AC 2007-700: INTRODUCING THERMAL AND FLUID SYSTEMS TO INDUSTRIAL ENGINEERING TECHNOLOGY STUDENTS WITH HANDS-ON LABORATORY EXPERIENCE

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Abstract

This paper describes a thermal-fluid systems course integrated with hands-on laboratory components to improve students learning. The course is assessed using student surveys, portfolio reviews and Accreditation Board for Engineering and Technology (ABET) outcomes. Overall, this course advances active learning through integrated thermal and fluid system educational components that comply with the Accreditation Board for Engineering and Technology (ABET) learning outcomes specified for Industrial Engineering Technology Programs.

Introduction

The industry needs technology graduates who can use combination of thermal and fluid science concepts in the design, installation, and service of products and production systems[1]. During the past few years, many universities have developed new thermal-fluids courses and others have modified their existing courses[2-5].

The Department of Technology Systems at East Carolina University supports the development of the trade and Industry in eastern North Carolina by providing professionals that cater to the needs of the region. The department has five undergraduate degree programs that include Mechanical Technology and Industrial Engineering Technology. Students in the department are engaged in hands on activities beginning the first semester as compared to long-established programs that wait for several semesters or years to expose students to technology courses. During the preceding years, notable efforts have been made by the department to alter and modernize instruction by incorporating hands-on lab experience.

The Thermal and fluid systems course is a 3 credit hours course , 2 hours lecture and 2 hour lab per week. This is a sophomore level course intended for students with a background in Physics and Material Science fundamentals. These include the basic elements of the design and analysis of thermal and power systems including boilers, air conditioning, refrigeration, pumps, compressors, heat exchangers and piping systems. The course is supported by a team-oriented, active-learning based laboratory component. The students are given wide-ranging instructions and procedures to carry out the experiments using effective learning strategies [6].

Course Description

The course is planned to give students a general idea and skills in thermal-fluid systems, an prospect for hands-on laboratory work and to support students interested in majoring in technology related professions. One of the desired goals of the course is to incorporate laboratory experiments that will be performed by the students to further attract their interest in thermal-fluids area and to generate real-world data sets for processing, analysis and reporting.

The thermal and fluid systems course is required for all students graduating with degrees in Industrial Engineering Technology, Design and Distribution. The course is described as the design and analysis of thermal and power systems including boilers, air conditioning, refrigeration, pumps, compressors, heat exchangers and piping systems. The semester is covered over a time period of fourteen academic weeks. The lecture is broken into two parts. The first part deals with the principles and applications of thermal systems followed by fluid systems. Table 1 provides the details of laboratory components along with the hardware and software used to achieve the objectives.

The course is designed to achieve several objectives. Upon completion of this course each student should be able to:

- Develop a basic understanding of thermodynamics.
- Define the thermal efficiency, second law efficiency, and energy availability.
- Develop an intuitive understanding of how to apply the first and the second law of thermodynamics to different thermal systems.
- Develop a basic understanding of heat and its applications.
- Develop a basic understanding of applied thermal systems.
- Demonstrate the knowledge of the basic refrigeration and heat pumps cycles.
- Apply the basic heat transfer laws governing different modes of heat transfer (conduction, convection and radiation).
- Develop a basic understanding of Fluid mechanics and its application.

