Linking Courses and Essential Experiences in an Undergraduate Environmental Engineering Curriculum

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Abstract

Many undergraduate engineering curricula develop introductory level knowledge of common engineering processes by using highly constrained problems, which call for a single "right" answer. This teaching approach meets the intent of providing the student with a basic level of understanding in the discipline. Environmental engineers as well as engineers in other disciplines, however, apply their skills in a dynamic environment where single solutions are the exception rather than the rule. A static approach to problem solving cannot fulfill the curriculum goal specified in most ABET accredited programs. Additional "significant experiences" are required to help students develop a holistic appreciation for professional practice issues and to prepare them for the workplace. Such experiences should relate course material to professional practice; be commensurate with a student's skill level according to their progression through a curriculum; and should be perceived by students as reinforcing rather than redundant. Examples of such experiences include field trips, hands-on laboratory exercises, modeling, technical designs, experimental designs, independent laboratory research projects, and research papers. This paper links the U.S. Military Academy Environmental Engineering curriculum, ABET outcomes a-k, and ABET Environmental Engineering Program Criteria to selected noteworthy experiences. Assessment results are presented, which attempt to evaluate the effectiveness of significant experiences. The drawbacks associated with omission of several desired experiences from the curriculum are also addressed.

Introduction

Besides providing a discipline-specific undergraduate education, the United States Military Academy's primary mission is "to educate, train, and inspire the Corps of Cadets so that each graduate is a commissioned leader of character committed to the values of Duty, Honor, Country; professional growth throughout a career as an officer in the United States Army; and a lifetime of selfless service to the Nation." In support of this mission, the overarching goal of the academic program is "to enable its graduates to anticipate and to respond effectively to the uncertainties of a changing technological, social, political, and economic world." The engineering programs at West Point emphasize the technological component of this goal. Graduates are expected to be able, among other skills, to define and then creatively design technological alternatives to complex problems – ultimately selecting a solution that is both effective and adaptable.

A static, constrained approach to teaching environmental engineering neither fulfills the Academy mission nor the academic program goals. Not only should the program equip a student with a basic foundation in the environmental engineering discipline, it must also provide a basic foundation of "experience" to assist in preparing a student for the application and synthesis of engineering in the field. Courses in a curriculum should include these "essential experiences." Many undergraduate engineering curricula develop introductory level knowledge of common engineering processes by using highly constrained problems with a single "right" answer. This teaching approach meets the intent of providing the student with a basic level of understanding in the discipline.[1] Environmental engineers as well as engineers in other engineering disciplines, however, apply their skills in a dynamic environment where single solutions are the exception rather than the rule. A static approach to problem solving cannot fulfill the curriculum goal specified in most ABET accredited programs. Additional "significant experiences" are required to help students develop a holistic appreciation for professional practice issues and to prepare them for the workplace.[2] Such experiences should relate course material to professional practice, be commensurate with a student's skill level according to their progression through a curriculum, and should be perceived by students as reinforcing rather than redundant. Examples of such experiences include field trips, hands-on laboratory exercises, field sampling, modeling, technical designs, experimental designs, independent laboratory research projects and research papers.

This paper links the U.S. Military Academy (USMA) Environmental Engineering Program curriculum, USMA Environmental Engineering Program Outcomes (based on ABET outcomes a-k), and ABET Environmental Engineering Program Criteria to selected noteworthy experiences. The focus of the discussion will be on the curriculum for the classes of 1999-2003, for which significant assessment data exist. Selected changes resulting from this assessment (being implemented for the class of 2005) will also be addressed.

Significant Experiences and the USMA Environmental Engineering Curriculum

Figure 1 depicts linkages between courses taught in the USMA Environmental Engineering Program, significant experiences in the curriculum, and program outcomes. Students also take engineering courses outside of the department and a 26 course core curriculum for a total of 43 courses. Because significant experiences in some courses, e.g. design projects, change periodically, the program outcomes supported by a particular course via significant experiences may change as well. Linkages illustrated in Figure 1 represent support over the past four years. Although several of the courses taken by Environmental Engineering majors outside of our department have significant experiences, these experiences have been omitted from the discussion because they are assessed elsewhere. Significant experiences within the USMA Environmental Engineering Program are discussed below.

