AC 2012-4088: INTEGRATING INNOVATIVE PEDAGOGIES INTO ENGINEERING ECONOMICS COURSES

Dr. Naveen Seth, New Community College at CUNY

Naveen Seth is a founding faculty member in business at the City University of New York's New Community College. He has also taught at Pratt Institute in the Construction Management Program. At Vaughn College of Aeronautics and Technology, he headed the Aviation Management programs and also taught engineering economics in the B.S. program in engineering.

Prof. Donald P. O'Keefe, Farmingdale State College

Donald P. O'Keefe has 15 years experience teaching at the college level. He taught courses in engineering graphics, quality control, and project management.

Integrating Innovative Pedagogies into Engineering Economics Courses

Abstract

In this paper, we make a case for incorporating high-impact practices into the engineering economics classroom as a way to increase student engagement, learning and performance. Wherever possible, we tie proposals to our own experiences. In some cases, the practices we refer to are extant in the education literature, but not ones that we have tried as yet; however, we plan to examine them in upcoming semesters and, possibly, incorporate them into our own classrooms. We also indicate how several of these practices help meet the requirements of agencies that accredit engineering and business programs.

Introduction and Overview

Over the past few decades, there has been a push toward more student-centric teaching. This has included a more holistic approach to address learning in a broader sense, as well as to connect specialized and major courses to introductory, skills and general education courses. Additionally, there is recognition for providing contextual subject matter to enhance the meaning that students derive from concept-heavy and theoretical courses.

In this paper we examine the use of several innovative and high-impact pedagogies for use in Engineering Economics and related courses. As identified by Kuh[1] (2008), several of these practices have been in use for a while in many fields of education. We believe that their concentrated and focused use in courses such as engineering economics and project management would make for stronger and more effective teaching and learning and, consequently, for better student retention, graduation and placement rates. We propose integrating such practices directly or by adaptation into engineering economics courses.

These courses are common in Engineering, Engineering Management, Technology Management and Construction Management programs. These majors fall under the purview of engineering-based accreditation agencies, such as ABET (formerly the Accreditation Board for Engineering and Technology) as well as those that accredit business programs, such as the International Assembly for Collegiate Business Education (IACBE). We also point out how some of the teaching and learning practices we examine address the standards proposed by these accreditation organizations. These connections are summarized in the appendices at the end.

Contextualization

Purpose

In terms of building students' basic and higher-level skills, the relevance of what they are learning is crucial. Students will often ask why they need to learn an abstract mathematical technique or why a particular fact is meaningful.

Contextualized teaching and learning involves connecting classroom subject matter to real-world situations (Berns and Erickson[2], 2001). Garfunkel and Mumford[3] (2011) have written about this in relation to teaching math concepts. For courses in engineering economics, this involves both the engineering and economics aspects of a course being brought alive for students. There are various ways to provide this context and relevance. We examine some below, several of which we have used.

Examples

a. Current issues

We have found it useful to consciously reference current news events during lectures. For example, the events in the Euro zone area, developments in the Chinese economy and movements in US interest rates are all issues that can have a direct or indirect impact on projects being analyzed using the tools of engineering economics. In this vein, one of us makes it a practice to require students to make short low- stakes presentations on current issues related to the course. Not only does this push students to conduct some outside research, it also requires them to present it in class in a safe environment, building their confidence and presentation skills.

Instructors can construct written assignments that require students to conduct research tied to course topics in engineering economics or project management. For example, as project management topics, students of one of the authors have examined, analyzed and evaluated major current construction projects in New York City. These included the reconstruction at the World Trade Center site, the building of a new stadium in Brooklyn and the development of a subway line along Second Avenue on Manhattan's East Side. Besides providing a real-world framework for classroom concepts and building students' research and writing skills, such practices reinforce business related professional skills such as communication (as recommended by the IACBE[4], 2011).

A few semesters back, one of the authors used these ideas in one section as a project management assignment and gave more artificially constructed, abstract assignments to students in another section. The degree of student engagement and quality of assignments were markedly higher in the section where students were able to tie what they were learning in class to what was happening in the world outside. In other respects, the class requirements were identical—other assignments, exams etc.—and students fared equally well on those measures.

b. Ethical and professional responsibilities

Issues such as ethics in engineering businesses are best addressed through context; otherwise the subject essentially receives lip service. The conflict between quality product/process and cost effectiveness should be illustrated through examples of where this issue arose and was/was not addressed, e.g., costs of oil spills, externalities in production processes, social vs. out of pocket

costs. Ethics is becoming increasingly important in engineering and business courses and is a focus of ABET[5] (2011) accreditation as reflected in the associate-level Criterion 3Ah and bachelor-level Criterion 3Bi. For the IACBE[4] (2011), as well, knowledge of ethical issues in business is part of the key learning requirements at the bachelor's and master's levels.

In order to emphasize professional responsibility, one of us required our students to review two projects, The Johnstown Flood and "The Fifty-Nine Story Crisis" by Joe Morganstern[6], which dealt with the structural errors of a newly occupied Citicorp Building. The material was discussed in class. The Johnstown Flood was the worst flood disaster in the nation's history that was the result from negligence in design, shoddy construction, and poor maintenance. The outcome was more stringent inspection techniques and oversight of infrastructure that affects the public safety. In the second case, errors in design calculations were only realized after occupancy of the Citicorp Building. The material provides examples of the importance of professional responsibility, courage, honesty, and ethics. The written assignments also assisted in satisfying ABET Criteria 3Af and 3Bg.

c. Historical connections

Major historical events can also provide context to theory. In a course recently taught by one of the authors, construction of the Panama Canal was used to illustrate various concepts. In addition to text references, students were provided with a link to a PBS film on the topic that they could view from the website. Course concepts were discussed in assessing the performance of activities and tasks. Students were asked to write about the project's progression in relation to factors such as technological impact, sustainability and conservation, and worker safety.

We describe below a recent experience where students were required to use current and historical data in a project to illustrate a basic concept in Engineering Economics.

Case Study 1

The population of students enrolled in a construction project management course can be very diverse. At the school where one of the authors teaches, the classes at any one time can be filled with students working full time in the industry alongside students with little or no experience as well as students from another discipline, such as Architecture or Civil Engineering taking the course as an elective or that have transferred. The coverage of concepts from an engineering economics course was a concern because of the diversity of the population. The intention was to improve the understanding of time value of money concepts, finance and interest costs for students enrolled in construction project management courses. Data was acquired by issuing a questionnaire during the first class to assess skill sets of the population. In two classes of twenty five each, a very low percentage responded positively in understanding that finance costs are a direct cost for a project.

