Integration of Class and Laboratory in Engineering Technology

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Abstract

This paper examines use of integrated class/lab and assignment of real practical problems in a specialized Engineering Technology program (Structural Analysis and Design). Courses in structural design combine theory, testing and applications. Typically, the problem is presented as a specific application and includes hands-on laboratory testing of structures. All student work is conducted in the laboratory (located in the same room as the classroom). For example, a 3-D computer model of a bridge is created according to specified geometry; then loads are applied to the structure to evaluate its strength. Finally, theoretical results are reviewed using computer results and appropriate modifications are applied to the design. Students also perform extensive tests of concrete mixes every semester, design and build actual beams, columns, or slabs that are tested to failure. Students are also exposed every summer to the latest technologies in total stations, global positioning systems (GPS), and global information systems (GIS).

For many years, student data has indicated that retention of students in the Structural Analysis and Design courses has been consistently high (94%+). Analysis of student exit interview results indicate that integration of class/labs, extensive use of computers, and assignment of real engineering problems, are the main reasons for student success.

Engineering Technology Bachelor of Science Program

This program covers the design of structures, bridges, buildings, towers, and offshore platforms and in general what is called civil structures. However, the program is not civil engineering because that field is considered broader. All aspects related to structural design are part of the program, including soil mechanics, foundation design, and GIS-GPS surveying. The Technology Accreditation Commission of the Associated Board for Engineering and Technology (TAC/ABET)[*] accredits the program. Figure 1 shows the program curriculum.

All courses in structural design combine theory, testing and applications. Typically, the problem is presented as a specific application. For example, in the design of a bridge, a 3-D computer model of the bridge is created according to specified geometry; then loads are applied to the

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structure to evaluate its strength. Finally, theoretical results are reviewed using computer results and appropriate modifications are applied to the design.

Students start by taking an intensive course in applications of computers to engineering. In this course they learn how to use the computer to solve engineering problems. The course involves a project selected by the student, combining computer languages, databases, data acquisition, and spreadsheets.

Computer modeling is an integral part of the program. Students start with a visualization course and two courses in computer-aided design, followed by a course in 3-D modeling. These courses include the most common CADD software packages: MicroStation, AutoCAD, and 3D Studio[1]. The latest version of software is always used in these courses.

There are two courses in structural analysis, the first one deals with application of finite element theory to beams and frames. Students write their own computer programs and validate the results, measuring loads and deflections in actual structures. The second course, Finite Element Analysis, utilizes ANSYS, the best-known "industrial-strength" FEA program for the analysis of members, connections and other structural details ROBOT is also used for finite element analysis of shells and plates. The course includes linear and nonlinear behavior.

Field measurement of vibration of bridges and other structures are also performed in structural courses. Once students realize that structures vibrate, they are exposed to computer programs that predict the frequency of vibration and present the theoretical basis for dynamic analysis of structures.

Design of steel structures is based on the ultimate design approach known as LRFD (Load and Resistance Factor Design) common in American engineering practice. This course uses the manual of the American Institute of Steel Construction as a textbook, and extensive examples are presented to illustrate practical design applications[2].

There are three courses in concrete structures: Modern Concrete Technology presents the principles, practice and testing of high performance and lightweight concrete. Students perform extensive tests of mixes every semester. Reinforced Concrete Design is a course where students design and build actual beams, columns and slabs that are tested to failure. The principles of reinforced concrete design are presented based on the results of these tests[3].

Self-compacting concrete is one of the newest technologies developed in Japan to reduce the labor cost of cast in place concrete. The design involves careful selection of the mix proportions and requires additives such as superplastisizers. The water-cement ratio has to be controlled with great precision to obtain the required results. In the fall of 2001 students and faculty of the structural program designed and built a self-compacting concrete beam.

