

**AC 2008-156: TWO INTRODUCTORY CIVIL, ARCHITECTURAL &
ENVIRONMENTAL ENGINEERING COURSES**

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Two Introductory Civil, Architectural and Environmental Engineering Courses

Background

In 2006 and 2007 Drexel's College of Engineering restructured their freshman and sophomore curricula. As part of that restructuring two introductory sophomore-level courses were to be delivered in each engineering curriculum. Three curricula are delivered by the Department of Civil, Architectural and Environmental Engineering at Drexel. Recognizing the importance of communication and cooperation among the three disciplines of civil, architectural and environmental engineering, the department's curriculum committee opted to introduce two courses common to all three majors in the department. The two courses, CAEE201 Introduction to Infrastructure Engineering and CAEE210 Engineering Measurements I, are offered during the first and second quarters of the sophomore year, respectively. Both courses are offered twice a year because Drexel's co-op program splits students into two parallel cohorts during their sophomore, pre-junior and junior years¹. A third course, CAEE211 Engineering Measurements II, provides instruction in surveying and geology during the first quarter of the pre-junior year.²

Introduction to Infrastructure Engineering (CAEE201)

CAEE201 is a team-taught 3 credit course with 2 hours lecture and 2 hours of computation laboratory. The course presents two or more engineering case studies of the design, construction, operation and maintenance of infrastructure projects. Key engineering elements of the projects illustrate the various disciplines within civil, architectural and environmental engineering including foundation engineering, structural engineering, site engineering, drainage, security, building systems, environmental issues and construction management. The concept of an "infrastructure system" that solves a problem within physical, economical, environmental, social and political constraints is presented along with the interrelationships among the various infrastructure engineering disciplines to produce a successful final project. Specific case studies change from year to year as various local infrastructure projects move from design toward construction and completion. One or two field trips to visit project sites are part of the team taught course. A course "project manager" oversees and organizes the course, lectures, and recruits practicing engineers and appropriate faculty to present the various elements of the course.

Not every case study includes elements of all three disciplines but each term with two (or more recently three) case studies does. Near-campus projects currently under construction are sought although one 10-year-old nearby completed bridge project has been used. Generally, each case study is introduced in class by a guest speaker, usually a design engineer or architect closely

¹ One cohort attends school for 6 months while the other is employed as an engineering intern at an engineering or construction firm or at a government agency. After 6 months the role of each cohort is reversed. Students return to school for three consecutive quarters during their senior year.

² Because Drexel's engineering programs are cooperative education programs requiring 5 years to complete, the middle year is designated the pre-junior year

involved with the project, who gives an overview and introduces the engineering elements of the project. This introduces students to professionals practicing in one or more of the three disciplines. Subsequent lectures and assignments are given by department faculty who discuss the project's engineering components such as its foundation, structure, drainage, environmental impact, HVAC and building systems, etc. Weekly assignments are given and mostly completed in a two-hour computation laboratory under the guidance of the department faculty member. Thus a second course objective is met: students are introduced to department faculty and their specialties. The case study is culminated by a visit to the project construction site. In the two offerings of CAEE201 in the 2006-2007 academic year, case studies included Drexel's Race Street Residence Hall which was then under construction, the Walnut Street Bridge over the Schuylkill River and its approach viaducts, and a building renovation to provide sodium hypochlorite storage and feed at the Philadelphia Water Department's Belmont Water Treatment Plant.

CAEE201 also provides an opportunity to introduce the content of each of the three curricula to the students some of whom have not yet decided on which branch of engineering they will pursue. In teams of four, students interview a practicing engineer, usually at the engineer's workplace.

Course Objectives:

- Describe the activities and responsibilities of civil, architectural and environmental engineers.
- Perform basic calculations relevant to design problems in civil, architectural and environmental engineering.
- Identify the major building systems and the logic of their construction sequence.
- Identify the major systems in a typical civil engineering project and the logic of their construction sequence.
- Identify major environmental issues and the approaches to resolving them, and
- Describe the student's major curriculum and why it is structured as it is.
- Obtain a basic understanding of professional issues, professional societies, engineering ethics and professional licensure requirements.