In the real world, professional estimators rely on historical data that includes past experience to put forth reliable estimates of work. The estimates represent “planned value” for a task and are compared with actual value that is accounted for while tracking production when the task commences. The project manager collects job tickets from the site that show rate of production for the task. The data tells them if they are under or over budget or ahead of or behind schedule. The importance has always been stressed that project managers should be aware of how the project was estimated in case any changes occur.

Data that is proprietary or that is acquired through a subscription fee can present a barrier for students. What were available were several resources focused on the construction industry that could be used to expose students to better understand time value of money. Simonson[7] (2005), “Digging into Construction Data” Business Economics-April 2005, describes both free and paid data sources. Some free resources include the Bureau of Census, the Bureau of Economic Analysis (BEA) and the Bureau of Labor Statistics (BLS). Aside from a wealth of information about construction labor in a specific region, the BLS[8] provides the Producer Price Index (PPI), which measures the average change over time in the selling prices received by domestic producers for their output for construction materials and equipment. In 2005, BLS produced PPI’s for several building types such as industrial, warehouse, office building and school. These indexes reflect price changes associated with the current materials and construction techniques used in the marketplace. This enables users to assess changes in productivity in the construction industry. Examples of these data are shown below in Table 1, reproduced from the Bureau of Labor Statistics.

Table 1

Percentage Change in Producer Price Indexes (PPIs) for Construction Materials, Structure Types & Subcontractors, 2003-2012

BLS Series ID		12 months through December--						to January 2012 since--			
		2006	2007	2008	2009	2010	2011	12/11	10/11	1/11	12/03
Table 1: Changes in Consumer, Producer & Construction Prices											
CUUR0000SA0	Consumer price index (CPI-U)	2.5	4.1	0.1	2.7	1.5	3.0	0.4	0.1	2.9	23.0
WPUSOP3000	Producer price index (PPI) for finished goods	1.1	6.2	-0.9	4.3	3.8	4.8	0.3	0.0	4.1	32.8
PCUBCON	PPI for inputs to construction industries	4.6	4.8	2.8	0.4	5.3	5.3	0.4	0.1	4.5	48.6
PCUBHWY	Highway and street construction	6.2	10.1	-0.6	3.9			discontinued after June 2010			
PCUBHVY	Other heavy construction	5.5	6.9	1.3	-0.1			discontinued after June 2010			
PCUBBLD	Nonresidential buildings	4.0	4.8	2.2	0.3			discontinued after June 2010			
PCUBNON	PPI for inputs to nonresidential construction						5.8	0.4	0.0	4.8	
PCUBNCS	Commercial structures						5.0	0.1	-0.2	4.0	
PCUBNIS	Industrial structures						5.4	0.4	0.5	4.8	
PCUBONS	Other nonresidential (highway, other heavy)						6.2	0.5	0.0	5.2	
PCUBRSM	PPI for inputs to multi-unit residential	4.9	3.8	3.0	-0.5			discontinued after June 2010			
PCUBRES	PPI for inputs to residential (formerly single-unit)	4.2	2.5	5.0	-0.6	4.3	4.8	0.6	0.5	4.4	40.2
Table 2: Changes in PPIs for New Buildings & Subcontractors											
PCU236211	New industrial building construction			7.8	-4.7	0.4	3.3	0.3	0.2	3.5	
PCU236221	New warehouse construction	8.1	4.5	6.3	-4.1	0.4	3.8	0.5	0.5	4.2	
PCU236222	New school construction	17.3	2.0	11.8	-2.6	1.3	4.7	0.6	0.9	4.6	
PCU236223	New office construction		4.8	6.1	-3.3	-0.3	3.9	0.6	0.9	4.0	
PCU23811X	Concrete contractors, nonresidential building work			4.9	-1.1	0.4	1.3	-0.2	-1.0	1.3	
PCU23816X	Roofing contractors, nonresidential building work			12.6	0.3	-1.9	4.3	0.7	0.6	4.6	
PCU23821X	Electrical contractors, nonresidential building work			4.8	-3.3	1.1	3.8	0.2	0.4	3.2	
PCU23822X	Plumbing contractors, nonresidential building work			9.0	-0.4	1.7	3.6	0.9	1.2	4.4	
Table 3: Changes in PPIs for Specific Construction Inputs											
WPU057303	#2 diesel fuel	2.3	33.9	-38.2	22.1	26.4	20.2	3.2	3.6	19.1	227.8
WPU139401	Asphalt paving mixtures and blocks	27.6	1.6	34.3	-9.3	4.4	8.4	1.4	1.3	9.7	116.3
WPU136	Asphalt felts and coatings	5.0	1.4	57.8	-7.5	1.8	5.8	-2.4	-5.2	2.6	96.1
WPU1361	Prepared asphalt & tar roofing & siding products	5.2	2.3	57.5	-5.5	1.9	2.6	-2.9	-7.3	-1.0	97.5
WPU133	Concrete products	8.1	3.8	4.1	-1.4	-0.4	1.0	0.7	1.4	1.4	38.2
WPU1331	Concrete block and brick	6.8	3.3	4.2	0.2	-1.1	1.1	1.1	0.3	2.1	31.8
WPU1332	Concrete pipe	2.5	10.0	4.2	-6.5	0.4	1.8	0.2	0.6	1.8	27.6
WPU1333	Ready-mixed concrete	10.1	3.1	4.2	-1.1	-1.2	0.6	0.7	2.0	1.3	41.6
WPU1334	Precast concrete products	4.7	4.7	4.3	1.6	1.0	2.6	0.7	0.6	2.6	36.1
WPU1335	Prestressed concrete products	4.9	2.2	2.8	-10.6	4.7	-3.1	-0.2	-0.5	-3.0	23.3
WPU1342	Brick and structural clay tile	6.0	0.0	0.3	-0.9	-0.3	-2.6	-3.2	-3.1	-2.8	11.5

In the course scheduling software, MS Project is used to expose the class to project management methods such as Gantt Charts and Critical Path Method (CPM). The "Commercial Construction Project Plan" is a template available on the website that includes the sequenced activities (tasks) for a 76,000 square foot building. A "Resource Sheet" included contains all required skilled labor (carpenters, electricians, plumbers, etc.) their assigned activities and their planned duration.