Course component	Lab Hardware/Software and Student Learning
Thermal	▪ Experiment: Calibration of temperature measurement devices *Equipment*: OMEGA HH68K Thermometer, OMEGA OS546 Infrared Non-Contact Thermometer (K-Type Thermocouple) and OMEGA HH64A Thermometer with K-type Thermocouple. *Supplier:* Omega Engineering Incorporated. ▪ Experiment: Heat Transfer *Objectives*: To develop an understanding of heat transfer, to develop an understanding of linear & radial heat conduction, to experimentally measure the temperature distribution for steady state heat flow and to experimentally determine the thermal conductivity. *Equipment*: Heat transfer service unit H111, Linear heat transfer unit H111A and Radial heat transfer unit H111B. *Supplier:* P.A. Hilton Ltd. ▪ Experiment: Heat Exchangers *Objectives*: To develop an understanding of heat exchangers, to develop an understanding of counter-current and co-current heat exchange, to experimentally measure the temperature distribution in concentric heat exchangers, to experimentally determine efficiency in concentric heat exchangers, to develop an understanding of plate heat exchanger, to develop an understanding of counter-current and co-current plate heat exchangers, to experimentally measure the temperature distribution in plate heat exchangers, and to experimentally determine the efficiency in plate heat exchangers. *Equipment*: Heat exchanger service unit H101, Concentric tube heat exchanger H101A and Plate heat exchanger H101B *Supplier:* P.A. Hilton Ltd.
Fluids	▪ Experiment: Calibration of a pressure gage. *Objectives*: To Calibrate a standard Bourdon type pressure gage using a dead weight tester, to plot results of calibration on a graph using the dead weight pressure as the ordinate and indicated gage pressure as the abscissa and to discuss / report discrepancies between deadweight and gage readings. *Equipment*: TQ Education & Training System H3A. *Supplier:* TQ Education & Training Ltd. ▪ Experiment: Density and Specific Gravity *Objectives*: To develop an understanding of measuring density of Substances and to develop an understanding of measuring specific gravity of a given liquid *Equipment*: TQ Education & Training System H314 Hydrostatic Bench *Supplier:* TQ Education & Training Ltd. ▪ Experiment: Viscosity measurement

Fluids continued.	*Objectives*: To gain experience in performing viscosity tests. *Equipment*: Saybolt Universal Viscometer. *Supplier:* Koehler Instrument Company. ▪ Experiment: Venturi as a flow measurement device *Objectives*: to study the axial distribution of pressure and velocity of a fluid flowing through a venture meter and to determine the discharge coefficient of the venture meter. *Equipment*: Venturi Meter H5 and Volumetric Hydraulic Bench H1d TQ Education and Training Ltd *Supplier:* TQ Education & Training Ltd. ▪ Experiment: Centrifugal pump performance characteristics. *Objectives*: To understand the operation of the centrifugal pump and it's operating characteristics. *Equipment*: Series and Parallel Pump Test Set H32 and Volumetric Hydraulic Bench H1d, *Supplier:* TQ Education & Training Ltd. ▪ Experiment: Jet impact force on a vane *Objectives*: This experiment demonstrates the relationship between the impact force exerted on a vane by a water jet and the mass flow rate of the jet. *Equipment*: Vane Test Set and Volumetric Hydraulic Bench H1d, *Supplier:* TQ Education & Training Ltd.

Table1: Course and lab components (hardware and software) and their relationships to student learning.

Sample hands on laboratory group experiments

Figure 1 shows the setup of a sample experiment for a steady state heat conduction system lab experiment and students engagement through team work. In this experiment students measure the temperature distribution for steady state conduction of energy through a composite plane wall and determine the overall heat transfer coefficient for the flow of heat through a combination of different materials in use. Here students work on a bench top heat transfer service unit designed to support seven optional heat transfer experiments which in turn demonstrates one or more fundamental methods of heat transfer.

The seven optional units are:

- Linear Heat Conduction
- Radial Heat Conduction
- Laws of Radiant Heat Transfer & Radiant Heat Exchange
- Combined Convection and Radiation
- Extended Surface Heat Transfer
- Radiation Errors in Temperature Measurement
- Unsteady State Heat Transfer

Figure1: Students engaged in constructing and executing the experiment

Students are required to calculate the heat transfer rate, overall heat transfer coefficient, plot the temperature against position for different thermocouple, discuss all possible sources of error and discuss results. The specimen cross sectional area is 0.00049 m^2, conductivity of brass heated and cooled sections are 121 W/mk and the conductivity of stainless steel intermediate section is 25 W/mk.