Freshman

			HRS	SEM				HRS	SEM
ENG	1302	Composition II	3	ALL	ENGR	1400	PC Applications in Engineering	4	F,S
ENGR	1401	Engineering Graphics	4	F,S	PHYS	1307	General Physics I	3	ALL
HIST	1305	US History to 1877	3	ALL	PHYS	1107	General Physics Lab I	1	ALL
PSY	1303	General Psychology	3	ALL	HIST	1306	US History after 1877	3	ALL
MATH	2401	Calculus I	4	ALL	EET	1411	Circuits	4	F
			17					15	

Sophomore

			HRS	SEM				HRS	SEM
ET	3321	Soil Mechanics	3	F	ENGR	2409	Engineering Mechanics	4	F,S
ENGR	2407	Surveying with GIS-GPS	4	SU	ENGR	2410	Analysis of Engineering Networks	4	F,S
POLS	2303	US Government I	3	ALL	CHEM	1307	General Chemistry	3	ALL
PHYS	1308	General Physics II	3	ALL	CHEM	1107	General Chemistry Lab I	1	ALL
PHYS	1108	General Physics Lab II	1	ALL	ENG	23XX	Sophomore English Literature	3	ALL
SPCH	1304	Introduction to Speech	3	ALL	POLS	2304	US Government II	3	ALL
			17					18	

Junior

			HRS	SEM				HRS	SEM
		Writing Proficiency Exam							
ENGR	3311	Structural Analysis	3	F	ET	3322	Finite Element Analysis of Struct.	3	S
ENGR	3312	Reinforced Concrete Design	3	F	ET	4321	Structural Steel Design	3	S
MATH	2307	Linear Algebra	3	ALL	ENG	3302	Business and Technical Writing	3	ALL
ET	3320	Modern Concrete Technology	3	F,S	ET	3325	3D Computer Modeling, Rend. & Anim.	3	F
ET	3308	Materials Science	3	F,S	ART		Fine Arts Course	3	ALL
			15					15	

Senior

			HRS	SEM				HRS	SEM
ET	4323	Technology Seminar	3	F,S	ET	4320	Prestressed Concrete	3	S
ET	4324	Senior Concrete Project	3	F,S	ET	4325	Senior Steel Project	3	S
ENGR	3302	Engineering Economics	3	S	ET	4322	Foundation Design	3	S
ENGR	3409	PC Facilities Management	4	ALL	ET		Elective	3	ALL
ET		Elective	3	ALL	ET		Elective	3	ALL
			16					15	

F= fall; S = spring; SU= summer

Figure 1 - Structural Analysis Design Curriculum

Prestressed concrete is an important subject in structural engineering. Students build statically indeterminate complex structures in this course, apply stressing forces, and test structures. Fiber reinforcements are included in the course.

Foundation design is a critical aspect of structural engineering. Students are exposed to the principles of foundation design. Foundations of different sizes on several different soils are tested during this course. Once the results of the test are available, students develop programs based on classical theories such as Terzaghi's to predict the capacity of foundations. This foundation course is preceded by a course in soil mechanics where students go to the field, take samples, and perform all tests necessary for soil classification and computation of typical Houston, Texas, soil strength.

During the fourth and last year of training, students work on their senior concrete and steel design projects. Students are encouraged to apply their creativity to the conception and design of a real structure. Some of the projects are also engineering design problems that students are assigned at their place of employment.

Creativity is the main characteristic of an engineer. In the past, technologists were employed to perform manual routine computations as "checkers" for structures that were created by engineers. Today, with the advent of the computer and proper training, the engineering technologist may be assigned the responsibility for creation and design of structures[4].

Construction surveying is perhaps the best example of an application of modern technology in the Structural Analysis Design program. With sponsorship of industry, students are exposed every summer to the latest technologies in total stations, global positioning systems (GPS), and global information systems (GIS). GPS and GIS have revolutionized surveying, because of the ability to determine a position with high precision and obtain its corresponding information[5].

Hands-on laboratory testing on a variety of structures is conducted in the laboratory (located in the same room as the classroom). Figures 2 through 4 show students at work in the laboratory.

Figure 2 - Structural Analysis and Design students preparing truss for testing

Figure 3 – Structural Analysis and Design student reading ultrasonic cover measurement

Figure 4 – Students applying fiberglass-reinforcing mesh to beam

Integrated Class/Laboratory - Examples

Other examples of classroom presentations integrated with laboratory activities include:

- Soil Mechanics: All principles are demonstrated with actual testing of soil samples.
- Modern Concrete Technology: Students design concrete mixes and test them to find their ultimate strength.
- Structural Analysis: Real trusses are analyzed and tested by application of loads to compare the results of computer models with actual measurements of deflections of the structures.
- Reinforced Concrete: Beams are manufactured by students and tested to failure. After that the beams are repaired using fiber reinforced composites and tested again to service load levels[6].
- Prestressed Concrete: A post-tensioned beam is stressed in the laboratory to compare theoretical and practical deformations.