What is not shown is what occurs almost 30 months prior to the start of the project. Dependent upon the type of project delivery method, project professionals could be included in several stages that occur prior to the commencement of construction see Tables 2 and 3):

1. Planning stage of 12-18 months' duration
2. Schematic stage of 3-5 months' duration
3. Financing stage of 1-1.5 months' in duration
4. Design Document (DD)/Construction Documents(CD) stage of 3 months' duration
5. Bidding stage of 1 month duration

Table 2

Task Name	WBS
Three-story Office Building (76,000 square feet)	**01**
General Conditions	**01-01**
Receive notice to proceed and sign contract	01-01-01
Submit bond and insurance documents	01-01-02
Prepare and submit project schedule	01-01-03
Prepare and submit schedule of values	01-01-04
Obtain building permits	01-01-05
Submit preliminary shop drawings	01-01-06
Submit monthly requests for payment	01-01-07
Long Lead Procurement	**01-02**
Submit shop drawings and order long lead items - steel	01-02-01

With the planned construction stage of almost 3 years, there is the possibility that a contractor may have to pay bills before he in turn bills and collects for work performed for the project owner. It becomes evident to the students that a project finance cost is a direct cost for a project and the importance of using forecast methods to estimate the interest costs as well as labor and material costs.

All of the project tasks are chained together and planned to take approximately 3 years (344 days). Because the project's start date can be adjusted to any point in time, students can use the data to determine their financing needs as a function of time. Using either a Gantt Chart or the Critical Path Method serves as a basis for charting the cash inflows and outflows for a building construction project and determines the project cash requirements. Another variable that could be included in future projects is labor rates of skilled workers from a geographic location to provide owners with feasibility estimates of types of buildings in a particular location.

Table 3

Task Name	Work	Duration	Start	Finish
Three-story Office Building (76,000 square feet)	**7,929.6 hrs**	**344 days**	**Mon 1/3/00**	**Thu 4/26/01**
General Conditions	**193.6 hrs**	**17 days**	**Mon 1/3/00**	**Tue 1/25/00**
Receive notice to proceed and sign contract	24 hrs	3 days	Mon 1/3/00	Wed 1/5/00
G.C. General Management	*24 hrs*		*Mon 1/3/00*	*Wed 1/5/00*
Submit bond and insurance documents	20 hrs	2 days	Thu 1/6/00	Fri 1/7/00
G.C. General Management	*4 hrs*		*Thu 1/6/00*	*Fri 1/7/00*
G.C. Project Management	*16 hrs*		*Thu 1/6/00*	*Fri 1/7/00*
Prepare and submit project schedule	20 hrs	2 days	Mon 1/10/00	Tue 1/11/00
G.C. Project Management	*4 hrs*		*Mon 1/10/00*	*Tue 1/11/00*
G.C. Scheduler	*16 hrs*		*Mon 1/10/00*	*Tue 1/11/00*
Prepare and submit schedule of values	17.6 hrs	2 days	Wed 1/12/00	Thu 1/13/00
G.C. General Management	*1.6 hrs*		*Wed 1/12/00*	*Thu 1/13/00*
G.C. Project Management	*16 hrs*		*Wed 1/12/00*	*Thu 1/13/00*
Obtain building permits	32 hrs	4 days	Thu 1/6/00	Tue 1/11/00
G.C. Project Management	*16 hrs*		*Thu 1/6/00*	*Tue 1/11/00*
G.C. Procurement	*16 hrs*		*Thu 1/6/00*	*Tue 1/11/00*
Submit preliminary shop drawings	80 hrs	2 wks	Wed 1/12/00	Tue 1/25/00
G.C. Project Management	*40 hrs*		*Wed 1/12/00*	*Tue 1/25/00*
G.C. Procurement	*40 hrs*		*Wed 1/12/00*	*Tue 1/25/00*
Submit monthly requests for payment	0 hrs	1 day	Thu 1/6/00	Thu 1/6/00
Long Lead Procurement	**960 hrs**	**70 days**	**Fri 1/7/00**	**Thu 4/13/00**
Submit shop drawings and order long lead items - steel	80 hrs	2 wks	Fri 1/7/00	Thu 1/20/00
Steel Erection Contractor Management	*80 hrs*		*Fri 1/7/00*	*Thu 1/20/00*
Submit shop drawings and order long lead items - roofing	80 hrs	2 wks	Wed 1/26/00	Tue 2/8/00
Roofing Contractor Management	*80 hrs*		*Wed 1/26/00*	*Tue 2/8/00*
Submit shop drawings and order long lead items - elevator	80 hrs	2 wks	Wed 1/26/00	Tue 2/8/00
Elevator Contractor Management	*80 hrs*		*Wed 1/26/00*	*Tue 2/8/00*
Submit shop drawings and order long lead items -	80 hrs	2 wks	Wed 1/26/00	Tue 2/8/00

Students were provided with the template and assigned asked to forecast materials, labor and cash flows for their project and presented their results to the class.

d. Co-curricular experiences

Experiential learning is another high impact practice that brings context to classroom lessons and strengthens their impact. Blair, Millea and Hammer[9] (2004) document the beneficial impact of cooperative education not just on engineering students' academic performance in terms of grade point average; they also find positive outcomes in terms of the effect of such experiences in improving students' salary prospects.

There are many forms that experiential learning can take. At one end of the spectrum is a substantive placement or internship for a significant period of time at a place of work connected to students' majors, a place where they could conceivably be hired upon completion of their studies. This is usually tied to the program of study or a capstone experience, rather than a particular course, such as Engineering Economics, in the program.

Such internships typically involve three parties, viz., students, their academic institution and the companies that participate. All three benefit in several ways. We have witnessed several students evolve and mature while we were assisting with and/or supervising their internship projects. Being accepted to an internship allows students to gain industry experience and sometimes receive compensation for their time. If there are a limited number of internships available, it increases competition amongst the student body. We have found that the students who participate

are noticeably motivated to maintain their grade point average and work ethic. The interns often receive the advantage of closer advisement and mentoring in both academic and company settings and profit from enhanced career preparation.

A school benefits from internships by promoting their existence and piquing the interest of potential students. We have observed higher rates of graduation among students who completed internships. This can give an institution the ability to set benchmarks for the future student population. The school is also able to establish strategic linkages with other companies. There is an increased possibility of having greater involvement between the participating company and academic institution in the form of research projects. Another benefit for the school is that internships provide it with an effective method to collect assessment data for accreditation purposes.

Companies providing internships gain by having access to a list of highly motivated and skilled students. The internships are low cost, low risk opportunities to recruit employees and future leaders. During this limited time, the company gets an opportunity to assess the students for full-time employment. The company gains visibility from the group of young people and can establish a closer or exclusive ongoing relationship with the academic institution.

An internship is not always available or logistically possible for students who may be working or otherwise occupied. Other options for providing students with experiential learning include visits to businesses in the industry, classroom presentations and discussions by practitioners and shadow days at workplaces.

Service learning experiences can be useful as well and of varying durations. For example, Hayden et al[10] (2010) describe how students at the University of Vermont were involved in local service learning projects which involved “adopting” a local town where they are involved in real-life engineering projects. Evaluation and assessment of broader student performance tied to these experiences is under way.