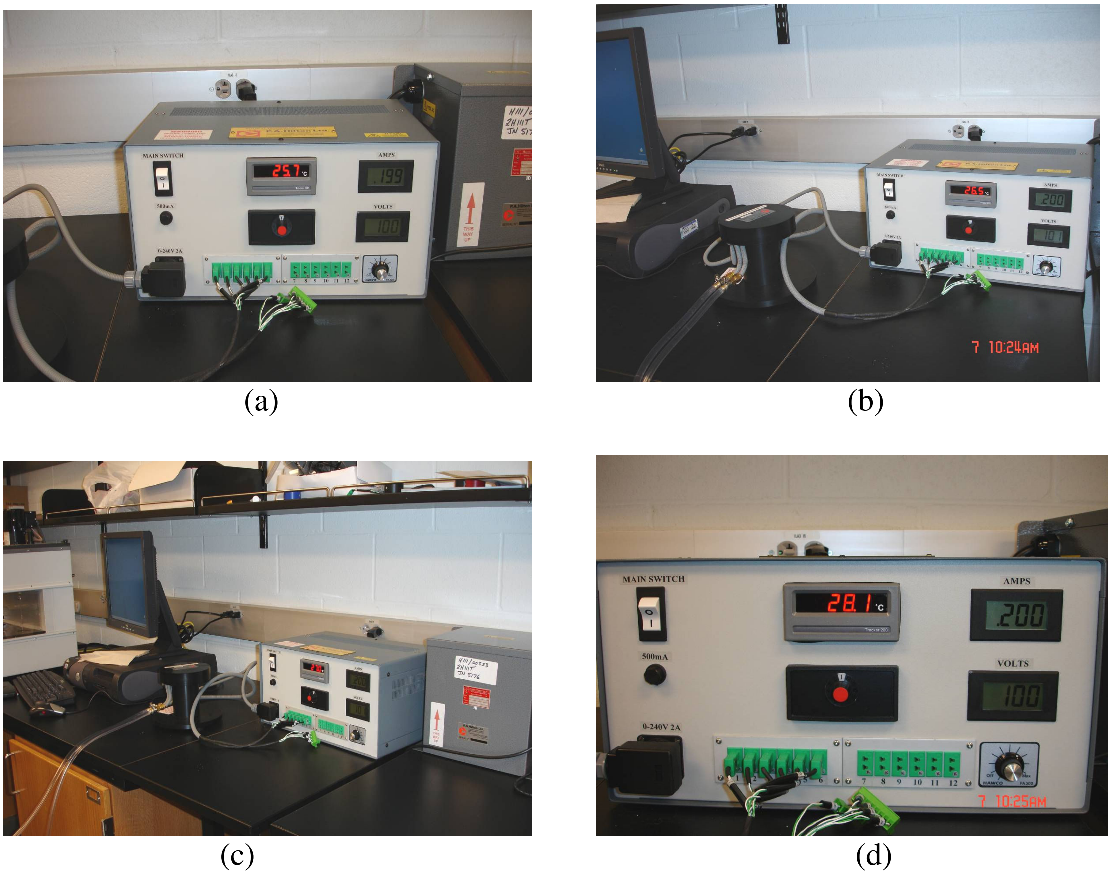


Figure2: Experiment Components and Interfaces

Figure 2 depicts the heat transfer service unit that students conduct the thermal conductivity experiment on. Figure 2(a) represents the front panel of the unit in which the thermocouple probes are inserted to digitally read the temperature values at various cross-sections of the specimen, for which the thermal conductivity has to be determined. Figure 2(b) depicts the heat conduction unit in which the specimen is inserted along with the thermocouples and through which the water is circulated. Figure 2(b) and 2(c) are in place to expand the views of (a) and (b).

Each group of students was required to submit reports for experiments in two forms: a data log book and a formal report. Each student was responsible for maintaining a data log book and the group was responsible for the formal reports. Each experiment was written in data ledgers (composition book) kept by each individual in the lab. The logbook was filled out as the experiment was conducted. Each experiment was reported in the following order;

- Title of experiment
- Objective of experiment
- Date performed
- Members in group
- Projected procedure
- Equipment used

- Data and tables
- Observations made during experiments

The formal reports were broken down into four sections. Each person in the group was responsible for different sections of different reports. The sections that were grouped together were as follows.

Section 1: Summary
Section 2: Theory, governing principles and standards
Section 3: Equipment and data
Section 4: Analysis, discussion and procedure/method

The reports were required to have a title page, bibliography and references. The order in which information was presented was as follows:

- Summary: A brief statement of the objective of experiment and findings in terms of results.
- Introduction and theory: The underlying principle, standards and methods used as guidelines for the experiment.
- Procedure/method: The students were required to state the procedure used by the group. They were also required to reference equipment list and indicate how the equipment was used.
- Equipment: The students were required to list all equipments including maker, model number, ranges, and neat sketch of apparatus set up showing relation and use of each piece of equipment.
- Conclusion: The students were required to include a brief discussion of the conclusion they derived.

