DAVIS EDUCATIONAL FOUNDATION

Grantee: University of New Haven Interim Report ____ Final Report __X__

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Project Title: Project to Integrate Technical Communication Habits (PITCH)

Date Awarded: July 2, 2012 **Amount Granted:** $185,500 **Term:** 3.5 years

Executive Summary

The goals, as initially proposed, of the Project to Integrate Technical Communication Habits (PITCH) were to:

- Produce graduates whose skills in professional communication enhance their career opportunities, or preparation for graduate studies
- Provide a sequential structure for teaching and learning that integrates development of professional communication skills in required courses across the engineering curricula
- Ensure the sustainability of that structure
- Develop assessments that lead to continuous quality improvement
- Share project knowledge both inside and outside the higher education community

All these goals have been achieved. PITCH has had a transformational effect within all the engineering and computer science programs in the Tagliatela College of Engineering. Technical communication skills of students are now developed over all four years of their undergraduate studies by integrating written, oral and visual communication assignments in required engineering and computer science courses. Specifically, the pathways across all programs consist of the development of:

1. Skills in writing technical memoranda starting with the first semester freshman course *EASC 1107: Introduction to Engineering*, and reinforced in the second semester course *EASC 1112: Methods of Engineering Analysis* and the sophomore course *EASC 2221: Introduction to Modeling of Engineering Systems*.
2. Skills in displaying data through graphs and tables in the second semester freshman course *EASC 1112: Methods of Engineering Analysis*, and reinforced in subsequent courses.
3. Oral communication skills in the freshman second semester course *EASC 1109: Project Planning and Development*.
4. Skills in writing laboratory reports in junior year disciplinary courses.
5. Skills in writing proposals and comprehensive engineering reports, and preparing and presenting posters, in disciplinary senior design courses.

Guidelines for writing technical memos, displaying data through graphs and tables, writing laboratory reports, writing proposals, writing engineering reports, and making oral and poster presentations were developed as part of PITCH. These guidelines are consistently used in all the courses referred to above, as well as in other courses and are available at www.newhaven.edu/engineering/PITCH/482611/. In addition, copyright for David Adams's book *COPE: A Technical Writing Guide for Engineers* was assigned to the University of New Haven and a third edition of the book was produced. The book is sold at a very nominal cost to all incoming freshmen and transfer students, and all faculty involved with PITCH courses receive a desk copy.

The paper by Harichandran et al. (2014b) describes the accomplishments during the first two years of PITCH and is included as Appendix A.

In summer 2015, the writing of select students over three years was reviewed and rated to conduct a preliminary assessment of the success of PITCH. The paper by Erdil et al. (2016) describes the results of this preliminary assessment and is included as Appendix B. Only in spring 2017 will there be a cohort of students who will have completed all four years of PITCH and a more complete assessment will be performed in summer 2017.

As PITCH was implemented over the first two years of the grant period, it became clear that in addition to providing written resources to students, formal instruction in technical communication was needed. While the integrated approach brought a strong focus to technical communication, there was insufficient time during most class meetings to discuss and reinforce effective communication techniques. A second problem was consistency in instruction. Several full-time and adjunct faculty are involved in teaching the courses and despite training many of them through summer workshops, consistent delivery of the technical communication material was problematic. To address these two needs, Dean Ron Harichandran proposed that four e-learning modules be developed and integrated into courses. Eight faculty members (Michael Collura, Jean Nocito-Gobel, Nadiye Erdil, Judy Randi, Eric Brisart, Sam Daniels, Amanda Simson and David Harding) developed the e-learning modules in summer and fall 2015 and spring 2016. The modules were to be used during the freshman, junior and senior years. Dean Ron Harichandran oversaw the module development and the University of New Haven's Office of E-Learning provided support. These modules will be piloted during the 2016-17 academic year and fully integrated into all programs beginning in fall 2017.

PITCH will be sustained following the end of the grant from the Davis Educational Foundation. Professor Judy Randi, who is currently with the Department of Education, will join the Tagliatela College of Engineering in fall 2017 to support and coordinate PITCH.

Work Implemented as Part of PITCH

The paper by Harichandran et al. (2014b) provides details regarding the work implemented in engineering and computer science courses as part of PITCH. The paper is included as Appendix A.

