New and Innovative Instructional Approaches for Teaching Engineering Technology Courses: A Case Study

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ABSTRACT

This paper describes new innovations in teaching digital electronics courses in the two-year electrical engineering technology program (2EET) at The Pennsylvania State University, Altoona College. The instructional approach used in the three credit-hour digital electronics theory course (EET 117) was based on the engineering case studies derived from actual industry situations. The teaching approach used in the one credit-hour digital electronics laboratory course (EET 120) was based on student centered engineering design teams.

The case-based teaching approach used in the EET 117 course was very helpful to students in gaining an insight into the industrial applications of digital systems technology. Learning through case studies helped engineering technology students work creatively in teams to solve engineering problems. Providing students with case study experiences can be viewed as equipping future engineers/engineering technologists with the tools they will need to effectively perform in industry.

The traditional approach to teaching the digital electronics laboratory (EET 120) included eleven weeks of laboratory exercises starting with basic gate circuits and ending with state control counters. The last three laboratories focuses on the design of a digital system. The new technique reversed the process by integrating the design into every laboratory and using a design team concept. The student teams were given the specifications for a digital system in the second week of the semester. The design problems had three major subsystems that included digital technology covering all the topics in the courses. As the teams worked on the digital circuits they learn the operation of the subsystems through the design, analysis, and testing process. In the

previous process, the laboratories were isolated weekly exercises; however, in the design method the students learned how each circuit functioned in the total system and arrived at a better understanding of integration of digital devices. In addition, the students had a fifteen week experience in team work which is vital for the current industrial work place.

The first part of this paper begins with a description of the need for an instructional model based on engineering case studies. Development and implementation of this model in the EET 117 course at Penn State Altoona is described next. The results of implementation of case-based instructional method in the EET 117 course are discussed and the conclusions are presented. In the second part of this paper the technique used to convert the traditional digital laboratory to a team based design process is described.

INTRODUCTION

The project described in the first half of this paper is the development and implementation of case study method for helping students develop real-world engineering skills. Like its law and business school counterparts, the engineering case presents a scenario that practicing engineers are likely to encounter in the workplace. The engineering cases developed for this project were derived from actual industry situations and reflected real-world concerns. Providing students with case experiences can be viewed as equipping future engineers/engineering technologists with the tools they will need to effectively perform in industry.

An engineering case is defined as an account of an engineering activity, event, or problem containing some of the background and complexities usually encountered by an engineer/engineering technologist. In his paper titled *On Writing Engineering Cases* published in the <u>Proceedings of ASEE National Conference on Engineering Case Studies</u>, March 1979, Geza Kardos explained the objectives and the content of engineering case studies as:

> The major objective of an Engineering Case is to provide a medium through which learning (e.g., analyzing, applying knowledge, reasoning, drawing conclusions) takes place. Imparting additional specific information is relatively minor and coincidental. A good case:
>
> 1. Is taken from real life (a necessity).
> 2. Consists of one or more parts, each part usually ending with problems and/or points for discussion.
> 3. Includes sufficient data for the reader to treat problems and issues.
>
> To make a case believable to the reader, a good case usually includes:
>
> 1. Setting

2. Personalities
3. Sequence of events
4. Problems
5. Conflicts

The course selected for this project was EET 117 (Digital Electronics). It is a 3 credit-hour **required** course for (i) all the two-year associate degree electrical engineering technology (2EET) majors, (ii) all the two-year associate degree biomedical engineering technology majors at The Pennsylvania State University. At the Altoona College, the average class size is 35-45 and the course is offered every year during the spring semester. This course involves an in-depth study of both combinational and sequential digital logic systems. Students design and build digital systems using digital IC chips. The instructional model currently used for this course is based on the delivery of formal classroom lectures, assignment of typical drill problems selected from the course text, and the work done by students to solve these problems. The above-mentioned teaching approach does not expose students to the actual industrial situations. There is very little that students can learn about state-of-the-art digital systems used in industry just by solving the textbook problems. Students need to have a thorough understanding of how digital systems are designed, built, and applied in industrial environment. The case-based teaching model developed and used in this project helped engineering technology students gain an insight into the industrial applications of digital system technology.