A colleague (Fuller[11], 2012) recently conducted a service learning exercise for her class where students were required to teach concepts they had studied in the classroom to first graders. This resulted in her students learning the material to find ways to break it down for and explain it to students at a much more basic level. In an Engineering Economics course, this can take the form of college students taking the responsibility to explain concepts such as costs, revenues, profits and interest rates to younger children. The same way that many of us never fully understood a topic until we had to teach it, our students are pushed to explore the concepts they are learning and teaching and possibly look for context as a way to put it across to younger learners.

We have also successfully found exercises such as crossword puzzles (e.g., using edhelper.com) to be useful in building a vocabulary of terms related to engineering economics and project management.

All of these practices are useful in bringing meaning and life to what could otherwise be dry, abstract concepts and in reinforcing classroom learning in multiple ways. They also serve to address IACBE's Principle 7: Internal and External Relationships as well student outcomes related to the application of business concepts at the graduate level and Aa and Ab under ABET's Criterion 3.

Conceptual clarity

Purpose

Engineering Economics courses integrate and build on material and concepts from several fields such as mathematics, statistics, economics and/or finance, depending on the structure of a particular program of study. Some of these concepts may be encountered in prerequisite courses; others may be directly addressed in an engineering economics course.

Bringing together all these strands of information in a meaningful and coherent way can be challenging. However, it is important to do so to enable students to make the relevant connections and to incorporate them into exercises and assignments in their Engineering Economics course.

For example, learning the mechanics of computations such as those related to time value of money is important; equally so is the intuition behind such computations and the interpretation of results therefrom. E.g., what would be the impact of a change in financing costs? How will a change in the time horizon play out for a business' cost/revenue profile?

How to enhance conceptual clarity

The development of students' basic mathematical skills needs to be addressed so as to ensure that they are adequately equipped to take on such computations in a meaningful and knowledgeable way. For example, we have often found that students are confused in the application of interest rate numbers for the purpose of discounting/compounding. The relationship and difference between a rate as a percentage and a rate as an absolute number are ideas that should be part of prerequisite math curricula, upon which Engineering Economics courses build.

The kind of scaffolding that ensures this progression requires careful planning of overall curriculum in programs of study so that concepts build upon previously-learned content. Instructors should intentionally reference concepts that have been studied in earlier classes as well as those that will be encountered in upcoming ones to establish clear connections and create a pathway of concepts that are logically related (Williams[12], 2009; Enomoto[13], 2011). In programs which include Engineering Economics courses, the prerequisite math courses should use engineering economics applications to illustrate math concepts.

At a college that one of the authors is involved in setting up, there will be additional time on task in math-based courses to review relevant math concepts. It is planned that a Statistics course, will meet for more than the requisite 3 hours per week. The extra time will be used to go over computations that relate to the statistical topic being discussed both to reinforce the requisite math skills and to make clear the connections between mathematical and statistical concepts.

Collaborative learning

Purpose

Learning in the workplace is often carried out through observation of more experienced co-workers and experts, whether in the same facility or farther afield, facilitated by technology. However, in an educational setting, learning is typically at an individual level, whether through home assignments or class exercises.

As noted by Williams[12] (2009), following Dewey's Laboratory School, classrooms can be restructured to accommodate non-individual learning as well, to mirror practices of the workplace. Assignments can be made collaborative so that students are working together and learning from one another. For example, time could be set aside in Engineering Economics classes every week for collaborative problem-solving exercises.

IACBE[4] (2011) accreditation requirements include teamwork and engineering economics courses can help students progress toward meeting outcomes in this area. ABET's Criterion 3 also encourages teamwork (3Ad, 3Bc) in engineering technology programs (ABET[5], 2011).

Ways to increase student collaboration

Collaboration can take place in-class or be the foundation of projects to be completed outside the classroom. The flexibility and easy availability of technology make this much easier today than in the past when students would have had to meet face to face. In a recent class that one of the writers taught, one student team working on the term project of evaluating prospects for investing in technology companies rarely met outside the classroom. The members did most of their work by using Google Docs (perhaps not coincidentally, the company the group was studying was Google).

Teams can also be formed where each member assumes a different role. The "Contract Clause Writing Assignment" uses standard contract forms from the appendices in the textbook. The instructor and students discuss many of the clauses in class. The students are assigned to a team and can choose one of various roles (owner, design professional, contractor, and subcontractor) for a particular project. It is intended that by assuming a role, they would gain perspective of their needs and help them select seven clauses they would want in their contract. They must provide an explanation to support their choices.

Low team accountability can be a consequence of rewarding individual effort (Porter, et al[14], 1994). In contrast to this, team-based learning is a particularly good instrument to help students to learn how to work collaboratively. ABET Criterion 3Ad or 3Be intends for students to experience the nature of a future work environment. It enables the faculty member to assume the role of "coordinator," who schedules meetings and insures that all team members know what they are supposed to do and the allowable time limitations.

This outcome has not always been the case in our experience. Team members would often complain about the assigned tasks of other members, incomplete material received, and ineffective communication among team members. For this reason, we felt the need for increased emphasis on teamwork and to assess team interactions so as to insure quality of the final product or report.

Another concern was to establish a method to assess a fair grade for all parties involved. The term "social loathing" (Kelley and Sadowsky[15], 2005)—commonly referred to as the free rider problem—has been used to describe individual team members who relied on conscientious members to take up the slack in completing their assignment.

Kelley and Sadowsky's[15] Rating Form provides a "Peer Review" method, where team members assess their own contribution and that of other members. In course assignments that involve teamwork, such a form is shared with the class, to make students aware of how they will be graded. In our more recent experiences with team assignments, we have used versions of peer review techniques and have found that team members tend to be more responsive and responsible; consequently the complaints about other members not pulling their weight have also declined.

Another practice that we have used is dividing a class into groups of 4-6 members and having each group discuss a topic during the class. The topics are related to the issue being covered in the class. The instructor goes from group to group, facilitating discussions. Groups are then required to hand in a short (1-page) write-up of their conclusions. We have found this useful in getting students to become comfortable in opening up, speaking and arguing their opinions back and forth. It is also a good way to push students to collaborate in writing. Some examples of topics that we have used for such discussion and writing assignments include:

- What is the impact of a recent Federal Reserve decision on interest rates on civic construction projects?
- Is outsourcing to China and other countries harmful or beneficial to US construction and engineering firms?
- Will proposals for hydraulic fracturing in New York State help engineering businesses?

Written and oral communication skills are enhanced by such exercises, a goal emphasized in ABET's criterion 3 (3Af for two-year or 3Bg for four-year programs). Likewise, communication skills are a key IACBE learning outcome at the two-year, four-year and master's levels. In

addition to helping satisfy IACBE team work related learning outcomes, group work may also encourage members to be more motivated and also make groups try and compete with each other, thereby improving performance (Webb and Palinscar[16], 1996).