Preliminary Assessment of PITCH

The paper by Erdil et al. (2016) provides details of a preliminary assessment of PITCH. The work of select students from several programs was used in this preliminary assessment and the results indicate that the technical writing of students showed noticeable improvement as a result of PITCH. The paper is included as Appendix B. Further improvement in student performance is expected as the e-learning modules described below are deployed.

E-Learning Modules Developed to Support PITCH

In the course of integrating technical communication into the various courses the faculty identified a critical need. Although written advice tables and guidelines were made available to students, not all of them learn by reading the materials. Other methods of teaching students the elements of technical communication related to their assignments are needed. Unfortunately, because of the need to cover technical content, instructors are unable to spend time to teach technical communication concepts in the courses.

E-learning modules covering the content to be delivered in support of each technical communication product (technical memos, oral and visual presentations, displays of data, laboratory reports, senior design proposals, senior design reports, and poster presentations) were developed in summer and fall 2015 and spring 2016. The eight faculty members who developed these modules were first trained by the UNH Office of e-Learning and worked closely with a course designer. These modules will be deployed on a pilot basis in academic year 2016-17 and will be fully integrated into programs in academic year 2017-18. Student learning of technical communication skills is expected to increase significantly when the modules are fully deployed.

The four e-learning modules that were developed are described below.

Module 1: Short Engineering Reports

The first e-learning module to be used during the freshman year is entitled *EASC 1101: Short Engineering Reports*. Michael Collura, Jean Nocito-Gobel, Nadiye Erdil and Judy Randi developed this module as a 1-credit course that will be taken at the same time as *EASC 1112: Methods of Engineering Analysis*. The learning outcomes of this module are to:

1. Create a well-organized structure for a technical memo
2. Identify the essential elements in reporting technical work including methods used, assumptions made and important results
3. Convey the essential elements in reporting technical work including methods used, assumptions made and important results
4. Use appropriate language, tone, format, style and level of technical detail for a specific audience
5. Create data displays with proper structure and format to support recommendations

Eli Review© will be used as an electronic tool to facilitate peer review. The online instructor for the course will be Judy Randi.

Module 2: Effective Presentations

Eric Brisart developed the e-learning module entitled *Effective Presentations*. This module will be used in the *EASC 1109: Project Planning and Development* course in a flipped classroom format. Students will learn the content outside of class time and use what they learned when making several PowerPoint presentations in the course. The course instructors will provide feedback to students on their presentations so that they may improve over time. The learning outcomes of this module are to:

1. Identify how to effectively apply communication principles in developing oral presentations
2. Explain how context shapes the nature of language in a communicative interaction
3. Describe the similarities and differences between verbal and nonverbal messages
4. Distinguish between effective and ineffective practices for team delivered oral presentations
5. Distinguish between effective and ineffective practices for designing PowerPoint slides
6. Identify how to employ appropriate communication principles to diverse audiences and contexts

Module 3: Laboratory Project Reports

The third e-learning module is intended to accompany a laboratory course in the discipline. The learning outcomes covered in this module are to:

1. Develop a clear response to a customer/client request that addresses stated goals
2. Describe the methods and materials used in an experiment or simulation clearly and in a structure that allows readers to understand them
3. Summarize key results from experimental or simulation work using effective graphical communication
4. Organize complex information from laboratory or simulation work within a specified structure
5. Summarize experimental or procedural inquiry by using principles of hierarchy and subordination

The laboratory courses in mechanical and chemical engineering will be increased from 2 to 3 credits beginning in fall 2017 and the entire e-learning module will be integrated into the courses. Other disciplines plan to use select sections of the e-learning module.