PROJECT IMPLEMENTATION

The implementation process for this project consisted of the following steps:

1. During the Fall 1996 semester, a student intern was selected by the EET 117 course instructor (Dr. Sohail Anwar) to help him in the implementation of a case-based teaching approach. The intern was a 2EET sophomore who had already completed the EET 117 course successfully. The salary of the student intern was paid from a grant awarded by The Schreyer Institute for Innovation in Learning, The Pennsylvania State University. The criteria for the selection of the student intern included superior academic performance and well developed oral and written communication skills. Good computer skills constituted another criterion considered in the selection of student for this project.

2. During the Fall 1996 semester and the early part of the Spring 1997 semester, the course instructor visited several companies to obtain all the information that was necessary to develop engineering case studies related to digital systems technology.

3. Every case study was reviewed and finalized with the assistance of the student intern. There were four components of each case study. They are listed below:

- Component 1: consisted of an examination of the situation that existed for a given industrial process before digital system technology was used for this process. The examination includes process description, technologies and tools used, and an analysis of the performance of this process.

- Component 2: consisted of an examination of all the technical problems which were associated with the performance of the above-mentioned industrial process.

- Component 3: consisted of an examination of all the possible solutions for the problems described above and the engineering considerations associated with these solutions.

- Component 4: consisted of a thorough examination of the engineering considerations which led to the implementation of a digital system for the given process. This component of the case study also includes an analysis of the design of the above-mentioned system, the development of the system, and the hardware used to build the system.

4. During the Spring 1997 semester, teams (each consisting of 4 students) of the EET 117 students were formed. Towards the middle of the semester, the student teams started getting the components 1, 2, and 3 of the case studies from the course instructor. The three components were discussed in the class and then each team was required to come up with a solution of the problems associated with the industrial process discussed in that case study. On the average, one week was given to the teams for working on each case study.

5. At the end of the assigned time, each team was required to submit the solution (resulting from the work done by the team members) of the given problem(s) (as described in the case study) to the course instructor. The solutions were evaluated by the course instructor and returned to the teams. At that time, component 4 (the actual digital system developed by the company) was discussed.

6. The process described above was repeated for all the case studies considered in this course.

IMPLEMENTATION RESULTS

It was an expectation that the study of several engineering cases has helped students gain an insight into the industrial applications of digital systems technology. It was also expected that learning through engineering cases has helped EET 117 students work creatively in teams to solve real-life engineering problems.

In order to assess how well the above mentioned expectations were met, the course instructor assigned a real-life engineering design and implementation project to the student teams, towards the end of the semester. The project was related to the design and the hardware implementation of a digital control system for a soft drink vending machine. The hardware implementation of this design was carried out by the student teams in the accompanying laboratory course EET 120 offered at Penn State Altoona during the same semester (Spring 1997). All the students who register for EET 117 are also required to take EET 120 which is the one credit-hour counterpart of EET 117. The design specifications for this lab project were as follows:

> The goal for this lab is to design and build a drink dispensing machine with the following specifications: The machine is to display the current input value; a reject button is to be present; it is to give correct change when the input value is more than the cost; the cost of each drink is to be $0.35; and the machine is only to accept dimes and quarters. It is assumed that the machine is equipped with an unlimited amount of nickels. For example if 4 dimes are inserted, a nickel will be discarded from the machine, if 2 quarters are inserted, one dime and one nickel will be discarded.