Active learning

What is active learning?

This practice involves a paradigm shift: Students are agents in their own learning, rather than passive recipients of knowledge from the instructor. Known as constructivism (Baker et al[17], 2009), the goal here is to use each student's distinct experiences and perceptions of an issue to build content and enhance learning. Each one of our students brings their background to bear on how they respond to our teaching (Smith et al[18], 2004). Their diverse experiences and prior knowledge help them, in partnership with instructors (Cross[19], 1998), to construct knowledge in different ways. Students who have an active role in constructing their learning are believed to be more motivated learners (Svinicki[20], 2004). At the very least, active learning involves students being more than listeners to the instructor's lectures (Bonwell and Eison[21], 1991).

Prince[22] (2004) notes the difficulties inherent in evaluating active learning practices and in a survey finds evidence related to their efficacy to be mixed. However, he does find support for practices that increase student engagement.

As instructors, it behooves us to allow students to explore and interpret the curriculum through their individual lenses. In turn, the instructors can use the ideas coming from students to build curriculum in directions that are familiar to students. Also, we can see where each of our students is coming from and attempt to meet them (at least halfway) there.

Some active learning practices

Active learning can be as simple as providing students with an environment that is conducive to their being comfortable enough to raise their hands to clarify doubts. Ruhl et al[23] (1987) discuss the benefits of interspersing standard lectures with short pauses for students to discuss, pairwise, their notes with each other. Asaro[24] recommends taking breaks during the class to allow students time to write questions or facts they have just learned on index cards which can be shuffled and read out to facilitate discussions.

Class discussion and collaborative exercises and short writing assignments such as those described in the previous section can also be examples of active learning. So are asking students questions of increasing complexity as the discussion progresses.

We have used active learning practices such as having students decide, individually or in groups, what major historical or contemporary project they are interested in analyzing. In recent years, our students have proposed projects such as a new stadium being built for the Nets basketball team, the New York City Marathon and renovations carried out at JFK International airport. All

of these are relevant to the curriculum. The fact that they are proposed by students makes for a more engaged classroom and for a richer and more meaningful research experience for each one of its members.

Encouraging students to reflect at important junctures during the course (midpoint, end) on their learning is useful. This pushes them toward greater self awareness and recognition of their strengths and shortcomings. Often, an electronic portfolio can help in this process as it is contains records of students' work and feedback of the work from the instructor. At the institution that one of the authors is involved in setting up, student reflections will form an important part of assessment of their learning. Electronic portfolios will be used throughout each student's program of study.

We have also found peer reviews by students to be a way to increase their engagement with each other's work. They can provide useful feedback that may be different from that supplied by the instructor. Depending on time pressures and logistical imperatives, this can be done pair-wise, in small groups or class-wide.

Learning communities

What are learning communities and why can they be beneficial?

A learning community is a pedagogical approach wherein the same group of students takes two or more classes together. These classes are related, but may often be from different disciplines. They encourage active engagement and reflection. They also promote collaboration between faculty members teaching the linked courses in the learning community.

Learning communities are common in every size of college and at all levels of undergraduate programs. In the institution being developed where one on the authors is working, most first-year courses will function as learning communities. In the second year as well, learning communities will be a major part of teaching practices. In the common core of the first year, all students, regardless of program of study, will be in learning communities. In the second year of the associate program, focus will be more on courses in the majors, but it is envisaged that students from different majors will participate in some common learning communities.

Learning communities, organically as well as intentionally, promote the identification of relationships between linked courses. This has been found to foster greater understanding and retention of subject matter in those courses. Studies from Fayetteville Technical Community College, LaGuardia Community College, Shoreline Community College and Spokane Falls Community College (Malnarich et al[25], 2003) speak to the effectiveness of this technique in promoting understanding and learning. They are also found to encourage collaboration amongst students, amongst faculty and between faculty and students.

As noted in Baker et al[17] (2009), individual courses in learning communities are seen to reinforce the shared goals of the community. They have to be carefully structured to ensure that the contents of separate courses are complementary. In the kind of curriculum being planned at the institution of one of the writers, teaching and learning in first-year learning communities will involve skills, content and disciplinary courses, all building upon one another.

Learning communities in Engineering Economics courses

There are several ways in which learning communities can be integrated into engineering and engineering technology programs. For example, an Engineering Economics course may be paired with a Statistics course where both include some integrative assignment(s) applying statistical concepts to engineering economics problems; these assignments reinforce learning in both subjects. The engineering economics course may go on to form the basis for a project management course where the second course intentionally, clearly and directly builds upon concepts introduced in the first. Likewise the engineering economics course introduces and identifies concepts that will be used in the project management course. Students get to see connections between concepts such as the earned value or work progress and cash flow; between motivating factors of project delivery types (such as Design Build or Job Order Contracting) and their competitive advantage; between a contractual obligation clause such as liquidated damages and performance bonding to their profit margin.

In one BS program in Engineering Management that we examined, 200-level Engineering Economics courses are offered in the same year as Finance and introductory Management. There are clear synergies between all three courses. Engineering Economics and finance or Engineering Economics and Management could be paired. Offering these courses as learning communities would help exploit those synergies and reinforce the learning in each course. Courses in Microeconomics or Macroeconomics are also good candidates to pair with an Engineering Economics course in a learning community. With Microeconomics, there are issues such as costs, revenue and profit as well as market structures that can form the basis for a learning community with Engineering Economics. In the case of Macroeconomics, concepts related to general economic conditions, inflation, interest rates and unemployment can tie the course to Engineering Economics.

Another possibility of providing a learning community experience for students in Engineering Economics courses is to pair the course with a technical communications course. The writing and presentation aspects of students' projects in the engineering economics course could be addressed in the technical communications course. Such practices build students' technical skills, and possibly those in oral and written communication as well. This helps address the relevant ABET criteria (3Aa, 3Ab and 3Af for associate's programs and 3Ba, 3Bb, 3Bg for bachelor's programs) as well as communications-related outcomes for IACBE accreditation.

Research Projects

Benefits

Student research projects involve students in empirical observation and the use of current technologies and also motivate them to apply their learning to address topical questions. Kuh[1] (2008) notes that such projects based on investigation and research can be used to connect concepts and questions that arise over the duration of a course. They need not be limited to upper-level or capstone courses.

Such projects can be beneficial to faculty as they are assisted in their own research (Moore[26], 2008). Additionally, research by students stands them in good stead to help them to be admitted into graduate school; the experience is useful in boosting their performance in graduate programs. Russell et al[27] (2007) note how undergraduate research projects can serve to increase students' interest in pursuing STEM careers.

