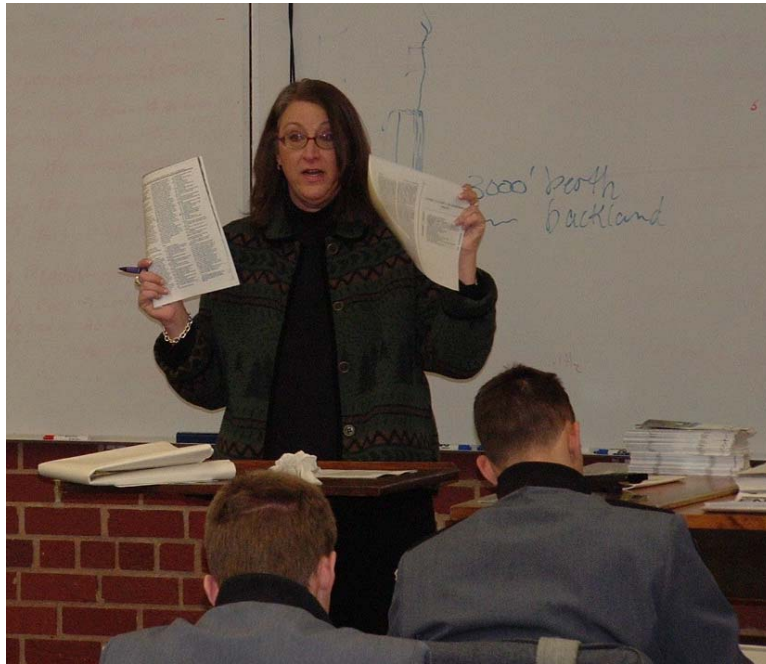
The main objective of the real world problem was to make the course structure and levels of design group interaction as much like the actual workplace as possible. This was accomplished with the involvement of a local developer, Walt Martin, who presented a fictitious 992-acre tract of land that he had purchased and wished to have developed. The site was broken into 25 acre tracts for development as commercial, multi-family or single family developments. In addition, the development was to have a community center with activities building and swimming pool. As part of the developers' agreement with the city upon purchasing the land, a lot for an elementary school was also to be located in the development area. The utilities (water and sewer) for the entire tract of land were also part of the development agreement.

## **REAL WORLD APPROACH**

The first four weeks of the class consisted of an information gathering phase. During this period, due to the enormous amount of information that needed to be conveyed, the three classes met simultaneously. The developer "hired" a number of consultants to provide information about the project to the class. The first such consultant that met with the class was an architect, John Gardner, AIA. Mr. Gardner provided design guidelines such as buffers, open space, aesthetics, handicap access, etc. He also discussed the creation of a sustainable design. Jack Ellis, P.E., was hired by the developer as an environmental engineering consultant. He met with the class to discuss topics such as SARA and CERCLA, Superfund sites, environmental site assessment, potential problem areas, and mitigation scenarios. The final consultant was Dave Hale. Mr. Hale was hired as a Geotechnical Engineering consultant. He discussed site exploration procedures, testing procedures, provided a "geologic and soils report" for the site, and made recommendations for the site design.

There were also representatives from various regulatory review agencies, which provided necessary information to the class. The first of these representatives was Matt Halter, P.E. & L.S., Town of Summerville Public Works Director, Storm Water Management Engineer and Zoning Officer. Mr. Halter provided extensive guidelines concerning subdivision regulations, zoning requirements, guidelines for plans and specifications, and permitting procedures. He made it clear to the students that if these guidelines were not followed explicitly, he would not be

able to approve the project. The next meeting was conducted by Bob Horner, P.E. Mr. Horner worked for the Charleston Commissioners of Public Works. He discussed with the class federal and state laws pertaining to clean water, provided design criteria for water and sewer systems, provided guidelines for construction specifications, and discussed permitting procedures. The US Army Corps of Engineers was the final regulatory agency to provide information to the class. Their involvement was required due to the fact that the property to be developed contained wetlands, an Indian burial ground, and a historic house. Their representative, Tina Hadden Chief of Regulatory Permits for the Charleston District (Figure 1), discussed the Clean Water Act 92-500, wetland mitigation, endangered species, NEPA (National Environmental Protection Agency), Coastal Zone Management Act, and navigable streams.