PROGRAM OUTCOMES

		Guest Speaker	Field Trips	Hands on Labs	Design of an Experiment	Application of Modeling	Significant Technical Design	Design and Construct
I	Mathematics and Science			x	x	x	x	x
II	Physical and Chemical Processes	x	x	x	x	x	x	x
III	Biochemical Processes	x	x	x	x	x	x	x
IV	Problem Solving				x	x	x	x
V	Engineering Solutions under Austere Conditions	x					x	
VI	Experimental Design, Execution, and Analysis			x	x			
VII	Written and Oral Communication			x	x	x	x	x
VIII	Environmental Responsibility	x	x				x	

Term	COURSES / **Significant Experience**	Guest Speaker	Field Trips	Hands on Labs	Design of an Experiment	Application of Modeling	Significant Technical Design	Design and Construct
5	*(EV301) Environmental Science [Fall]*	x	x		x			
6	(EV388A) Physical Geology [Spring]	x	x	x		x		
6	*(EV389H) Meteorology and Air Pollution*	x	x					
6	(EV401) Env Systems Analysis & Design I [Spring]	x	x	x			x	x
7	(EV394) Hydrogeology [Fall]	x	x	x		x		
7	(EV402) Env Systems Analysis & Design II [Fall]	x	x	x		x	x	
7	(EV481) Water Resources [Spring]	x	x				x	
8	(EV488) Solid & Hazardous Wastes [Spring]	x	x				x	
8	(EV490) Advanced Environmental Design [Spring]	x	x		x		x	

Figure 1. Linkages between Environmental Engineering Courses, significant experiences in the curriculum and program outcomes. Italicized courses are new for the class of 2005.

Guest Lectures and Field Trips

One of the eight USMA Environmental Engineering Program Outcomes states that graduates will have an appreciation for environmental sensitivity (feeling concern for and acting to conserve the environment).[3] In addition, the ABET Environmental Engineering Program Criteria state that a program must demonstrate that graduates have knowledge of the roles and responsibilities of public institutions as well as private organizations in environmental management. One approach for addressing these outcomes and criteria is to include guest lectures and field trips in a curriculum.[4] A wide variety of guest speakers from the Army, regulatory agencies and private consulting firms make presentations in our courses each semester (Table 1).

Table 1. Environmental Engineering Program Guest Speakers 2001-2002.

Name of Speaker	Organization	Topic of lecture	Course
Mr. Rich	Adams LLC	Contaminant transport/	Groundwater

Adams		practice of environmental engineering	
Mr. Pat Hughes	Chevron	Groundwater contamination	Groundwater
Ms. Amy Jennes	Army Preventive Medicine (CHPPM)	Atmospheric dispersion	Air Pollution
Mr. Jeff Grow	CHPPM	Air quality monitoring	Air Pollution
Mr. Ray Wuertz	Bayway Refinery	Air pollution & operations	Air Pollution
Mr. Mike Conley	Lockheed Martin	Satellite meteorology	Air Pollution
COL Stan Lillie	US Army Environmental Center	Role of USAEC in the Army's Environmental Program	Physical and chemical treatment
Mr. Christian S. Miller, P.E.	Desalcott (Desalinization Company of Trinidad and Tobago, Limited)	Desalinization of seawater using reverse osmosis	Physical and chemical treatment
CPT R. Cowher / SFC J. Brown	U.S. Army Quartermaster Officer/NCO	Water production/distribution during contingency operations	Physical and chemical treatment
Dr. Glen Daigger Senior Vice President	CH2M Hill	The wastewater treatment plant of the future	Biochemical treatment
Dr. Gerry Galloway	International Joint Commission on the Great Lakes	Water-sharing	Water resources
Mr. Robert Adamski	Dept. of Environmental Protection, City of New York	NYC watershed protection plan	Water resources
Mr. Pat Hughes	Chevron	Bioremediation	Solid and hazardous waste
LTC Glen Dewillie	US Army Corps of Engineers Buffalo, NY	Nuclear waste clean-up	Solid and hazardous waste
COL John O'Dowd	US Army Corps of Engineers NY, NY	The Corps' role in the clean up of the WTC in NYC	Adv. Environmental Process Design
LTC George Marquart	Dept. of Defense	Professional aspects of environmental engineering	Adv. Environmental

			Design
Ms. Hanna Uusitalo	Former Finnish Exchange Student	Waste management for peace keeping operations	Adv. Environmental Design

The specific guest lecturers in some courses vary each academic year, however, the total number of guest lectures per year is typically about 15. Student assessment of guest lectures has resulted in mixed responses. We have learned that first-time guest speakers can sometimes deliver guest lectures that are not fully appreciated at the undergraduate level.