CAEE201 Course Content

As of this writing, CAEE201 has been offered 3 times; each has included two or three case studies. During the first offering the two case studies were Drexel's Race Street Residence Hall then under construction, and the Walnut Street Bridge over the Schuylkill River and its associated approach viaducts which was built in the mid-1980s. During the second course offering the dormitory was replaced with a the sodium hypochlorite storage building at the Philadelphia Water Department's (PWD's) Belmont Treatment Plant. The treatment plant was included in the second offering in response to student feedback that the first offering was light on environmental engineering content. During the third course offering the nearby Penn Alexander Elementary school replaced the treatment plant, while the new research tower at the Children's Hospital of Philadelphia became the AE focus. The Penn- Alexander School has a number of "environment friendly" and sustainability elements that make it a good candidate for study. The Walnut Street Bridge was used in each of the three offerings. The content of the four case studies is discussed below.

In addition to lectures pertaining to the case studies, lectures on project management, active listening, professional societies, ethics professional licensure and the civil, architectural and environmental curricula are included.

Race Street Residence Hall

As with each of the case studies, the first lecture is usually by a practicing professional who either worked on the project or is familiar with its engineering elements. Drexel University's architect provided the overview for the dormitory project and described the building's elements including its structural, mechanical and electrical systems. Subsequent lectures by faculty addressed site development including utilities, permitting and drainage; HVAC and mechanical systems in general and those systems specific to the dormitory; structural components, live and dead loads, factors of safety and contributing areas to beam and column loads; foundation engineering in general and the foundation system of the dormitory including the uncertainty surrounding soil conditions in urban areas, and the site drainage including the site and building roof drainage system as related to historical rainfall statistics for the Philadelphia area. In all cases the "language of engineering" for each discipline is introduced. The case study culminated in a visit to the construction site guided by the project's construction managers. Students ascended the 11 story building to inspect the structural, mechanical and electrical systems. At the time of the visit the building was enclosed; however, key building systems were still visible.

Assignments

- Drawing – use "Sketch-up" to construct a building with given dimensions on a site. Construct perspective and orthometric views with floor plans and sections. Move the building onto a real site using Google Earth.
- Site Conditions – use building layout to determine fraction of site covered by building's "footprint" and determine if a zoning variance was needed.
- Site Drainage - use historical rainfall statistics to determine volume of water put on the site by a storm with given duration and return period. Use site contours to determine drainage paths. Determine the required capacity of the building's roof drains.
- Structural - Determine the contributing areas of building to each column for the given building layout. Determine the flange area for a beam given the moment, allowable stress and factor of safety.
- Foundation - Determine dead and live loads and design footprint pressure. Perform a drilled shaft foundation analysis for a caisson that penetrates three soil layers with different thicknesses and coefficients of friction.
- HVAC/Mechanical Systems – Determine the number and size of various components of a distributed HVAC system including as air handling fans, heaters and air conditioners given the loading and the characteristics of the individual system components.

Walnut Street Bridge

The first lecture was by a professional engineer involved with the initial design of the bridge and its approach viaducts in the mid 1980's. He presented an overview of the project including the constraints imposed by replacing an existing structure in a physically limited urban environment, utilities, and the reuse of existing components such as piers and abutments. The bridge and approaches span the Schuylkill River, I-76 (the Schuylkill Expressway) and AMTRAK's northeast corridor tracks and is crossed overhead by a major north-south rail freight line. While