**Figure 1. Tina Hadden from the Army Corp of engineers talking to students about wetland legislation.**

Once all the necessary meetings had been conducted and the required information had been obtained, the class split into its separate sections. These sections included Land Development, Environmental, and Structural. Each of these sections had their own individual portions of the project that would be solely theirs to complete. However, in order to complete the entire project a collaborative effort between all sections was required. The way each class was taught also varied significantly.

## **INDIVIDUAL COURSE PROJECTS AND PEDAGOGY**

### **Land Development Capstone Class**

The Land Development section was responsible for formulating the conceptual plan for the project. The initial guidelines were that 25% of the land would be used for commercial development and the remaining 75% would be used for residential development. Each member of the Land Development section made a rough sketch of the property and came up with several options for the layout. The main issues that were taken into account were the wetland areas, indian burial ground, and historic house that were located on the property. The group then met and discussed each option's advantages and disadvantages. Two options were then chosen, one with on-site mitigation of wetlands, and another with off-site mitigation. These options were presented to the developer who made the decision to continue design using the on-site mitigation.

The next step was to begin design of the main roads and individual subdivisions. The road layout was decided upon after several options were discussed at a meeting of the entire class. The decision was made to break up the residential portion of the land into individual 25-acre tracts of land. Each member of the Land Development section would design a single and multi-family subdivision for one of these tracts.

The design process of the individual tracts began with the design of the storm drainage network. The 25-acre tracts were divided into separate drainage basins. Using the rational method, the storm drainage pipes were sized. Next, the storm drainage network was analyzed with the computer program HYDROS. Following the storm drainage design was the design of the roadway system. Based on the drainage and preliminary plans, the PVIs (Point of Vertical Intersection) were set for the roads within the subdivision. A minimum slope of 0.3%, and 100 ft and 200 ft vertical curves were used throughout the design. Once all PVI elevations and slopes were determined the computer program VCURVE was used to station off the roads at 50 ft intervals. The sanitary sewer was designed using a 0.33% slope, and 8 in. PVC pipe. Microsoft Excel spreadsheets were used to determine the inlet and outlet elevation for the pipes. The sanitary sewer system for the individual tracts was to tie into the mainline for the entire subdivision. Upon the completion of the storm drainage, roadway, and sanitary sewer, AutoCAD was used to draw the systems in a profile view. The required cover on the storm sewer and sanitary sewer was 1 ft and 3 ft, respectively. The required cover and invert elevations of each pipe was closely monitored during this process to prevent any problems. The potable water system was the last to be designed. Two-inch diameter mains were used past the last fire hydrant on each line, and six-inch diameter mains were used elsewhere. A plan view of the pipe lengths and sizes was the only requirement for this system's design.

Upon completion of the design process an erosion control plan was prepared. The plan called for silt fences to be installed around the entire job site, hay bales to be placed around all drop inlets, a temporary riser pipe to be installed in the detention pond, and a temporary wash-down area for all trucks leaving the site. This plan was sketched in AutoCAD and included with the construction plans.

The Land Development section of the capstone course divided their class time between classroom lecture and individual work in the computer lab. Generally, the professor would use one course period per week to instruct the students about the areas of the project they would be working on in the lab during the next course meeting. The professor was usually present in the lab to answer any questions that the students had. The students were also encouraged to help each other and work together when problems arose.

### **Environmental Engineering Capstone Class**

The Environmental section was responsible for the wetland mitigation plan, the design of sanitary trunk sewer, and the design of a pump station to service the sanitary sewer system.

The design began with a preliminary study of the sewer and force main routing options as well as proposed pump station location. The group generated a combined report focusing on three alternatives and the preliminary opinion of probable cost of construction for each alternative. The report was sent to the developer for final recommendations.

Once a final routing was determined, the sewer and force main final design began. The pump station preliminary layout consisting of wet well size, overall footprint, preliminary pump sizing was sent to the developer and CPW for approval. The 11 MGD pump station had two solids handling pumps in a suction lift configuration. The pump station was also equipped with a mag meter with a totalizer to monitor flow.