Such projects also directly address the Essential Learning Outcomes proposed by the American Association of Colleges and Universities, particularly in the intellectual and practical skills category (aacu.org[28]). Additionally, research projects, whether individual or in teams, would address a majority of ABET'S Student Outcomes under Criterion 3.

At the associate's level, research projects, especially if paired with a presentation, address IACBE's key learning outcome 3 (effective communication); at the bachelor's level, they help students work toward outcomes 6 (effective communication) and 7 (applications of business concepts) at the very least. At the master's level, they promote the achievement of outcomes 1 (problem recognition), 2 (strategic analysis and integration) and 4 (effective communication).

Research projects can be used to make courses more writing intensive. This also helps meet ABET and IACBE outcomes related to communications skills.

Examples of research projects used in Engineering Economics courses

Several of the projects we have used have been listed in earlier sections. They have involved using real-life (ideally current) issues that relate to the course content. They should involve application of concepts related to interest rates, time value of money, rates of return, cost-benefit analysis, budgeting and replacement vs. retention decisions.

Research projects can also be scaffolded so that different concepts feed into different parts of the project, making for an integrated whole.

For example, an examination of the viability of the newly-built Yankee Stadium can take into account the feasibility of continuing with the older stadium, the financial costs of the new one under different time periods and interest rate scenarios, integrating the broader costs of public assistance to the project and the benefits from the stadium to the team as a business and to the broader community.

Future directions in teaching engineering economics and project management courses

The Architecture/Engineering/Construction (AEC) industry is changing rapidly with increasing adoption of integrated practices involving stakeholders along the many stages of the design and procurement process. Building Information Models (BIM) are software applications that establish processes to enable data to be used over a building's lifecycle. A recent SmartMarket Report stated that "almost 50% of the industry is using BIM." (McGraw Hill[29], 2009).

In light of this news, educators will have to adapt many of their programs and courses, especially in areas such as Estimating, Project Management, and Mechanical, Electrical and Plumbing Systems to promote proficiency in the use of these tools, thereby increasing students' marketability.

There are already several commercially available BIM applications that are widely used in Project Management (e.g., 4D BIM for monitoring costs and time during construction). Introducing a time element and decomposing the BIM allows the construction plan to be sequenced as in a Gantt chart or network diagram. Students can thus simulate and visualize earned value of a project versus its planned value in order to answer questions related to budgeting and scheduling. The BIM is adaptive, able to schedule changes to catch up or "crash costs."

BIM and other emerging applications can also be integrated with the high-impact practices described in the preceding pages for effective teaching and learning.

Digital tablets have been used as a tool to document project status and record the deliveries of building components to job sites of construction projects. In response to these practices and to keep pace with technology, iPad 2s were used to run Google SketchUp, Google Earth and other three-dimensional BIM applications to replicate these processes. Use of the tablets exposes students to the processes of recording the changing conditions on a construction job site. Punch lists are used by contractors to correct and complete unfinished items on a project. The tablets can be used to record the status in order to have a more accurate "as-built" condition of the construction project. This will satisfy ABET's Criterion 3Aa or 3Ba. It is believed that the increasing use of iPads and other tablets will be accompanied by a corresponding decline in use of traditional laptop computers (Wingfield[30], 2012), especially due to the portability and ease of use of tablets at project sites.

We also envisage using Google SketchUp and the Google Earth applications to simulate renovation plans of buildings on campus to increase energy efficiency and sustainability. Students will be tasked to employ a strategy that abides by sustainable requirements using the Leadership in Energy and Environmental Design (LEED) certification process. Because of the efforts to improve energy efficiency and sustainability of buildings, engineering economic concepts can be reinforced in accessing the current replacement value (CRV) of existing building components with energy-efficient products. Building Integrated Photovoltaics (BIPV) that

generate clean sustainable electricity and Low Emittance (Low-e) building products, that reduce the sensible heat content of the object, will be evaluated in comparison with the existing building materials and commercially available products that were not manufactured to energy-efficient criteria. The benefits can be assessed using lifecycle costing analysis to understand the return on the investment and tradeoffs of these products. LEED Certification requires having a Construction Waste Management Program that earns points when recycling building components. Construction Management students will be tasked to establish demolition plans, construction staging plans, mobilization and site access employing these applications.

An example of using these techniques is described below:

Case Study2

Students examined alternative project delivery methods.

- Design-Bid-Build, DBB: A project delivery method where construction documents are 100% complete prior to the commencement of construction
- Design-Build, DB: A delivery method where the construction documents are 30% complete prior to the commencement of construction, is also known as “fast-track” delivery method and is intended to save time and money. The burden is on the Design-Builder to complete the project with only 30% complete construction documents.
- Integrated Building Design, IBD: A variation of Integrated Product Design (IPD), where many stakeholders have access and participate in the planning stage of the design. It is included as one of the five guiding principles of EO 13514, The Federal Leadership in Energy, Environmental and Economic Performance Bill[31].

In this assignment, the goal was to expose students to sustainable design methods using a Leadership in Energy and Environmental Design (LEED) project. The project has a rating system that requires AEC) professionals to adjust their methods in the planning, design, construction and operation of a building. This type of project relies on the exchange of information in a shared format. The Building Information Model (BIM) is a process where this data may be shared. There are several variations of BIM, and the one important for construction students is called 5D BIM. The ASHRAE Guide define 5-D BIM as “one that has objects and assemblies that have schedule and time constraint data added to them.” The information can be contained in the BIM or can be linked or otherwise associated (integrated and/or interoperable) with project design and construction activity scheduling and time sensitivity estimating and analysis systems.

The computer graphics skill sets of the students were assessed through a questionnaire and it was decided that Google Sketch Up and Google Earth would be used. Both applications are easily accessible and can be downloaded. There are YouTube training videos to help users increase proficiency in these programs. Prior to the project each student was assigned a building on

campus to model in SketchUp and geo-reference on campus using Google Earth. This allowed all students to have some practice time.

The project required students to coordinate and simulate a construction project (horse stable) in the shared environment of Google Earth. The class was broken into 6 teams of 4 and given a set of drawings of an existing stable on City Island, N.Y. (see photograph on next page). The existing site's address was given so that students could assess the site's constraints and access to and from staging areas. All groups were tasked to coordinate and model their activities (building components) and sequence them in the required order.

On LEED projects, credit is earned through re-use and recycling methods which require construction personnel to create a construction waste management program (CWMP). Materials must be sorted and carted away and this recycling method takes a significantly longer time than the former method of demolition. Thus, project durations must be carefully planned. The students were also able to coordinate the building components and assess how well they fit together through clash detection.