- Foundations: Models of footings are tested to soil failure to illustrate the validity of complex bearing capacity formulas.

Computer programs to predict results and monitor the progress of testing have been developed for all tests performed in the laboratory. The standard testing procedure involves the following steps:

Presentation of the theory
Computer simulation of the test
Testing with continuous monitoring of results

The laboratory includes the following facilities:

- Soil Mechanics and Foundations: All necessary equipment for soil testing including a triaxial testing apparatus and consolidometers were built by students. Also, a rig to test foundations to failure was built be students. This device allows students to visualize failure of soils under structural loads.
- Testing Bed for Concrete Beams: This device is use to test beams that students design and cast. After failure, the beams are repaired using fiber composites and tested again to failure. Following this procedure, students learn reinforced concrete design and structural repair using composites using a single beam. Description of this approach has received great attention at international conferences where faculty and students described the methodology[6]. Figure 5 shows a concrete beam reinforced with composites after failure.

Figure 5 - Testing of concrete beam reinforced with fiber composites

- Testing Bed for Steel Elements: This facility is used to test trusses, beams and girders. The elements are not tested to failure because the educational goal is to show deflections, flange buckling, web bucking and other behavior typical of steel structures. Figure 6 shows a steel joist ready for testing.

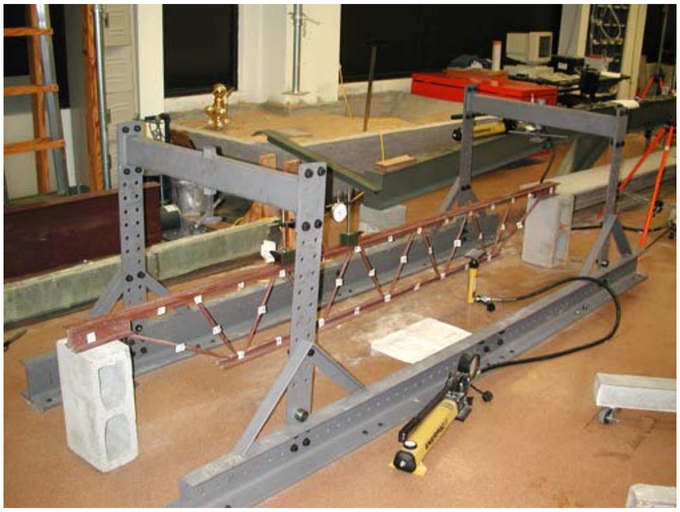

Figure 6 - New rig for testing of steel elements with truss in preparation for testing.

- Post-tensioned Concrete Beam. Figure 7 shows a two-span continuous beam used to train students in the procedures required to design and apply the required tension to the strands of prestressed concrete beams. The trajectory of strands is delineated on the surface of the sides of the beam for easier visualization of their position inside of the beam.

Figure 7 - Two span continuous beam used to teach post-tensioning techniques

- Post-tensioned Crane: Figure 8 shows a crane designed and built to handle heavy loads in the laboratory. Details of its design and construction were presented at the ACI annual conference in Montreal gaining great compliments from fellow educators.

Figure 8 - Post-tensioned concrete crane used to lift heavy equipment in the lab.

Student retention and graduation measures in the Structural Analysis and Design program

The program was established in 1985 to instruct students in the Houston Area in design of civil structures and their foundations. This subject is a core component of civil engineering programs. However most engineering schools do not offer a separate degree in structural engineering. Houston was a good choice to offer the program due to the intense activity in structural design related to the offshore platforms for exploration and production of oil and gas and also due the presence of some of the largest U.S. and foreign engineering companies in the city. Furthermore, the Texas Department of Transportation performs all design of structures for the metropolitan and surrounding areas in its Houston office.

The program did not flourish during the first seven years and in fact in the period 1998 to 1991 there were no graduates from the program.

The educational and research activities reported in this paper started in 1993 following the appointment of a coordinator with extensive academic background in the field and with experience in developing testing facilities for educational purposes at the University of Texas, Austin. The new coordinator came to the program with the following specific goals:

- Improving retention and graduation measures,
- Developing testing and computer facilities and
- Seeking TAC/ABET accreditation for the program.