The water main design consisted of the generation of a comprehensive EPAnet water model. The need for additional elevated storage and a booster chlorination station was investigated but deemed unnecessary. Ultimately the final design consisted of the civil and mechanical sheets for the 11 MGD pump station, plan and profile sheets for the sanitary trunk sewer, plan and profile sheets for the force main, and plan and profile sheets for the water main. In addition a complete set of construction specifications and opinion of probable cost of construction was developed.

The Environmental section of the course was taught utilizing Problem Based Learning (PBL). PBL is a method used to teach students how to effectively solve problems, never before encountered, without being continuously directed by the instructor. This process was broken down into eight tasks [6]:

1. Explore the problem, create hypotheses, identify issues, and elaborate.
2. Identify what you know is already pertinent.
3. Identify what you do not know and therefore need to know because your lack of that knowledge is impeding the solution of the problem.
4. Prioritize the learning needs, set learning goals and objectives, and allocate resources so that you know what is expected of you by when. For a group, members can identify which tasks each will do.
5. Individual self-study and preparation.
6. Return to the group; share the new knowledge effectively so that the entire group learns the information.
7. Apply the knowledge to solve the problem.
8. Give yourself feedback by assessing the new knowledge, the problem solution, and the effectiveness of the process used. Reflect on the process.

These tasks were put into effect when problems were assigned to the groups. A general guideline for the problem solving process was also provided:

Stage 1:

- Write out and identify Problem statement(s) based on information from the situation.
- Draft objectives developed by group based on the problem statement.
- Each group has a goal/planning meeting to outline goals, preliminary learning objectives, and assign material for teach meeting.

Stage 2:

- Teach meetings are held by individuals (12 to 15 minutes each) to present new knowledge.
- Individual teaching effectiveness is immediately evaluated by the group using a feedback form. The chairperson is responsible for recording the scores, averaging them, and then turning them in to the instructor for each group member.

Stage 3:

- The group reviews/finalizes learning objectives.
- The group finalizes problem solution.
- Group performance evaluation/discussion takes place.

Stage 4:

- Group and individual assessment response report is due. The chairperson for the problem set being evaluated is responsible for the group response and collecting individual responses.
- Problem solutions and learning objectives are due.
- Group selects chairperson for the next problem cycle.
- A new problem cycle begins.

The idea behind this format was that in each group for each problem one individual had to learn the material well enough that he could teach it to the rest of the group. The student was then rated on how well they presented the material. This motivated the individual teaching the particular session to attain a thorough understanding so that he

could present the material clearly and in doing so receive a good evaluation. Overall this method of instruction can be a very useful way in which to teach a course of this type.

### **Structural Engineering Capstone Class**

The Structural section of the course was responsible for the design of the buildings that would occupy the commercial section of the development. There were two hospitals and six office buildings designed. There was one hospital that was designed to be six stories in height. The other hospital was also planned to be constructed to six stories initially. However, it was designed to carry a future six-story addition. The hospital designs were based on actual design concepts in coordination with Davis & Floyd, Inc., a local engineering and architecture firm in South Carolina. The office buildings were all two-story rectangular buildings. Four custom homes were also designed using timber construction. One of the office buildings was to be leased by the Corps of Engineers and was designed for the latest antiterrorism standards.

To begin the design process for all of the buildings, the dead and live loads that comprised the weight of the building were calculated. Once these loads were determined, all other loads were calculated to include wind, rain, snow, and seismic loads. All loads were then considered using appropriate load combinations.

The structural elements for the buildings were designed in a logical order. The concrete slab was the first element to be designed. The slab was designed to carry the dead load, its own weight, as well as any live loads it would resist. Due to the presence of corridors and unknown floor space in some areas, a general live load of 80 pounds per square foot was used throughout the design. The floor joists were sized to resist the loads transmitted through the floor slab. Open web steel joists were used. The girders were sized in much the same way, but were hot rolled sections and designed to carry the loads from the tributary floor joists. Loads from the girders were used to size the columns. The columns used were all two floors in height between splices. They were sized from the top down, increasing in size at lower levels. Where the columns tied into the foundation, base plates were required and appropriately sized. Once all of the building elements were designed, the buildings foundation was designed. The total weight of all the building components was computed. The geotechnical consultant, Dave Hale, had previously provided the class with the amount of load that each individual pile could hold, and it was simply a matter of dividing the total weight of the structure by the individual capacity of the pile to obtain the number required. This completed the design portion of the project. All elements of the design were then shown in a set of construction drawings generated by the students. The final set of student generated plans and specifications were compared to Davis & Floyd's real design and the semester's end.