Module 4: Written Communication in Engineering Design

The final e-learning module is designed to be integrated into the senior design courses in all engineering and computer science programs during both the fall and spring semesters of the senior year. The learning outcomes of this module are to:

1. Describe the major components of engineering design proposals
2. Prepare a design proposal for a project using appropriate format and relevant content
3. Interpret critical information in a request for proposal from a client
4. Create a multi-author written design proposal in response to request from client
5. Describe the major components of engineering design reports
6. Plan a comprehensive design report that documents details of design process/product
7. Create a multi-author design report to effectively document the final design process/product
8. Prepare a poster to effectively document the results of a design project

Sharing Information about PITCH

Information about PITCH has been shared with the broader engineering community in the following ways:

- A pre-conference workshop on PITCH was conducted on June 15, 2014 at the American Society for Engineering Education (ASEE) Annual Conference in Indianapolis, Indiana. Professors Collura, Nocito-Gobel, Erdil, Daniels, Harding, Dean Harichandran and PITCH consultant David Adams participated in this workshop. About 35 faculty from other institutions attended the workshop and feedback was immediate and positive.
- The paper by Harichandran et al. (2014a) was presented by Dean Harichandran at the 2014 ASEE Annual Conference and published in the conference proceedings.
- The paper by Harichandran et al. (2014b) was presented by Dean Harichandran at the international Frontiers in Education conference sponsored by the Institute for Electronics and Electrical Engineering and ASEE in Madrid, Spain in October 2014.
- Dean Harichandran will present the paper by Erdil et al. (2016) at the ASEE Annual Conference in New Orleans in June 2016.

In all of the above publications, support from the Davis Educational Foundation was noted in the papers and presentations.

References

Erdil, N. O., Harichandran, R. S., Adams, D., Collura, M. A., Nocito-Gobel, J., and Simson, A. (2016). "Preliminary assessment of and lessons learned in PITCH: an integrated approach to developing technical communication skills in engineers." *Proceedings, ASEE Annual Conference*, New Orleans, LA.

Harichandran, R. S., Adams, D. J., Nocito-Gobel, J., Collura, M. A., Thompson, A. E., Harding, W. D., and Erdil, N. O. (2014a). "An integrated approach to developing technical communication skills in engineering students." *Proceedings, ASEE Annual Conference*, Indianapolis, IN, Paper 8570.

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Appendix A

A Comprehensive Engineering College-Wide Program for Developing Technical Communication Skills in Students

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***Abstract*—The Project to Integrate Technical Communication Habits (PITCH) is being implemented in the Tagliatela College of Engineering at the University of New Haven across seven engineering and computer science undergraduate programs. PITCH develops written, oral and visual communication skills in students starting in the very first semester and continuing through all four years of each program. Communication instruments encompass technical memoranda, poster presentations, oral presentations, laboratory reports, proposals, and senior design reports, including the use of tables and graphics in each. Advice tables, annotated sample assignments and grading rubrics are being developed for each instrument to assist students in their work and facilitate consistency in instruction and assessment across multiple instructors teaching different course sections. Within each of the seven programs, specific courses that span all four years are targeted for implementation and assessment of technical communication skills. The different communication instruments are distributed across courses as appropriate, and the skills are developed at deeper and deeper levels as students progress through the years. A critical feature of the project is that technical communication skills are integrated into the content of regular engineering courses and are taught by regular engineering faculty.

Keywords—technical communication; curriculum; professional skills;

I. Introduction

Engineering colleges face a significant challenge in meeting industry expectations regarding the development of technical communication skills while trying to accommodate the ever-growing demands of engineering curricula. The Tagliatela College of Engineering (TCoE) at the University of New Haven (UNH) embarked on the PITCH (Project to Integrate Technical Communication Habits) initiative in fall 2012. PITCH engages students through all four years of college in seven ABET accredited engineering and computer science programs.

The goal of PITCH is to emphasize professional communication skills and professional habits across engineering disciplines. Many engineering colleges require students to take one or more courses in technical communication, an approach that is expensive and not always effective because it is divorced from engineering content and is often a one-time experience [1,2]. Based on earlier models developed at Michigan State University and The University of Maine, the communication skills training at UNH is woven into regular engineering courses. PITCH contains a number of features that refine and extend that model [3-6]:

- PITCH faculty developed a comprehensive set of learning outcomes based on surveys of both UNH engineering faculty and engineering alumni and employers.
- Communication assignments are based on engineering content and designed to have students achieve stated outcomes in a developmental progression throughout their programs.
- PITCH leverages technology to provide students and faculty with supporting resources.

Engineering faculty engaged with PITCH participated in ongoing training to develop and evaluate effective technical communication assignments. That step, along with using a consultant, avoids the need to hire instructors from outside engineering and will help make PITCH sustainable and cost-effective.