Students also take field trips in many courses, which introduce them to private and public environmental organizations. Table 2 lists field trips taken during the 2001 and 2002 academic years.

Table 2. Environmental Engineering Program Field Trips 2001-2002.

Organization	**Location**	**Purpose of trip**	**Course**
Tilcon Inc.	Haverstraw, NY	Local quarrying	Physical Geology
Instructor led	Road cuts west of USMA	Local geology and land use	Physical Geology
Bayway Refinery	Newark, NJ	Air pollution control at the refinery	Air Pollution
USMA Water Treatment Plant	West Point, NY	Tour a package plant that features tube settlers and a static mixer	Physical and Chemical Treatment
Anheuser-Busch	Newark, NJ	Industrial application of WWTP (anaerobic digestion)	Biochemical Teatment
Diamond Alkali	Newark, NJ	Superfund clean-up	Groundwater
Orange County and Al Turi Landfills	Goshen, NY	Landfill facilities	Solid and Hazardous Waste
Blenheim-Gilboa Facility	New York Power Authority	Pump storage facility	Water Resources
Hazen and Sawyer	NY City, NY	Visit a consulting firm	Adv. Environmental Design
Millwood WTP	Millwood, NY	DAF and ozone DWTP	Adv. Environmental Design

During the 1999 academic year, student assessment of trips indicated that some redundancy existed with several different courses visiting the same USMA water and wastewater treatment plants. While some students relished the opportunity to build on what they learned during the first trip, most wished to visit a new facility. Thus, these redundancies were eliminated. A significant drawback to field trips at USMA is that they occur during the academic day, which requires students to miss other classes. Consequently, field trips in each course are assessed to ensure that sufficient value is added to justify missing other classes.

At many institutions, extended field trip or other enrichment experiences are characteristically pursued during the summer months. These opportunities are limited at USMA because our students are heavily engaged in military training during the summer. One exception, however, is our Geology Field Course, a three-week long three-credit course conducted during the summer academic term. Geologic concepts are presented in a classroom setting and supplemented with laboratory exercises. The majority of the course, however, is conducted at geologic sites in the field where concepts are illustrated and expanded. This course is highly sought after by the students because it provides the opportunity to study field geology in one of the best classrooms available, the Rocky Mountains of Colorado. Extended field trips throughout southern and northern Colorado are conducted; field study sites include Garden of the Gods, Great Sand Dunes National Monument, the Black Canyon of the Gunnison, and Rocky Mountain National Park. These field experiences make this course uniquely different from traditional classroom-centered geology courses. The students are exposed to diverse landscapes ranging from the alpine tundra to aeolian deserts. They observe modern environmental safety processes at an active gold mine, tour a Superfund Site with a water treatment facility responsible for treating highly acidic water draining from abandoned underground mines, and produce their own geologic map and interpretation of Garden of the Gods. The range of opportunities provided by the field course challenges the students by exposing them to the complexity of modern environmental issues while greatly enhancing student appreciation and understanding of the forces that shape our fragile Planet Earth.

Our extensive speaker and field trip programs augment our classroom experiences. The overall assessment of this aspect of the program is that these activities enhance our graduates appreciation for environmental sensitivity and knowledge of public institutions and private organizations in environmental management.

Labs

Many of the critical thinking skills described in Blooms taxonomy can be accomplished via laboratory experiences.[5,6] Indeed, ABET accredited programs are required to include lab experiences. The objectives of lab experiences include:[5,7] instrumentation, experiment, data analysis, design, learning from failure, creativity, communications, teamwork, and ethics. One of the eight USMA Environmental Engineering Program Outcomes states that graduates will develop the skills necessary to plan, design, execute, and critically interpret results from experiments. Students in the USMA Environmental Engineering Program have lab experiences in many courses in the curriculum. These iterative and comprehensive laboratory experiences foster sound skills and knowledge in this area.