The Structural section of the capstone project was taught in much the same way as the Land Development section. Lectures and group examples were sometimes necessary to provide the students with technical information about portions of the design (Figure 2). There was also a large portion of the course time devoted to work in the lab using finite element and design software. The professor was always available for questions in case the students encountered a problem.



**Figure 2. Students working on part of the design.**

## LEVEL OF GROUP INVOLVEMENT

While there was a substantial amount of individual work done within each section, the project could not have been completed without teamwork between the groups. The best example of an ongoing situation in which two sections had to work together was with the Environmental and Land Development sections. Each 25-acre residential development had its own sanitary sewer system. Each of these systems had to tie into the mainline sanitary sewer system, which was designed by the Environmental section. Therefore all members of the Land Development section had to be in communication with the Environmental section for this portion of the project to work. Another example of two groups working together was between the Structural and Environmental sections. The pump station designed by the Environmental section had to have properly designed walls and floors for a very specific reason. Because the majority of the structure was underground, if there was not enough weight present the pump station could be forced out of the ground due to the presence of groundwater. Therefore, the two sections worked closely to ensure that the design took this into account. The Structural and Land Development sections also worked together. The commercial section of the development, which was to house the two hospitals and six office buildings, also needed a preliminary design layout. One of the members of the Structural section worked with the Land Development section to create the layout for the roads, buildings, parking, potable water system, sanitary sewer system, and storm drainage system. The best example of teamwork, however, came in the planning meetings, during which all sections were present. There were many challenges and obstacles to overcome in order to see this project through to its completion. Many of these did not involve any specific section, but rather the collective ideas and cooperation of the entire class. Without everyone working together as a team, the project could not have been completed on time. This is a lesson that is valuable both in the classroom and beyond.

## STUDENT FEEDBACK AND RECOMMENDATIONS FOR FUTURE WORK

Table 1 outlines the results from the teaching evaluations conducted at the end of the class. The data clearly illustrates that students felt the class was helpful and had no significant negative comments on the pedagogy. The data presented is on an average, but no significant outliers were observed.

**Table 1. Summary of Important Teaching Evaluation Scores Averaged between the Three Capstone Sections.**

Student Evaluation Question	Average Score Out of 5.00
Professor displays a clear understanding of course topics	4.9
Professor seems well prepared for class	4.9
Professor make good use of examples and illustrations	4.9
Assignments are related to goals specified in the syllabus	4.9
I learned a lot in this class	4.9
Professor makes effective use of class time	4.9
Professor effectively challenged me to think	4.9
In this course many methods are used to involve me in learning	4.9

The written feedback from students provides additional insight into their experience and suggestions for future classes. The following bullets item paraphrase and characterize the students' comments:

- Milestones should continue to be used or should be established to keep students on track

- Provide a more in-depth overview of the process prior to starting the project
- Keep team leaders and overall project leader but expand on the responsibilities of these individuals
- Stress the importance of the initial meetings
- Stress the importance of accurate drawings because other students depend on the information

Both the students and faculty involved found the experience to be fun and worthwhile. The class will be conducted using this format next time. While each faculty member is making minor adjustments to the class, the general format will stay the same. The only major problem encountered involved the dependence on outside agencies. In one instance, the outside resource did not hold up to their end of the agreement leaving a critical piece of the project uncompleted. While this emulated a real world condition, it made it difficult to finish a portion of the project. The only major change in the class will be to reduce some of the dependence on outside agencies.

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**Thomas Dion**

COL. Dion graduated from The Citadel in 1968 with a BS degree in Civil Engineering. He earned an MS degree in Civil Engineering from Clemson University in 1973 and was registered as a professional engineer and land surveyor in the state of South Carolina in 1976. He became a full time faculty member of the Civil and Environmental Engineering Department at The Citadel 29 years ago when he began teaching undergraduate students. Part of his departmental duties includes being coordinator of the Civil and Environmental Engineering Department's Capstone Design course in engineering practice. COL. Dion formerly served as President of the Section 2000-2001 and is currently serving as Campus Representative Coordinator for the Southeastern Section.