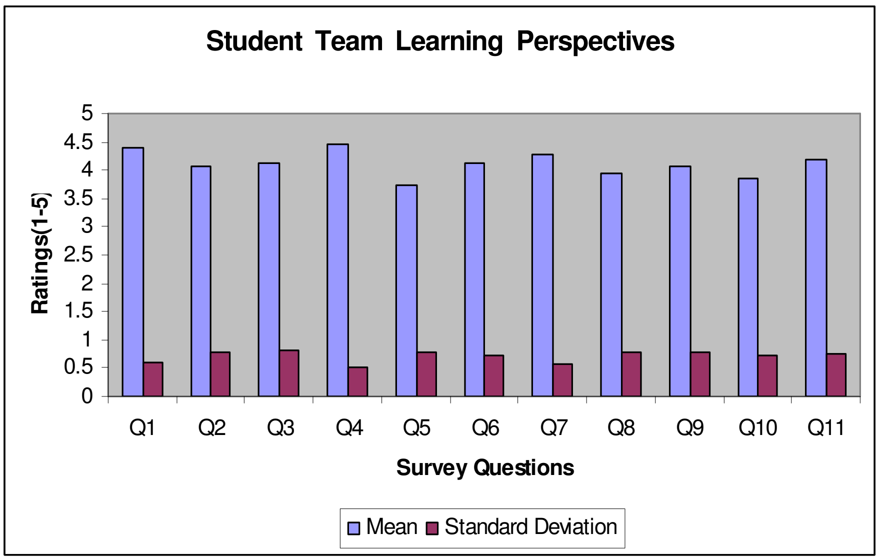
Evaluation and Assessment

The students were surveyed in the class with respect to their learning achievements in a collaborative team environment [7]. The survey results presented in Figure 3 depicts the mean and standard deviation of student achievements results in relation to each survey question. The mean value of each survey item indicated the average score of the student evaluation while the standard deviation indicated the deviation from the mean and the frequency of such deviation. Scale of 1 indicated that the students needed to improve on a particular skill while a scale of 5 indicated that the students did well.

It was observed that the students did well in the areas of listening skills, skills to receive feedback and skills to receive feedback from other team members. The students performed acceptably in the areas of evaluating the performance of other team members, team feedback, team communication, project management, negotiating skills leadership and adapting to different cultural norms of team members. These skills are extremely useful for the success of a team and its assignments. These skills helped students distribute their workload, reinforce individual capabilities, create participation and involvement, make better decisions and generate diversity of ideas.

From the survey results, it was also evident that the students required improvement in the areas of managing a team and skills to adapt to different cultural norms of team members. Additional student comments are provided in Table 2.

The Industrial Engineering Technology program seeks to be accredited by the Technology Accreditation commission (TAC) of ABET. Therefore every new course needs to be assessed against the published engineering technology specific ABET criteria. The course level assessment with respect to ABET criteria is provided in Table 3. Here K indicates knowledge, A indicates application and M indicates mastery of course competencies attained by students with respect to ABET criteria 3. .



Area of Student Improvement
Q1. Listening skills
Q2. Skills to evaluate the performance of other team members
Q3. Skills to provide constructive feedback to team members
Q4. Skills to receive feedback from team members
Q5. Coaching skills
Q6. Negotiating skills
Q7. Skills to communicate with other team members
Q8. Skills to manage a team project
Q9. Skills to be a team leader
Q10. Skills to adapt to differences in team members' work styles.
Q11. Skills to adapt to different cultural norms of team members

Figure 3: Results of students learning achievements.