For example, in Physical Geology students work in pairs completing ten scheduled labs. These labs provide hands-on practice identifying minerals and rocks and creating student flow-charts to distinguish one from another on the basis of physical properties. Later labs have students interpreting geologic maps to decode the geologic history of different regions of the world. These labs also give students practice drawing cross-sections based on map-views, a skill which greatly enhances their ability to visualize in three dimensions.

The Hydrogeology course includes seven labs that utilize sieves, Darcy columns, a rain table, and groundwater physical models to study various media properties of groundwater and contaminant flow. Topics covered include soil classification, hydraulic conductivity, aquifer properties, energy gradients, and dispersion. These labs not only provide students experimental hands-on experience involving math and science principles, they also reinforce cause and effect relationships that strengthen a student's problem recognition and solving capabilities. Equipment availability and small class sizes ensure every student's active participation.

The students also took an introductory environmental engineering course that included basic water quality, jar testing, BOD, and microbiology labs. As part of the curricular restructuring, this course has been deleted from the curriculum for the class of 2005. Consequently, these labs have been added into other courses. The influence of this change on these courses is addressed below.

Design of an Experiment

As part of our curriculum revision, an Environmental Science course has been added to the Environmental Engineering curriculum. Taken in the fifth semester, this course introduces students to the scientific method. The course's term project requires the students, working in four-person teams, to develop an original hypothesis regarding some aspect of an environmental issue at USMA. The students then design a data collection protocol that will allow them to test their hypothesis. They collect data following their protocol, present the collected data in tabular or graphical form, analyze and interpret their results, and formulate a new hypothesis based on what they have discovered. The emphasis of this project is not on the correctness of the original hypothesis or even on the results themselves; rather the emphasis is on the skill required to design a useful, testable hypothesis and on discovering the iterative nature of the scientific method.

These introductory skills are further developed in Advanced Environmental Design, a course taken in the eighth semester. In this course, students design and conduct experiments to test a process or product. For example, as part of a larger research project[8] students in the class of 2001 and 2002 evaluated individual drinking water treatment (backpacker and small home appliance) devices. To accomplish this task, students prescribed a challenge water based upon the potential use of the devices for Army soldiers under austere conditions. They then developed an experimental procedure for testing their device. Their constraints as they designed the laboratory evaluation included their resources (i.e., time, people, instrument and equipment availability) and safety as they considered evaluating multiple contaminants across the physical, chemical (organic and inorganic), and microbiological realms. The student teams analyzed the data and prepared a laboratory evaluation report of their findings.

Application of Models

Students in Physical Geology are introduced to a computer program, Drillbit, which simulates three dimensional geology.[9] Students, working in pairs, are provided with a geologic map of an unknown region and a brief geologic history of the area. Given only this surface geology, students use the program to simulate drilling beneath the surface. They must plan their drill sites carefully, however, as drilling is expensive and they are required to stay within a fixed budget. Ultimately, they drill to construct cross-sections of the region and to locate a granite pluton of sufficient dimensions to construct a potential nuclear waste repository. The program has an infinite number of different student models, so each pair of students works on a unique geologic site. In end-of-course critiques, students routinely comment that this project required them to integrate all the material in the course and to think critically and creatively to solve the problem.

The Hydrogeology course utilizes MODFLOW and MODPATH, two models included in the Department of Defense Groundwater Modeling System (GMS) developed by the Environmental Modeling Research Laboratory of Brigham Young University. These software models are applied in two labs and in the course end design project. The project involves landfill siting and leachate contaminant capture requirements to protect a town's potable groundwater well. Students use the GMS package to model an aquifer with several pumping wells and a proposed landfill site. Based upon model outputs, the students determine the suitability of the landfill site. They also propose an alternative site and propose a site for a pump and treat well in the event that the landfill is built on the original site and the aquifer is contaminated. The students then run the model several times to iteratively find a site for the pump and treat well that will adequately protect the town drinking water well from potential landfill leachate.