II. Learning Outcomes

A first step in designing the PITCH was a survey administered to alumni, faculty and employers who often hire UNH engineering and computer science graduates. The survey was designed to determine which technical communication attributes, products and professional behaviors are essential, and to inform development of communication learning outcomes. We received 124 responses from alumni and employers and 32 responses from faculty. The results of the survey (available at http://www.newhaven.edu/482669.pdf) reinforced the notion that alumni and employers really do desire technical communication skills from engineering graduates. They desire such skills both in terms of the ability to produce communication products and to exhibit professional communication habits. Responses to two particular questions are shown in Figures 1 and 2. More than 68% of those surveyed indicated that skill in technical communication played a "critical" role in hiring and promotion decisions, while another 29% marked those skills as "somewhat important." Furthermore, over 80% of those responding indicated that in their jobs they spend between 11 and 40 hours a week or more on the communication tasks: writing, reading, speaking and listening. The results of the survey indicated that alumni and employers consider technical communication skills to be critical attributes in engineering graduates. These survey results mirror those from similar surveys conducted at Michigan State University and The University of Maine [1,3,4]. Based on the survey results, faculty developed the PITCH outcomes shown in Table 1 that students should demonstrate at the time of graduation.

III. PITCH ROADMAPS

In order to ensure that the PITCH outcomes would be met at the time of graduation, technical communication products (i.e., letters, technical memoranda, short reports, formal e-mails, reports documenting experimental or simulation methods and results, and formal reports) and specific technical communication habits were distributed among course sequences in each of the seven ABET-accredited engineering programs. These distributions were planned to introduce skills and habits in introductory courses. Those skills and habits would then be reinforced and extended to new levels as students moved into more advanced courses in their programs and encountered deeper engineering content and more complex communication situations.

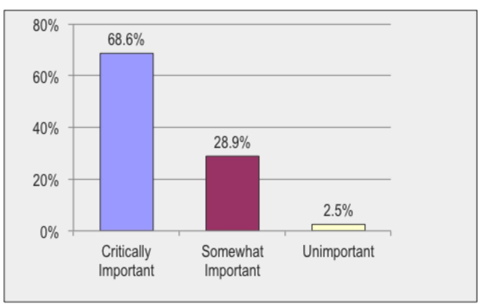

Fig. 1. Response to question: "Within my organization, to what degree are technical communications skills considered in hiring and promotion decisions?" $N = 121$.

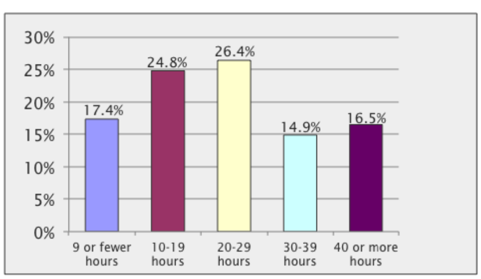

Fig. 2. Response to question: "In a typical work week, I spend about the following number of hours performing technical communication tasks (writing, reading, speaking or listening)." $N = 121$.

The TCoE offers a core interdisciplinary curriculum in the first year-and-a-half that is taken by most engineering students. These courses provide an ideal structure for consistent introduction of PITCH concepts in assignments. Technical communication products such as letters, technical memoranda, short reports, and formal e-mails were implemented in four courses that are a part of this curriculum. Reports documenting experimental or simulation methods and results were implemented in second or third year disciplinary courses, and formal reports (proposals, analyses, progress reports, and design documents) were implemented in senior design courses. The sequence of courses that developed PITCH outcomes through the four years of each program are depicted in www.newhaven.edu/engineering/PITCH/roadmaps/. Students receive the roadmaps at the beginning of their first semester so that they can see how they will experience PITCH throughout their program.

IV. FACULTY TRAINING

Most engineering faculty teaching PITCH courses were not previously trained to deliver instruction related to the development of technical communication skills in students or to effectively assess and provide feedback on technical communication products. The external consultant conducted three-day workshops during the summers of 2012 and 2013, and two previously trained faculty led a workshop in summer 2014, to train faculty to accomplish these tasks. Items covered in these workshops included inclusion of PITCH outcomes in course syllabi, developing effective technical communication assignments, development and use of rubrics to facilitate consistent evaluation of technical communication products, and use of advice tables.