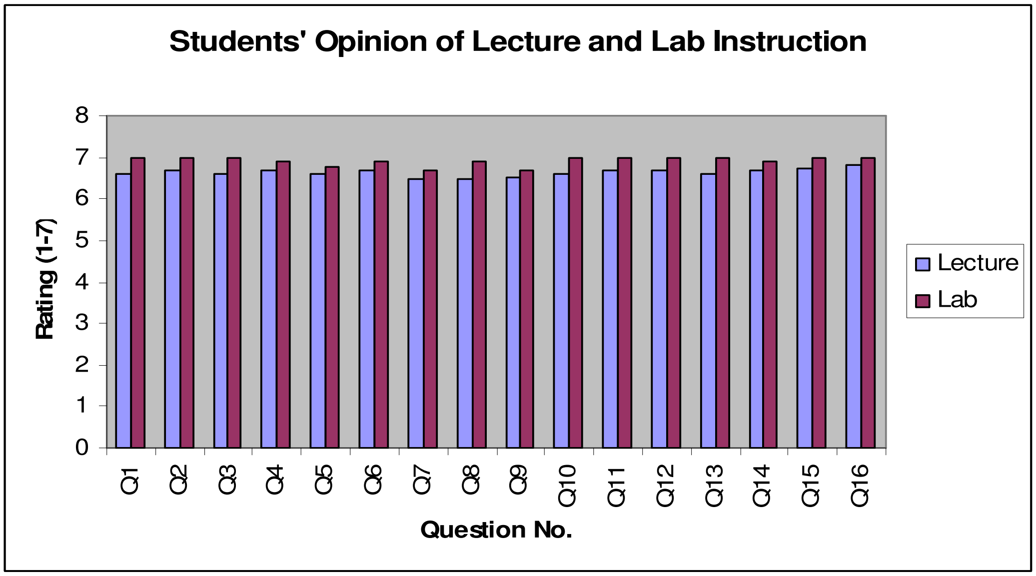
Student assessment results were satisfactory and provided useful pointers for class and group work definitions to be attained by future engineering technology students. Student assessment results indicate the need for improvement in team members adapting to different cultural norms and work styles within the team. There is also a need for individual team members to provide constructive feedback to fellow team members. Course level assessment indicates satisfactory fulfillment of ABET program outcomes towards the accreditation requirements of the overall program.

Student	Comments
Student 1	**“**From hearing form other team member and mine that there had been quite a few instances where group members did not show up or do their part of the report and other people had to pick up their work”.
Student 2	**“**I like leasing a team more than managing a team. I don’t like keeping track of what everyone is doing, but I like to offer some direction. Everyone has a skill they excel at more than others”
Student 3	**“** I need to work on my methods of providing feedback to other team members”
Student 4	“I’m friendly and sociable person. I have the skills to know how to get the job done on time. “

Table 2: Student comments on their perspective of team learning achievement

ABET [8] Program Outcomes (a-k): Criteria 3	K	A	M
a) An appropriate mastery of the knowledge, techniques, skills and modern tools		X	
b) An ability to apply current knowledge and adapt to emerging applications of mathematics, science, engineering and technology.		X	
c) An ability to conduct, analyze and interpret experiments and apply experimental results to improve processes.			X
d) An ability to apply creativity in the design of systems, components or processes.	X		
e) An ability to function effectively on teams.		X	
f) An ability to identify, analyze & solve technical problems.		X	
g) An ability to communicate effectively.	X		
h) A recognition of the need for, and an ability to engage in lifelong learning.			
i) An ability to understand professional, ethical and social responsibilities.			
j) A respect for diversity & knowledge of contemporary professional, societal & global issues.	X		
k) A commitment to quality, timeliness, & continuous improvement.	X		

Table 3: Course level assessment with respect to ABET criteria 3



Questions related to the Students Opinion of lecture and Lab Instruction
Q1. The instructor has created an atmosphere of helpfulness.
Q2. The instructor has informed the students about criteria for grading.
Q3. The instructor has made the objectives of the course clear.
Q4. The instructor has been well prepared for each class.
Q5. The instructor has shown enthusiasm in teaching this course.
Q6. The instructor's course evaluation methods (quizzes, exams, papers, etc.) have been fair.
Q7. The textbooks used have been appropriate for this course.
Q8. The class has challenged students to learn course materials, concepts and skills.
Q9. The instructor's syllabus has clarified expectations of this course.
Q10. The instructor has provided opportunities to ask questions.
Q11. The assignments, including reading and projects, have contributed the students understating of the subject.
Q12. The instructor has been available to students outside of class.
Q13. The instructor has provided useful feedback when returning tests and assignments.
Q14. The instructor has demonstrated respect for students.
Q15. When applicable, the instructor has provided different points of view towards the subject.
Q16. The instructor has tested on materials emphasized.

Figure 4: Students' opinion of lecture and lab Instruction.

The students had a positive rating for the delivery of instruction. Overall, the students felt that the Instructor did very well (greater than 6.5) in all elements of instruction. But the most important feedback as depicted figure 4, suggests that the students rated the laboratory instruction higher than lecture. These results validate the strengths that the laboratory based components bring to a curriculum thereby enhancing student learning experience.