In the Biochemical treatment course, students are required to use a spreadsheet to design an aeration basin and secondary clarifier for an activated sludge wastewater treatment plant. In 2003, students were required to consider tradeoffs between increased cost and performance. An iterative approach was necessary to develop the optimum solution. Commercial software is being considered for use in future semesters.

Technical Design

A well-structured progression of design content is integrated throughout the USMA Environmental Engineering curriculum. The concept of engineering *design* is introduced to students in their engineering science courses, through the use of small design projects. These projects are relatively narrow in scope and simple in character. They serve to build student confidence and demonstrate practical applications of the engineering and science concepts students are learning in the classroom. In subsequent courses, the character of the design projects becomes progressively broader in scope, more complex, more ambiguous, and increasingly subject to real-world constraints. Students must adapt to incomplete or inadequate information and solve problems that have no single correct answer. This progression develops the engineering thought process, promotes creativity, helps students learn to respond comfortably to ambiguity, and facilitates their understanding of the broader societal context within which engineering solutions are developed. Throughout the design experience in the Environmental Engineering Program students must consider realistic constraints. Table 3 cross references design credit and selected realistic constraints considered in engineering design.

Table 3. Application of Realistic Constraints in the Environmental Engineering Design Experience AY01-02 (See Figure 1 for course names; √√√ Strong Support, √√ Moderate Support, √ Modest Support, and -- No Support).

Course	ED Credits	Constraints					
		Economic	Safety	Reliability	Aesthetics	Ethics	Social/ Impact
EV401	1.5	√	√	√√	√	√	
EV388A	1.0	√√√	√	√√		√	√√
EV394	1.0					√	√√
EV402	1.5	√		√√	√√	√	√√
EV481	2.0	√√√	√	√	√	√	√√√
EV488	2.0			√√	√	√√	√√√
EV490	2.5	√√√	√√√	√√		√	

During the junior year, the required design experiences provide for the application of each of the six mandated areas of realistic constraints/considerations. This experience is reinforced during the senior year. Of the six focus areas of realistic constraints (i.e. economics, safety, reliability, aesthetics, ethics, and social impact) assessment data indicate that safety is the least well covered. The core military experience, however, provides additional coverage of safety and risk management. In cumulative experience, students are exposed to applications of these six constraints in several venues.

The fundamental elements of engineering design (i.e. establishment of objectives and criteria, synthesis, analysis, construction, and testing and evaluation) are integrated throughout the environmental engineering curriculum. Table 5 summarizes the design experience as it relates to these fundamental elements.

Table 4. Application of Fundamental Elements in the Environmental Engineering Program (See Figure 1 for course names; √√√ Strong Support, √√ Moderate Support, √ Modest Support, and -- No Support).

Course	ED Credits	Elements				
		Establishment of Objectives & Criteria	Synthesis	Analysis	Construction	Testing & Evaluation
EV401	1.5	√√√	√√√	√√	√√√	√√√
EV388A	1.0	√	√√	√√√	--	--
EV394	1.0	√	√√	√√√	--	--
EV402	1.5	√√	√√√	√√	--	--
EV481	2.0	√√√	√√√		--	--
EV488	2.0	--	√√√	√√√	--	--
EV490	2.5	√√√	√√√	√√√	√√	√√

During the junior year, the required courses containing design experiences provide the students with numerous examples in which to apply the fundamental elements of engineering design with EV401 applying all of the fundamental elements of design to at least a modest degree. During the senior year the fundamental elements of engineering design are reinforced.

Key features of engineering design are integrated throughout the environmental engineering curriculum as summarized in Table 5.

Table 5. Features in Engineering Design in the Environmental Engineering Program (See Figure 1 for course names; √√√ Strong Support, √√ Moderate Support, √ Modest Support, and -- No Support).