A discussion on the tools for use in the IBD process was conducted after the project. From the discussion the following items were mentioned as possible future use by construction professionals:

1. Limitations and feature of these free applications in comparison with the professional versions.
2. Possible use for traffic redirection, lane closure in construction projects.
3. Location of a site and driving directions supplied to drivers delivering supplies.
4. Coordination with police directing traffic adjacent to a construction site.
5. Contours from Google Map may be used to better address slope of terrain at site when planning construction.

If we take the perspective that we are stewards that want to hand down a better planet to our descendants, by teaching LEED and other sustainable design concepts to construction professionals, then an indirect contribution of the course material will satisfy ABET Criterion 3Ah and 3Bi, related to professional and ethical responsibility.

If we take the perspective that we are stewards that want to hand down a better planet to our descendants, by teaching LEED and other sustainable design concepts to construction professionals, then an indirect contribution of the course material will satisfy ABET Criterion 3Ah and 3Bi, related to professional and ethical responsibility.

Assessment

The outcomes from the aforementioned practices should be carefully assessed to ensure that they are proving effective; if not, they should be reevaluated. Continuous assessment should be the hallmark of academic practices at the course, program and institutional levels.

At the course level, a rubric is an excellent tool for this purpose. A rubric is a scoring guide used to assess student performance based on the course learning objectives. Handing out rubrics prior to class assignments helps students by providing them with a working guide of how their work will be graded. As Goodrich Andrade[32] (1997) notes, rubrics are useful to instructors as well as to students. In addition to being powerful tools for both teaching and assessment, rubrics can serve to improve students' performance by defining quality, by making teachers' expectations clear and by showing students how to meet these expectations. The three common features of rubrics are that they focus on measuring a stated objective, i.e., a performance, behavior or quality; they display a range of values to rate a performance; they contain specific characteristics that indicate a degree to which a standard was met.

In an effort to more rigorously collect data about student populations, the need to acquire a survey instrument has become evident. Adapting and adjusting the survey instrument from one

semester or year to the next presents a few problems. Creswell[33] (2003) has observed that when one modifies an instrument or combines instruments in a study, the original validity and reliability may not hold for the new instrument, and it becomes important to reestablish the validity and reliability during data analysis." This means the reporting efforts by researchers must establish validity to draw meaningful and useful inferences from scores on the instrument.

SurveyMonkey.com is an online survey tool, which can be used in gathering information from future respondents. By using this service, researchers can create their own surveys quickly using custom templates and post them on Web sites or e-mail them for students to complete. This service compiles the results and provides the researcher with a report of descriptive statistics or as graphed information. The data can be used again and downloaded into spreadsheet and or database applications for further use. It is a tiered system with a basic program that is free but has a limit of ten questions per survey and a maximum of 100 responses per survey. If more questions are required and/or more respondents needed, SurveyMonkey charges a monthly or annual fee.

Conclusions

There are many steps that can be taken to improve learning outcomes in engineering, engineering technology, technology/engineering/construction management programs in general and, more specifically, in Engineering Economics courses. The ones listed above are a few that are easily used or adapted and could go some way toward improving teaching, learning and student outcomes in such courses.

While it may appear to be a tall order, in reality, many of these are practices that we already use in our classrooms. Several of them can be combined in the form of a single artifact of student work. For example, a **group research project**, which promotes **team work**, could be the major assignment in a **learning community**. It may be constructed in a scaffolded manner to increase **conceptual clarity** and to improve student learning along the way. It could be structured so that an additional component of the project that builds on preceding ones could be due every few weeks. The exact assignment may be a result of an engaged, **active learning** process, where students explore their own interests and work on an assignment that has meaning, interest and resonance for them.

Bibliography

1. Kuh, G. D. (2008). *High-impact educational practices: What they are, who has access to them and why they matter*. Washington, DC: Association of American Colleges and Universities.
2. Berns, R. G. & Erickson, E. (2001). Contextual teaching and learning: Preparing students for the new economy. *The Highlight Zone: Research @ Work, 5*, 2-9, 2001.
3. Garfinkel, S. and Mumford, D. (2011, August 25). How to fix our math education, *The New York Times*.
4. International Assembly for Collegiate Business Education. (2011). *Self-study manual, International*

Association for Collegiate Business Education. Retrieved from http://iacbe.org/accreditation-documents.asp.
5. ABET. (2011). *Criteria for accrediting engineering technology programs, 2012 – 2013*. Retrieved from http://www.abet.org/criteria-engineering-technology-2012-2013/.
6. Morgenstern, J. (1995, May 29). City perils: The fifty-nine-story crisis, *The New Yorker*, 45-53.
7. Simpnson, K. (2005, April), Digging into construction data, *Business Economics*.
8. Bureau of Labor Statistics. (2012). http://www.bls.gov/ppi/.
9. Benjamin, B., Millea, Meghan & Hammer, J. (2004). The impact of cooperative education on academic performance and compensation of engineering majors. *Journal of Engineering Education, 93*, (4), 333-338.
10. Hayden, N. J., Dewoolkar, M. M., Rizzo, D. M., Neumann, M. & Oka, L. G. (2010, June). *Incorporating service-learning projects dealing with sustainability within the civil and environmental engineering capstone design course*. Abstract and poster presented at Capstone Design Conference, Boulder, CO.
11. Fuller, K. "Service Learning in STEM Disciplines." The New Community College, Service Learning and Experiential Education Workshop. New York, NY, 29 February, 2012.
12. Williams, S. (2009). *The impact of collaborative, scaffolded learning in k-12 Schools: A meta-analysis*. Culver City: The Metiri Group.
13. Enomoto, K. (2011). Promoting deep learning through a scaffolded language curriculum: Double tasking language-specific and research-skills development. *Languages and Cultures Network for Australian Universities, Colloquium*.
14. Porter, D.V., Brickell, J.L., Cosgrove, R.D. & Reynolds, M.F. (1994). Assigning students to groups for engineering design projects: A comparison of five methods. *Journal of Engineering Education, 83* (3), 259-262.
15. Kelley, D. & Sadowski, M. (2005). Peer evaluation within a team design project. *Engineering Design Graphics Division-American Society for Engineering Education, Conference Proceedings- 60th Annual Midyear Conference*.
16. Webb, N. & Palincsar, A. (1996). Group processes in the classroom. In D.C. Berliner & R.C. Calfee (Eds.), *Handbook of educational psychology* (841-873). New York: Simon & Schuster.
17. Baker, E., Hope, L. & Karandjeff, K. (2009). *Contextualized teaching and Learning: A Faculty Primer*. A review of literature and faculty practices with implications for California community college practitioners prepared in association with The Center for Student Success, The Research and Planning Group for California Community Colleges and The Academic Senate for California Community Colleges.
18. Smith, B., MacGregor, J., Matthews, R. and Gabelnick, F. (2004). *Learning communities: Reforming undergraduate education*. San Francisco: Jossey-Bass.
19. Cross, K. P. (1998). What do we know about students' learning and how do we know it? *AAHE National Conference on Higher Education*.
20. Svinicki, M. D. (2004). *Learning and motivation in the postsecondary classroom*. San Francisco: Jossey-Bass.
21. Bonwell, C., and Eison, J. (1991). Active learning: Creating excitement in the classroom. *The National Teacher and Learning Forum*, September. Retrieved from http://www.ntlf.com/html/lib/bib/91-9dig.htm.
22. Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education, 93*, 223-231.
23. Ruhl, K., Hughes, C. & Schloss, P. (1987). Using the pause procedure to enhance student recall. *Teacher Education and Special Education, 10*, Winter, 14 – 18.
24. Asaro, J. *Tips: Great active learning strategies*. Retrieved from http://www.inspiringteachers.com/classroom_resources/tips/curriculum_and_instruction/great_active_learning_strategies.html
25. Malnarich, G., Dusenberry, P., Sloan, B., Swinton, J. & van Slyck, P. (2003). *The Pedagogy of Possibilities: Developmental Education, College-Level Studies, and Learning Communities*. National Learning Communities Project Monograph Series, Washington Center for Improving the Quality of Undergraduate Education, 2003.
26. Moore, J. (2008, October 13). Undergraduate research benefits students and professors." *Ventura County Star*.