This machine consists of three major circuits to simulate the desired functions of a drink machine. The first circuit is the clock which consists of 'one-shot' circuits. The clock produces three separate pulses: a clock pulse, a Q-pulse, and a reset pulse. These pulses are sent to the next circuit, the count. The counter consists of flip flops and IC chips, which change from one state to another when activated by the clock pulse. The counter also decides whether there is enough money inputted to allow a selection to be made. In the display circuit the one's column reads Q_D and the other three columns read Q_A, Q_B, & Q_C, to display the current amount of money present in the machine.

The knowledge gained by students through study of several engineering cases and the collaborative problem solving skill which the students practiced by working in teams were very helpful to students in designing and building the above mentioned digital control system (for the soft drink vending machine).

STUDENT EVALUATION

The evaluation of the students' work related to case studies and the engineering design & implementation project had three components: (1) a team grade based on the correctness, quality, and timeliness of the design and documentation of the system; (2) an instructor's assessment of each individual's contribution to the work done by his/her team; and (3) peer evaluation of every team member by his/her own team members.

CONCLUSIONS AND FUTURE DIRECTIONS

The knowledge about real-life engineering problems gained by the EET 117 students through a detailed study of several engineering cases and the collaborative problem solving skills practiced by them through teamwork were very helpful to them in the design and implementation of a practical digital control system for a vending machine. The documentation submitted by the student teams reflected the experience and the knowledge that the EET 117 students had gained through a study of engineering cases and through working collaboratively in teams.

The case-based teaching approach along with the team based collaborative problem solving will be used again in the EET 117 course in Spring 1998. The hardware implementation of the digital control system for the vending machine will be carried out in EET 120.

INNOVATION IN DIGITAL ELECTRONICS LABORATORIES (EET 120) TAUGHT AT PENN STATE ALTOONA

In the past the laboratory (EET 120) for the digital electronics course (EET 117) used a laboratory manual with a traditional experiment format. In the traditional laboratory sequence, the students performed eleven digital experiments with the following content: Introduction to Test Equipment, Input/Output Circuits, Logic Gates, Combinational Circuits, Arithmetic Circuits, Clock and Pulse Circuits, Sequential Circuits, Decoding and Multiplexing, Counters and Shift Registers, and State Counters. The final three weeks were used for the design of a soft drink machine controller project. In each laboratory, eight teams with two students each built the digital circuit on IC proto boards, tested the circuits performance, and documented the results in bound laboratory note books. A copy of the laboratory note book from each student was submitted for grading.

Analysis of the laboratory exercises and process by the faculty, results from student interviews, and surveys of the students revealed the following problems with the traditional sequence.

- Students viewed the digital content as isolated topics and had difficulty integrating the concepts in the design phase of the course.
- The laboratory exercises did not have any significant design component.
- The level of difficulty associated with the design project was limited due to the three week time period.
- The quality of the final project formal report was rarely at the level desired because the report had to be generated just before the start of final exams.
- Student interest in the design project was high but interest in the exercises was lukewarm at best.

TEAM BASED DESIGN APPROACH

The process and content from the current experiment sequence was reviewed to determine how the laboratory experience could be improved. The review indicated that the drink machine controller project should continue to be used because the project is scaleable. The level of project difficulty is adjusted by changing the cost of a drink, changing the number of different coins that can be used, and by adding other options such as ice or no ice and returning change in different coin mixes. The highlight of the course was the design project in the last three weeks; however, due to the short time frame less than half of the student groups were able to get their systems completely operational. Students were frustrated by the incomplete final projects, the short time provided for generation of the final formal report, and questioned why so little time was spent on the part of the laboratory they enjoyed. As a result of this review, the experiment sequence was inverted and the design project was made the primary focus of the laboratory. The new digital laboratory sequence had the following characteristics.