Course	ED Credits	Features								
		Creativity	Open Ended Problems	Modern Design Theory	Scope and Specifica-tions	Alternative Solutions	Feasibility	Production	Concurrent Engineering	Detailed System Descriptions
EV401	1.5	√√√	√√	--	--	√	√√√	√√√	√√√	√√√
EV388A	1.0	√√√	√√√	--	--	√	√	--	--	√
EV394	1.0	√√	√√	--	--	√√	√	--	√	--
EV402	1.5	√	√	--	--	--	√√	--	√	√√
EV481	2.0	√√√	√√√	√	√√	√√√	√√	--	√√	√√
EV488	2.0	√√	√√	√√√	√	√√√	√√	--	√	√√√
EV490	2.5	√√	√√√	√√	√√	√√	√√	√√√	√	√√

Assessment data provided in Tables 3-5 indicate that design complexity is consistent with assigned ED credit and sequencing of the course. For example, EV490, the capstone design course, provides the most coverage, has the highest ED credit, and is offered during the eighth term. Selected design projects are addressed below.

Students in Water Resources work as members of a design team to develop solutions to specific water resource problems using information and techniques learned in the course. The design project requires students to contact governmental or private agencies; conduct a literature search; complete an annotated bibliography; develop a proposal; and complete a design proposal. The project serves as an outreach opportunity to local communities and it emphasizes the planning and design guidance set forth by NEPA. Student teams must develop viable alternatives to solve complex, real-world, water-related problems. Initially, the student teams are constrained by a lack of data and must coordinate with customers for further problem definition and data. Based on research of viable remediation techniques, economic analysis, social/cultural acceptability and impact on the environment, alternative solutions are developed. These solutions must include two structural and two nonstructural alternatives. Student teams develop criteria to analyze each alternative solution and then apply a Multi-Attribute Decision-making Model to determine the best alternative.

Students in Solid and Hazardous Waste Management are required to design solutions for the treatment, storage, and/or disposal of solid and hazardous wastes. By the time students encounter this course, they have learned and applied fundamental math, science, and environmental engineering principles to specific forms of pollutant remediation in the areas of drinking water, wastewater, and air pollution. Students are asked to synthesize this information in the evaluation of a complex problem with multiple solution alternatives.

Curriculum assessment provided by the Environmental Engineering Program Board of Advisors indicated that our curriculum needed more emphasis on risk. This concern was addressed, in part, by providing the students in Solid and Hazardous Waste Management with a risk-based design experience in 2003. For this design, students were required to include the use of the Mackay Level III Fugacity Model, Environmental Protection Agency's EPI Suite, and MODFLOW as discussed previously for the Hydrogeology course. The Mackay Level III Fugacity Model is a non-equilibrium steady state model that permits a user to predict fate, persistence, and concentration of a contaminant in various media (air, water, soil, sediment, biota, and suspended solids) given a release of this contaminant in a modeled environment (http://www.trentu.ca/cemc/models/L1L2L3.html). The EPA EPI (Estimation Program Interface) Suite is a compilation of ten estimation models interfaced together in a suite by EPA's Office of Pollution Prevention Toxics and Syracuse Research Corporation. A single data input provides users with estimates of physical, chemical, and environmental fate properties of the chosen compound (http://www.epa.gov/opptintr/exposure/docs/episuite.htm). Outputs from these models combined with worldwide web information databases (e.g., toxicological profiles by the Agency for Toxic Substances and Disease Registry and EPA's Integrated Risk Information System) permit developing spreadsheet models to evaluate exposure and risk assessment predictions. Risk assessment is integrated into the technical design where students predict dosage exposure from various pathways and routes, characterize this risk, and determine in which media and by what technique the hazard could be minimized. The design is tailored to identify the specific chemicals of concern and to devise alternatives that reduce exposure risk and are also economically, socially, and technically feasible. Program outcomes reinforced by these modeling tools include review of physical, chemical, and biological processes, problem solving, and communication using model outputs as the medium. Throughout the process the students receive feedback as they formulate an effective and adaptable solution moving from the current presented situation to the desired end state.

Students in Advanced Environmental Design are required to complete an open-ended capstone design project. Students establish objectives, synthesize available information, analyze alternatives, propose a design, and develop a testing and evaluation plan. Application of project management and previous course material is essential to successful project completion. In 2003, students were required to design a prototype reactor that is capable of providing multi-barrier water treatment to soldiers serving under austere conditions and protect them across a range of nuclear, biological, and chemical (NBC) contaminants. Design requirements included the use of UV light as a primary disinfectant, the power (including source, duration and intensity) required, the need for a residual disinfectant for water stored (e.g., in a canteen), and the packaging of all of the required technologies into a constrained package.[8]

Assessment of the design experiences suggested that students appreciated having multiple venues to apply the fundamental elements of design, design under constraint, and the opportunity to provide customers with achievable solutions to real world problems. Changes associated with the curriculum for the class of 2005, however, will result in less design emphasis in EV401 and EV402 to allow for additional hands-on laboratory experiences. Future assessment will be used to evaluate the influence of these changes on the design experience.