27. Russell, S., Hancock, M. and McCullough, J. (2007). Benefits of undergraduate research experiences. *Science, 316*, April 27.
28. Association of American Colleges and Universities. *Liberal Education and America's Promise (LEAP), Essential Learning Outcomes*. Retrieved from http://www.aacu.org/leap/vision.cfm.
29. McGraw Hill Construction Division. (2009). *The Business Value of BIM: Getting Building Information Modeling to the Bottom Lin*e.
30. Wingfield, N. (2012, March 6). As new iPad debut nears, some see decline of PCs. *The New York Times*.
31. Executive Order 13514, Federal Leadership in Environmental, Energy, and Economic Performance retrieved from http://www.fedcenter.gov/Bookmarks/index.cfm?id=13641.
32. Goodrich Andrade, H. (1996-97). Understanding Rubrics. Educational Leadership., 54(4). Retrieved from http://www.ascd.org/publications/educational-leadership/dec96/vol54/num04/Understanding-Rubrics.aspx.
33. Creswell, J. M. (2003). *Research design: Qualitative, quantitative, and mixed methods*. Thousand Oaks: Sage Publications.
34. Gaston, P. L., Clark, E., Ferren, A. S., Maki, P., Rhodes, T. L. Schilling, K. M. and Smith, D. (2008). *General Education and Liberal Learning: Principles of Effective Practice*. Washington, DC: Association of American Colleges and Universities.
35. Lechner, N. (2008). *Heating, cooling, lighting: Sustainable design methods for architects*. Hoboken: J. Wiley & Sons.
36. Michaelsen, L.K. (2004). Getting started with team-based learning. In L. K. Michaelsen, A. B. Knight & Fink, L.D. (Eds.), *Team-based learning: A transformative use of small groups* (27-52). Westport: Praeger Publishers.
37. Ullmer, J. H. & Lewandowski, A. H. (2003). The value of learning communities in the economics classroom. *Mountain Rise*, *1*(1).
38. The City University of New York Office of Academic Affairs. (2008). *A New Community College Concept Paper*. Retrieved from http://www.cuny.edu/academics/initiatives/ncc/about/NCC_Concept_paper.pdf.

APPENDIX 1a: Recommended pedagogies and ABET criteria they address

	ABET Criterion 3										
	A: Associate Programs					B: Bachelor Programs					
RECOMMENDATIONS	3Aa	3Ab	3Ad	3Af	3Ah	3Ba	3Bb	3Bc	3Be	3Bg	3Bi
Contextualization: Ethical and professional responsibilities				✓	✓					✓	✓
Contextualization: Co-curricular experiences	✓	✓				✓	✓				
Collaborative learning: Purpose			✓					✓			
Collaborative learning: Team accountability			✓						✓		
Collaborative learning: Communication skills				✓						✓	
Learning communities: recommendations	✓	✓		✓		✓	✓			✓	
Research projects	✓	✓		✓		✓	✓	✓		✓	
Future directions: Use of technology	✓				✓	✓					✓

Appendix 1b: Description of relevant ABET criteria

(from http://www.abet.org/criteria-engineering-technology-2012-2013/)

A. For associate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:

a. an ability to apply the knowledge, techniques, skills, and modern tools of the discipline to narrowly defined engineering technology activities;
b. an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge;
d. an ability to function effectively as a member of a technical team;
f. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
h. an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity.

B. For baccalaureate degree programs, these student outcomes must include, but are not limited to, the following learned capabilities:

a. an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
b. an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
c. an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;
e. an ability to function effectively as a member or leader on a technical team;
g. an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
i. an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity.

APPENDIX 2a: Recommended pedagogies and IACBE criteria they address

	IACBE Criteria						
	Associate programs	Bachelor's programs			Master's programs		
RECOMMENDATIONS	3	4	6	7	4	5	6
Contextualization: Current issues	✓		✓		✓		
Contextualization: Ethical and professional responsibilities		✓					✓
Contextualization: Co-curricular experiences				✓			
Collaborative learning: Small group work	✓		✓		✓	✓	
Learning communities: Recommendations to build technical and communications skills	✓		✓		✓		
Research projects	✓		✓	✓	✓		

Appendix 2b: Description of relevant IACBE criteria
(From http://iacbe.org/accreditation-documents.asp)

Associate-Level Programs
Graduates of associate-level programs in business should be able to demonstrate that they possess:
3. The ability to communicate effectively

Bachelor's-Level Programs
Graduates of bachelor's-level programs in business should be able to demonstrate that they possess:
4. Knowledge of the ethical obligations and responsibilities of business
6. The ability to communicate effectively
7. The ability to apply knowledge of business concepts and functions in an integrated manner

Master's-Level Programs
In master's-level programs, knowledge of the key content areas of business is assumed. Graduates of master's-level programs should acquire a depth of knowledge in these areas that exceeds that of the typical bachelor's degree graduate. Graduates of master's-level programs in business should be able to demonstrate that they possess:
4. The ability to communicate to relevant publics:
    a. Effective written communication skills
    b. Effective oral communication and business presentation skills
5. Teamwork skills: The ability to work with a team of colleagues on projects
6. In-depth knowledge of the ethical obligations and responsibilities of business