Walnut Street was closed to traffic during construction, access to buildings along and at the level beneath the viaduct had to be maintained; also AMTRAK and I-76 traffic could not be interrupted. Subsequent lectures by faculty dealt with transportation issues and the constraints imposed by building within an existing right of way and how only limited improvements in traffic flow could be attained. Faculty lectures also addressed the structural aspects of the bridge and its approaches including moment diagrams for the three-span continuous portion over the river, the locations of bolted connections near points of zero moment and thermal expansion of the deck for typical temperature ranges in the Philadelphia area. Bridge foundation conditions were discussed and a general lecture on hydrology and hydraulics used the bridge's drainage system and the Schuylkill River to describe open channel flow (Manning's equation). Historical flood data was used to derive the 100-year flood for the Schuylkill River. The last lecture in the series was by the engineer/contractor who built the bridge. He discussed problems that had to be solved to construct the bridge including the safe removal of the existing river span, providing access to adjacent buildings and maintaining AMTRAK's rail traffic. The contractor undertook a major cost-reducing redesign effort that increased the span lengths of the approach viaducts and substituted prestressed concrete for steel. The study culminated in a walk of the finished project from 32nd Street across the river and beneath the river span. Characteristics of the bridge discussed during the lectures were pointed out. The inspection of two other nearby Schuylkill River bridges during the field trip, at Chestnut and Market Streets, provided another opportunity to discuss elements of bridge engineering.

Assignments

- Traffic Analysis – Conduct a traffic count of autos, trucks, bicycles and pedestrians. Calculate capacity of lanes and highway based on physical constraints. Determine level of service possible.
- Hydraulics and Hydrology – Determine roadway elevations given the centerline elevation and side slopes. Calculate the flow handled by a bridge scupper given the contributing area. Determine the discharge in a gutter given the slope and type of surface for storms having various durations and return periods. Using historical annual flood data for the Schuylkill River obtained online, determine the 50- and 100-year flood discharges at Walnut Street.
- Foundation Engineering – Read an article on the World Trade Center “bathtub” and answer questions about the slurry wall and its performance in the September 11th terrorist attack.
- Structural – calculate the thermal expansion of three-spans for various bearing conditions and fixed bearing locations for a 100°F temperature change, e.g., a fixed pin at various locations on a three-span continuous structure, and a three-span continuous structure v. three individual spans. Calculate the flange area required for a beam in a three-span-continuous structure v. a structure with three individual spans.

Philadelphia Water Department's (PWD's) Sodium Hypochlorite Storage and Feed System

This case study described retrofitting of an existing building at the PWD's Belmont Water Treatment Plant to store and feed sodium hypochlorite to replace liquefied gaseous chlorine as a disinfectant. A description of the project to modify the building structure as well as the chemical storage and feed systems was provided by the PWD's consulting engineer. This lecture included the safety and security issues that prompted the replacement of chlorine with sodium hypochlorite. Subsequent lectures by faculty provided an overview of water treatment processes

as well as general environmental engineering issues. A site visit to the Belmont Plant followed the lectures. Students toured the plant in the company of a PWD engineer familiar with it. In addition to the chemical storage and feed building, the tour included the flocculation tanks, the flocculent dosing system and the rapid sand filters. The PWD engineer was also familiar with a pilot plant (also housed at the Belmont Plant) used to investigate the change from chlorine to sodium hypochlorite.

Assignment

- Determine the maximum daily demand for an 800 acre residential development with 3 homes per acre and a 1000 gpm fire flow. Determine the peak hourly demand. Find the total water demand for a city block with given commercial, industrial, business and residential development. Answer several questions about water treatment processes. Estimate the amount of chlorine needed to treat a given volume of water per day with specified combined and free residuals.