Design and Build

Design and build are valuable experiences that enhance an undergraduate education.[8,10,11] Evaluating the constructability of a design can be an important aspect of the hands-on experience.[11,12] Lack of consideration for constructability has been noted as a common shortcoming among engineering graduates.[12] In addition, real-world projects can be rewarding experiences for students.[8,13] By linking design projects in our introductory physicochemical treatment processes course (taken in the sixth semester) and our senior capstone design course (taken in the eighth semester), we have addressed these design considerations. For example, in 2001 students designed a surface water treatment bench scale model for the environmental engineering laboratory manager[11] and small scale reactors for UV disinfection systems for the Army in 2002 and 2003.[8] Students were required to communicate with their customers, an illustrator, and tradesmen, three forms of communications that are necessarily quite different from traditional student-professor exchanges. Students were required to design under resource constraints that included: time to complete the project, a limited budget to purchase materials and labor, availability of materials, and constructability. The students also designed an experiment to test the product, conducted the tests, and analyzed the results. These students continued working on the same designs as part of their senior design course. Because the students worked on projects in both their junior and senior years, there was both a reflective period and an iterative component to these projects which allowed the students to grow as fledgling engineers and advance their designs. The addition of labs to EV401 may result in the deletion of this experience. An overview of how this research project has been implemented into this multiphase learning model and lessons learned is reported elsewhere.[8,11]

Significant Experiences Omitted From Our Program

Other significant experiences exist that can broaden the "depth of experience" a student achieves with an undergraduate engineering program. Inclusion of these experiences is dependent on availability of time, resources, and connections with external activities. Assessment results indicated that Environmental Engineering majors should have additional hands-on laboratory experiences in biology, physicochemical processes, and biochemical processes. Curriculum changes are in place to increase these experiences at the expense of some design in the water and water-treatment classes. Lack of hands-on experiences in biology is addressed via a new Environmental Biological Processes course offered to the class of 2005. Because the Environmental Engineering curriculum also lacks a significant experience in field sampling, this course will include a field sampling lab. Environmental Engineering majors are not currently required to conduct a formal research project, e.g. conduct a literature-search and write a paper on an environmental topic. An approach for addressing this weakness has yet to be determined, however some students elect this experience as an independent study. Other significant experiences might include giving students an opportunity to work one shift with a water or wastewater plant operator or conduct a summer internship where a student works for several weeks in a private engineering firm. Students might also compete in an environmental organization design competition as part of a course or independent study.

Method of Assessment

Merely showing that concepts were covered in class is insufficient to demonstrate achievement of objectives.[5,14] Students perceptions and performance can be a more accurate measurement of objective attainment.[5] At the end of each semester, students at USMA complete an on-line course assessment survey for each course in which they were enrolled. Included in this survey are questions used to assess labs, guest lectures, and field trips. Specific questions are "The lab exercises in this course provided worthwhile hands on experience and supported the course learning objectives," "Guest lectures added a unique dimension to the course beyond that presented by my instructor or text," and "Field trip experiences enhanced my understanding of the course objectives and were appropriate for the course." Each question uses a five-point Likert scale ranking with the average visible for the individual course hour up to the program level. Freeform questions are used to assess other significant experiences. These student comments provide input on how students perceived the value of each of these experiences. Linkages between course experiences and the curriculum are tracked with course assessment plans and program assessment reports.[15]

Conclusions

Significant experiences are an important aspect of the USMA Environmental Engineering curriculum. They enhance the linkage between class work and the program outcomes. Assessment of these experiences has resulted in program improvements. Because assessment is on-going and the USMA Environmental Engineering Program is in a state of transition, changes in the curriculum that are being completed for the class of 2005 will influence several of the significant experiences described here.

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