At the end of each semester each instructor in the department completes a course improvement summary log to create an archival record of how each course competencies were accomplished and how improvement will be made for subsequent offerings of the course. Table 4 summarizes the problems identified, assessment tools and remedies recommended for the current semester.

Improvement summary log [9]

Course: ITEC 2080/2081 **Date: Spring 2006**

This document summarizes changes that will be implemented to improve the effectiveness of this course, based on feedback from students, faculty, surveys, and other assessment means.

Problem Diagnosed	**Assessment Tool**	**Remedy Implemented**
Students tend to forget material from physics and mathematics (units, dimensions, conversions etc)	Student test results	Use the first week to go through units, unit conversions, mathematic requirements etc.(comprehensive assignment for students to recollect prior knowledge). This will be implemented in Spring 2007.
Critical lab equipments not present or improperly installed (Viscosity measurement and Heat Exchanger)	Learning Objectives	Instructor will successfully install the Heat Exchanger and the department will procure a Viscometer.
Students do not tend to adhere to lab safety requirements all the time.	Faculty Observations	Instructor will make the "carrots and sticks" of adherence to the lab safety policy, as a part of lab participation grade in Spring 2007.
Not all students tend to respect the spirit of team work.	Faculty Observations	The instructor will make team evaluation as a pert of the lab grade in Spring 2007.

Other Notes: Conducted SOIS and course specific team learning survey.

Table 4: Course Improvement Summary Log

Lessons learned

Student assessment results indicated the need for improvement in team members adapting to diverse cultural norms and work styles within a team. It also indicated a need for individual team members to provide constructive feedback to fellow team members. One of the key lessons learned was that the students need to work on their communication skills in order to covey their ideas smoothly to fellow team members. Though course level assessment indicated satisfactory fulfillment of ABET program outcomes towards the accreditation needs of the overall program, there is still a need for some components of the course to cover more outcomes at the levels of application and mastery.

It was also observed that lab equipped with all critical equipments provides a better learning environment. Also, effective review of previous materials (pre-requisite contents) is paramount to student success in the course.

It was observed that the students do not tend to adhere to lab safety requirements all the time. Therefore instructors who teach such courses may adopt a "carrots and sticks" policy wherein, adherence to lab safety policy may be a part of lab participation grade. It was also observed that not all students tend to respect the spirit of team work. Therefore, instructors teaching such courses may make team evaluation a part of the lab grade.

The results of the student opinion of instruction conveyed that hands on instruction with laboratory components fosters active learning and creates a better environment for students to absorb the contents of instruction.

Conclusions

The Department of Technology Systems at East Carolina University has embarked on this undertaking to improve the learning experience of industrial engineering technology students. The department faculty at ECU are working together to take this course into advanced levels of assimilation through laboratory experiences which imitate real world scenarios. Hence, our approach will help develop students' understanding of educational components from both mental analysis and hands-on viewpoints.

References

1. Rehg, J., and Muller, B." Interdisciplinary Automated Manufacturing Laboratory," Proceedings of the 1996 ASEE Annual Conference, Session 1463.

2. Mueller, D., "A New Design of Thermal-Fluid Systems Elective: Description, Observations, and Experiences," Proceedings of 2006 ASEE Annual Conference.

3. Ardebili, M., "Active-Learning Based Laboratory For Introductory Thermodynamics Course," Proceedings of 2006 ASEE Annual Conference.

4. Bailey, M. and Chambers, J., "Using the Experiential Learning Model to Transform an Engineering Thermodynamics Course", 34th ASEE/IEEE Frontiers in Education Conference, 2004, Savannah, GA

5. Bean, J., Carroll, J., Dempsey, J., Strong, A., and Wilcox, W., "Adding A Hands-On Laboratory Experience To The Freshman Engineering Programming Class At Clarkson University," Proceedings of 2006 ASEE Annual Conference.

6. Somerton, C., And Benard, A., "Developing A Design Based Alternative Energy Course," Proceedings of 2006 ASEE Annual Conference.

7. Agarwala R., Salam A. T., Sander C.; A New Undergraduate Course in Electromechanical Systems for Industrial Engineering Technology; Proceedings of 2007 ASEE Annual Conference.

8. Website: www.abet.org

9. Department of Technology Systems, East Carolina University; Continuous Improvement Plan.