Penn Alexander Elementary School

In its third offering, emphasis was made to balance the course content to include all three of the department's majors. The civil and architectural engineering portions were reduced to four weeks each and a two-week environmental component was added. The environmental faculty decided to focus on water-related issues, making the choice of the nearby Penn-Alexander public elementary school an excellent resource (the Race Street dormitory was replaced by a new research tower at Children's Hospital of Philadelphia). With the cooperation of the school, the Philadelphia Water Department (PWD) and the Environmental Protection Agency (EPA) students developed the skills in class to perform a water-budget laboratory assignment using Penn-Alexander as its basis. General issues of managing urban stormwater runoff were discussed and then specifically related to the design and construction of the Penn-Alexander school. Students walked to the school where they heard presentations by representatives of the PWD and EPA on three innovative storm water management systems put in place at the school: a gravel stormwater retention area under an athletic field, a rain-garden using native plants, and a porous-asphalt parking lot. In addition they heard presentations from Penn-Alexander elementary school students who were just completing a term project on the water cycle.

Assignment

- Develop an EXCEL-based water budget using modified Penn Alexander data. Show that runoff from the school site into Philadelphia's combined-sewer system is essentially eliminated by the stormwater management innovations implemented at the school.

Table 1 Typical Schedule for CAEE201

Week 1 Course Introduction and Professional Issues

- Introduction – elements of infrastructure projects
- The engineering profession – professional societies, ethics and licensure
- Preparation for the engineer interview
- Introduction to “Sketch up” and drawing practice

Week 2 – Race Street Residence Hall

- Overview of project by Drexel University's Architect
- Architectural issues – aesthetics, space and other general issues
- Sketch up practice continued – place structure on real site

Week 3 – Race Street Residence Hall (continued)

- Site development, regulation, permits (what, why and who?)
- Site characterization - utilities, environmental impact, grading & drainage
- Calculation lab

Week 4 – Race Street Residence Hall (continued)

- Building interior environment – HVAC, indoor environmental concerns
- HVAC calculation lab
- Students interview a practicing engineer in the workplace

Week 5 – Race Street Residence Hall (continued)

- Site and building drainage – fundamentals of hydrology and hydraulics, runoff calculations
- Building foundation including calculation lab
- Building structure including calculation lab (based on what students know from freshman physics courses)

Week 6 – Race Street Residence Hall (continued)

- Construction, project management, scheduling
- Construction site visit (two groups on two separate days)

Week 7 – Walnut Street Bridge & Viaducts

- Overview of project by structural design engineer
- Transportation/traffic issues
- Highway capacity and design laboratory

Week 8 – Walnut Street Bridge & Viaducts (continued)

- Hydrology and bridge drainage – general introductory lecture on hydrology
- Schuylkill River flood flows
- Calculations lab – Bridge drainage and 100-year flood for Schuylkill River

Weeks 9 & 10– Walnut Street Bridge & Viaducts (continued)

- Construction safety presentation
- Bridge foundation presentation
- Bridge structure presentation
- Foundation and structural calculations – girder flange sizing for given moment, thermal expansion, support options (simple spans v. 3-span continuous)

Week 11 – Walnut Street Bridge & Course Wrap-up

- Presentation on construction of the Walnut Street Bridge by engineer/construction contractor
- Walnut Street Bridge and viaducts site visit
- Students attend and evaluate senior design presentations
- Course evaluation exercise

Student Feedback

Student feedback was obtained by, (1) a questionnaire distributed in class for which the students were awarded points toward their final grade and (2) anonymously, on line, using Drexel's College of Engineering's course evaluation system. For the in-class questionnaire, students were given the course objectives and asked if those objectives had been met and, if not, which had not been met. They were asked what they liked and disliked about CAEE201 and what might be eliminated from the course. Specific recommendations for improvements were solicited. Most

comments were favorable; however, several students commented on the dearth of environmental content in the first offering of the course. This prompted the inclusion of the Belmont Treatment Plant sodium hypochlorite facility in the second offering. Others requested that discussion of the three curricula be expanded which just happened to be on the course schedule for the period following solicitation of course evaluations. Also, throughout the course students are required to write weekly logs recording and commenting on the activities of the week. They are also encouraged to ask questions and make suggestions. These log comments were quite valuable to the instructors in identifying areas requiring clarification as well as student response to the elements of the class. While most were quite positive, some valuable mid-course corrections were made as a result of the ongoing feedback.