- The class was divided into four teams of four student.
- Each team member was responsible for the design and testing of a major subsystem component in the drink machine controller. The function of the subsystems were dictated by the overall control strategy adopted by the team, but in most cases the subsystems included: sequential circuit design, decoder and display design, and clock and timing circuit design. In all the projects, the subsystems included a minimum of 90 percent of the learning competencies that were present in the previous experiment sequence. The assignment for the fourth team member was team project director and system integrator.
- The subsystem component designers from the four teams were encouraged to collaborate with the similar specialist from the other teams.
- Each designer was required to brief the rest of the team on the design process, resulting circuit, and test results for the subsystem design they produced.
- Each team member was responsible for the part of the final report dealing with their design area. The project coordinator had the final responsibility for integrating all of the team contributions into a well written final report.
- The project coordinator assisted other team members in troubleshooting and locating design, bread-boarding, and testing errors.

- The design was documented on a weekly basis in the bound design logbook and preliminary drafts of the final report were required at weeks four, eight, and twelve.
- The subsystem designs were tested using Pspice before bread-boarding and were drawn in Electronic Workbenck for documentation.

THE NEW PROCESS

The activities for the fifteen weeks of laboratory were redistributed as follows:

Week	Activity
1 – 4	Week 1: Formation of eight teams with two students per team, introduction to the laboratory and basic test equipment, and an overview of the laboratory requirements. Week 2, 3 and 4: Basic experiments using gates and counters to familiarize the students with the two basic building blocks of digital systems.
5	Introduction of the design problem and team brainstorming on general solution options. Reduction of the class to four teams of four students per team, assignment of subsystem design components to team members, and assignment of the team project coordinator.
6 - 9	Subsystem design, software analysis, bread-boarding, testing, and drafting portions of the final report.
10 – 12	Integration of the subsystems into an operational machine controller.
13 – 14	Integration of all the subsystem drafts into a final report.
15	Demonstration of operational systems to the class and industry visitors. Oral reports on the design results.

CONCLUSIONS

The new laboratory process for the EET 120 Digital Electronics Laboratory was a significant improvement over the previous process when judged on student interest, development of team skills, design experience achieved by the students at the component, circuit, and system level, the number of projects that were 100 percent operational, and the quality of the final reports. In addition, the new format provided students with the opportunity to teach peers as they briefed their team on the design process and results of subsystem design work. Students experienced the fun associated with the design and implementation of a digital control system while working through the frustration associated with design, bread-boarding, testing, and peer interaction issues.

The new structure did create some problems that should be addressed. The most significant problem was that the competencies needed for the designs often occurred in the laboratory before it was presented in the lecture portion of the course sequence. If the same instructor was teaching both portions of the sequence that problem could be eliminated. In this offering, the laboratory sections and lecture section were taught by different instructors. To overcome the problem, it was necessary to hold mini-lectures in the lab with students from each team who were working on specific sections of the controller. However, these mini-lectures provide a forum for lively discussion of design issues, options, and compromises. Other problems included additional stress in teams when a member did not participate 100 percent in the project, but the team members learned what a real life design project is like. This problem was minimized because the team members knew that they would be graded by their team peers at the end of the semester on the level of contribution to the success of the project. Adoption of this laboratory model is recommended for all future digital laboratory offerings.

BIOGRAPHY

SOHAIL ANWAR - Sohail Anwar obtained a Ph.D. in Industrial and Vocational Education from The Pennsylvania State University in December 1995 and an M.S. degree in Electrical Engineering from the University of Texas at Arlington in May 1982. He completed additional graduate coursework in control theory and applied mathematical sciences at the University of Texas at Arlington during 1982-1984. Since August 1992, Sohail has been working as an assistant professor of engineering and Department Coordinator of Electrical Engineering Technology at Penn State Altoona.

JAMES A. REHG - James Rehg received a B. S. and M. S. in Electrical Engineering from St. Louis University and has complete additional graduate work at the University of South Carolina and Clemson University. Since August 1995, Jim has been working as an assistant professor of engineering and Program Coordinator of the B. S. program in Electro-mechanical Engineering Technology at Penn State Altoona. He is the author of five texts including the following Prentice Hall texts: Introduction to Robotics in CIM Systems and Computer Integrated Manufacturing.