Program growth in terms of retention and graduation from the program has been monitored. Figure 9 shows the growth of the program. It is important to note that during the history of the program enrolments in the lower levels of the program have remained almost constant. Number of program graduates was nil and unacceptable in the years 1989 to 1993 but then improved with the end result that the number of graduates each academic year substantially increased in the manner presented in the figure. Very positive changes in the number of graduates after 1995 is clearly due to implementation of substantial program changes in 1993. Program changes are described in the first part of this paper.

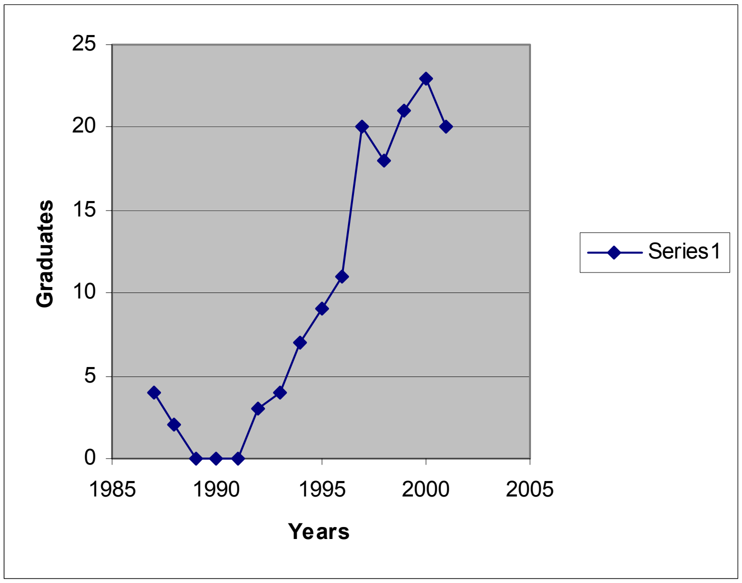

Figure 9 – Number of program graduates

Exit interviews have been the main tool used to measure the satisfaction of students with the program. The department chair meets privately with each one of the graduates after all academic requirements for graduation have been completed. A written exit survey form is also completed. The interviews last for no less than forty-five minutes and provide students the opportunity to express themselves without fear of grade retaliation.

Student retention is a closely related measure to % of students registering and completing a course. Statistical data gathered by the Office of Institutional Research is shown below. For Engineering Technology programs the following results are available:

	Fall 97	**Change in %**	**Fall 98**	**Change in %**	**Fall 99**	**Change in %**	**Fall 00**	**Change in %**	**Fall 01**	**Change in %**
Engineering Technology	94%	-	94%	0.00%	93%	-1.00%	94%	1.00%	96%	2.00%

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Data is gathered during the student exit interviews. Data indicates that the following factors are described by students as the main reasons for their successful completion of the program:

- First, practical application coursework that involves combined theory and practice
- Second, faculty with extensive industry experience that can share their experiences with the students
- Third, emphasis on class projects where students can work in an environment similar to the one in found in industry and
- Students always make the point that they remained in school because their companies continued covering the educational costs in view of the combined theory-practical experience that they were receiving in the program

Conclusions

- Analysis of student exit interviews indicate that integration of class/labs, extensive use of computers, and assignment of real engineering problems, are the main reasons for high program completion rates.
- The Engineering Technology Department at the University of Houston-Downtown focuses on unique programs relevant to the Houston, Texas area. Structural Analysis Design was designed to meet the needs of the community at-large.
- Faculty interacts continuously with industry in order to provide feedback to the department about employers' expectations and the performance of the graduates. In addition, an Industry Advisory Committee provides continuing feedback to program faculty and administrators.
- The strong emphasis on computer technology provides comparative advantage to graduates of the program because they are immediately productive after employment.
- Students become more efficient in the learning process since computer simulations and laboratory testing are more attractive to students than abstract numerical computations and as a result, they spend more time studying the material.

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Biographical Information

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George Pincus is Dean of the College of Sciences and Technology, and Professor at the University of Houston-Downtown (1986-date). Prior service includes Dean of the Newark College of Engineering and Professor, New Jersey Institute of Technology (1986-1994). Dean Pincus received the Ph.D. degree from Cornell University and the M.B.A degree from the University of Houston. Dr. Pincus has published over 40 journal articles, 2 books and is a Registered Professional Engineer in 5 states.