Engineering Measurements I (CAEE210)

CAEE210 introduces students to the various technical specialties within civil, architectural and environmental engineering through hands-on experience of conducting field and laboratory measurements typical of the various specialties. The course emphasizes the graphical presentation of data using EXCEL, SKETCHUP and other software. Students make several trips into the field or laboratory to collect data. Topics include: the visual display of quantitative data, structural engineering, construction materials, geotechnical engineering, hydraulics and hydrology, environmental engineering and architectural engineering.

The introduction to the profession is continued in CAEE210 by introducing students to field and laboratory measurements in the three disciplines. Following introductory lectures on the presentation of quantitative information and on the required format for the field/laboratory observations, department faculty give two lectures preliminary to a field or laboratory experiment. The lectures include the technical background for the experiment, the instruments and principals of their operation, a description of the experiment itself and the report requirements. Because in most cases students have not yet had a course in which the field measurements and experiments would be presented, the lectures are basic and tutorial in nature. Experiments have included water quality measurements around campus and in the Schuylkill River, sieve analyses of soils, stress-strain characteristics of various materials including metals and plastics, the behavior of model structures, viscosity measurements and the transition from laminar to turbulent flow.

Course Objectives

- Introduce to the students the various sub-disciplines in civil, architectural and environmental engineering
- Introduce to students the various types of measurements that civil, architectural and environmental engineers must make as part of the design process.
- Encourage student interaction and team work in the environment of engineering practice and sharpen student skills in observation and measurement techniques.
- Organize data collection efforts, analyze and present data in a logical, clear and systematic way, and to communicate that information in memoranda and laboratory reports.
- Identify the types and sources of errors in measurements and establish quality assurance methods.

CAEE210 Course Content

CAEE210 like CAEE201 is a 3 credit course with two hours lecture and two hours of laboratory or field measurements. CAEE210 has been offered twice, first during the Winter Quarter of 2007 and again during the Summer Quarter of 2007. At the time of this writing it is being offered for the third time. Like CAEE201, CAEE210 involves a number of department faculty drawn from the various areas of civil, architectural and environmental engineering; thus, like CAEE201, introducing department faculty to the student is an objective of this course as is introducing students to the work of the various disciplines. The course involves eight field and/or laboratory experiences preceded by an introductory lecture on the analysis and presentation of quantitative data. A report format in EXCEL which outlines objectives and procedures and poses questions the students must answer is provided for each laboratory. The form includes a cover sheet indicating the point value for each part of the report that is used by the TA for reporting the report grade to the student. Some data is collected by the students working on teams, other data is collected by the class as a whole. While students are encouraged to discuss their findings, all reports are to be the work of the individual student. Some of the experiments were taken from the courses students take later in their academic careers thus freeing up time in those later courses for more advanced work. Other experiments were new and unique to CAEE210. The content of the various laboratory/field experiment is described below.

- Environmental Engineering Laboratory 1 – Calibrate a multi-purpose instrument used to measure temperature, specific conductance, pH, dissolved oxygen, redox potential, turbidity, salinity and total dissolved solids using standards with known characteristics.
- Environmental Engineering Laboratory 2 – Obtain water samples from various locations around campus and use the multi-purpose instrument calibrated during the preceding week to determine the various water characteristics. Discuss the interdependence of the measured parameters such as pH and conductivity dependence on temperature. (The Schuylkill River was the water source used by one class; however, a second class was unable to sample the river because of weather.)
- Architectural Engineering Laboratory 1 – For a student-selected space on campus, determine that space's dimensions, temperature and humidity using a "tool box" of equipment provided to a team of two students. (Instruments to measure the space's dimensions include: a laser tape, acoustic tape and regular tape measure. Temperature and humidity were measured with a digital hygrometer-thermometer combination.) Determine the floor and wall areas of a room and sketch elevations showing the locations of doors, windows, wall outlets, heating ducts, etc. In three separate rooms determine the maximum, minimum and average temperatures. Determine the "comfort level" of each space.
- Architectural Engineering Laboratory 2 – Determine the sound level variation in a space over a period of 10 minutes. Measure the light level variation in a space and show the results graphically. Measure electrical voltage at 3 locations and the power consumption of a light fixture or appliance.
- Geotechnical Engineering Laboratory – Determine the bulk density and porosity of a sand and describe how one would use these data. Perform a grain size analysis and determine the D_{50} . Calculate the coefficient of uniformity. Observe a demonstration of soil liquefaction and learn the soil characteristics that are conducive to liquefaction.

- Hydraulics Laboratory – Plot the dynamic and kinematic viscosities of water as a function of temperature. Determine and plot the value of the water’s density as a function of temperature using the viscosities to determine density. Using a Gilmore falling sphere viscometer, determine the kinematic viscosity of water at several different temperatures. Compare their measured values with the published values. Using the Reynolds’ apparatus, determine the value of the Reynolds number at the onset of turbulence for an increasing flow velocity. For a decreasing flow velocity, determine when the flow again becomes laminar.
- Engineering Materials Laboratory – What is the force needed to fracture a concrete cylinder when it is loaded axially; when it is loaded laterally? What is the compressive stress? Determine the density of various plastics. Plot the stress-strain curve for aluminum from given data and determine Young’s modulus, maximum tensile stress and strain and the true stress and strain at failure. Determine the tensile properties of high density polyethylene.
- Structural Engineering Laboratory – Design and construct a K’nex bridge truss and determine its “cost.” Sketch the truss and label its joints and members. Compare your “cost” with the cost of other designs in the class. Determine the deflections of the truss under various loads and report any beam and/or connection failures. Compare student designed trusses with “standard” truss types.

Table 2 Typical Schedule for CAEE210

Week 1 - Visual Display of Quantitative Data –

- Course introduction and organization
- Presentation on display of quantitative data
- Formulation of standard laboratory report format using EXCEL – template to be used for all experiments/field data collection exercises.

Weeks 2 & 3 - Environmental Engineering

- Overview of environmental engineering
- General presentation on water quality
- Laboratory
 - calibration of multipurpose meter
 - measure water quality at various locations on campus and in Schuylkill River
 - present and discuss results

Weeks 4 & 5 Architectural Engineering

- Role of Measurements in AE
- Phases of Building Life: Programming, Design, Construction, Occupancy, Operation, Renovation, Demolition
- Building Elements
 - HVAC – Comfort variables
 - Electrical, Lighting,
 - Plumbing
 - Acoustics
 - Transportation

- Instruments and their limitations
- Building Design: components, validation of post-construction conditions
- Laboratories
 - Dimensions & HVAC
 - Lighting, Power, Acoustics

Week 6 - Hydraulics/Hydrology

- Presentation on properties of water, e.g. density, unit weight, and viscosity
- Presentation on laminar and turbulent flows and the transition Reynolds number.
- Laboratory
 - Measure viscosity using Gilmore viscometer.
 - Determine Reynolds number for transition from laminar to turbulent flow.

Week 7 - Geotechnical Engineering

- Presentations: General introduction to soil mechanics and soil properties
- Laboratory
 - Demonstration of soil liquefaction
 - Determine bulk density and porosity of sand
 - Perform sieve analysis and report D50 and coefficient of uniformity

Week 8 - Materials of Construction

- Introduction to construction materials and applications
 - Conventional construction materials
 - New construction materials
- Material properties: physical, chemical and mechanical.
- Mechanical properties of brittle, plastic and elastic materials
 - Define load, deformation, stress and strain in tensile, compression and flexural tests
 - Define engineering stress and strain and true stress and strain
 - Differences in stress/strain curve among the three types of materials and their characteristic parameters
- Laboratory
 - Demonstration of concrete compressive strength
 - Tensile properties of aluminum
 - Tensile properties of high density polyethylene

Week 9 - Structural Engineering

- Types of structures, e.g., buildings, bridges, towers, etc.
- Elements/components of structures, e.g., nomenclature, beams, stringers, floor and deck systems, connections, etc.
- Bridge structures, trusses, etc.
- Laboratory
 - Construction and testing of K' nex truss.

Week 10 Course Wrap-up

- Students attend and evaluate several senior design presentations.
- Students evaluate course

Student Feedback

As with CAEE201 student feedback was solicited in class by a questionnaire and anonymously on-line using the College of Engineering system. In the in-class questionnaire students were asked for an overall evaluation of the course including their suggestions for improving it. For each individual laboratory component students were asked what they liked, what they disliked and how each laboratory component could be improved. These comments were provided to faculty delivering each of the course components and led to improvements in the second offering. In general, students complained about the large size of the laboratory sections and the inability of some to participate directly in obtaining data. Others expressed a desire for more field experiments rather than indoor lab experiments. Others suggested that the course be taught in the fall and spring to avoid the possibility of inclement winter weather for the field experiment. Students also made constructive comments to improve the laboratory; for example, they suggested clarifying the instructions on some of the laboratory templates.

Conclusion

Lectures and assignment preparation in the two courses are distributed among the number of participating faculty; however, the two courses are administratively demanding. The project coordinator must plan and work in the weeks leading up to the course and throughout its delivery. For this reason it would be easy for the courses to degenerate into a series of unrelated lectures. In addition to the occasional lecture, the project coordinator needs to recruit and schedule lecturers and coordinate lectures to assure topic coverage and continuity. Also, the laboratory-intensive nature of CAEE210 and the breadth of its content make the assignment of appropriate teaching assistants difficult. The use of outside speakers also has its perils since last minute changes in their schedules often overrides their appearance in class. Needless to say, contingency lectures and/or speakers should be available.

The commitment of individual faculty in both CAEE201 and CAEE210 generally amounts to two lectures and the oversight of a two-hour laboratory during one week of the 10-week term. The laboratory in CAEE201 is mostly computational in nature and is usually overseen by the faculty member. The laboratory in CAEE210 is usually taught by a teaching assistant.

One of the challenges is having faculty recognize that the sophomores in these courses lack the technical experience that faculty usually encounter in the upper level courses they usually teach. For example, while the students have had mechanics in their freshman physics courses, those courses have not been taught from an engineering perspective. Faculty need to recognize that they must bridge the gap between the science-based courses of the students' experience and the engineering applications of that science.

Student feedback on the two courses has been consistently very positive. Feedback was solicited through voluntary questionnaires (for extra credit) as part of a final exercise and, anonymously, by on-line course evaluations. For the on-line evaluations students provide numerical ratings of the course and faculty as well as their understanding of the course material before and after having completed the course. Based on comments received from both of these sources, the students (as well as the instructors) believe that the course objectives have been met. The

courses have been very popular with students. They particularly like the opportunity to talk with design engineers about specific projects and visit construction sites. They also enjoy the opportunity to get into the laboratory and field to collect data. Students also have been very positive about how the courses clarify the goals, scope and specifics of their chosen major – a major that they often only vaguely understood on entering the university. In addition, the courses address a number of the ABET (a) through (k) outcomes; the outcomes specifically addressed include:

- a. Apply knowledge of mathematics, science and engineering
- b. Design and conduct experiments, as well as analyze and interpret data
- d. Function on a multi-disciplinary team
- f. Understand professional and ethical responsibility
- g. Communicate effectively, and
- k. Use the techniques, skills and modern engineering tools necessary for engineering practice