TABLE I. PITCH OUTCOMES

1. Technical Communication Products	
a)	Plan, design and produce letters, technical memoranda, short reports, formal e-mails, reports documenting experimental or simulation methods and results, and formal reports (proposals, analyses, progress reports, senior design documents).
b)	Plan, prepare and deliver oral presentations and poster displays.
2. Technical Communication Habits	
a)	Use appropriate format and content;
b)	Exhibit clear, precise and logical expression;
c)	Demonstrate appropriate organization, level of detail, style and tone for a given audience, situation and purpose;
d)	Demonstrate appropriate syntax and correct usage of grammar and spelling;
e)	Highlight or identify critical information;
f)	Present, discuss, and summarize data accurately and persuasively;
g)	Write thoughtful and persuasive conclusions and recommendations;
h)	Work effectively to produce multi-author communications.

In addition to the summer workshops, the external consultant visited the university three to five times each year to work with individual faculty and conduct additional short workshops. The short workshops focused on clarity, organization, precision and economy in technical communication [6]. He also interacted with individual faculty remotely to provide continuous assistance in refining assignments and developing course resources such as rubrics, advice tables and guidelines.

To incentivize faculty participation in PITCH they were offered modest stipends to participate in the summer workshops and compensated for developing and evaluating PITCH assignments. By the end of the third year 19 full-time and 3 part-time engineering and computer science faculty were trained to deliver PITCH courses. The workshops have developed a core of faculty experienced in PITCH activities who can continue to provide training and sustain PITCH leadership after the initial external funding is exhausted.

V. Assignments and Resources in PITCH Courses

While communication assignments existed in the Tagliatela College of Engineering courses prior to PITCH, there has been a substantial effort to revise these assignments to simulate the types of situations that engineers would encounter in professional settings. The fact that a number of faculty associated with PITCH have extensive industry experience has facilitated these revisions. In addition, incorporating a defined set of learning outcomes for assignments has brought consistency and appropriate sequencing across courses. PITCH resources for the courses described below are available at www.newhaven.edu/engineering/PITCH/482611/.

A. Introduction to Engineering

The Introduction to Engineering course taken by all engineering and computer science students during the first semester of the freshman year deploys technical memoranda. General guidelines on writing technical memos are posted on BlackBoard® and discussed in class prior to each writing assignment. Although only the final two project memos are graded as PITCH assignments, students are given other opportunities earlier in the semester to begin developing their technical writing skills through feedback provided by the instructors. The Lifeboat Exercise is an individual assignment and the Structural Systems Project requires that results are reported using a memo written by each team. Both of these assignments are written in the technical memo format so that students begin to understand the difference between the direct and context driven writing style required when addressing the reader's questions/concerns in a technical memo compared with a research paper (see Exhibit I). The PITCH outcomes (see Table 1) addressed in this course are 1a, 2b, 2c and 2d.

Feedback from the initial two non-graded PITCH assignments in fall 2013 was used to develop a general advice table outlining common mistakes made by students (see www.newhaven.edu/773472.pdf). Examples are provided to illustrate these mistakes and how to correct them. The usefulness of the advice table is limited if it does not reflect the mistakes made by the students taking the course. Thus, it is expected that the table will change and expand with subsequent offerings of the course. Some faculty voiced concern that students may not read a multipage table. Thus, in addition, a one-page advice table/grading rubric was developed for each of the graded PITCH assignments (see Table II). Details of each dimension of the memo are outlined in this table and assigned weights for each dimension are given. The purpose of the advice tables [7] is to provide guidelines as to the structure and content of the specific memo in a concise format.

EXHIBIT I. Assignment Sheet for Remote Pumping Station System Project

DATE: October 1, 2013
TO: EASC1107 Students
FROM: Representative for McKim & Creed, Inc.
RE: Design for Renewable Energy System

McKim & Creed, Inc. has hired you to assess the feasibility of using a renewable energy system to deliver water to a remote town in Nepal. One of the alternatives to be considered is a pumping station powered using a renewable energy system that includes a solar cell array, an electrolyser, and fuel cells (see figure on following page). Water at the pumping station is stored in a supply tank that is supported by a base elevated 40 ft from the ground. Design requirements are listed below.

- Supply water for a town in Nepal with a population of 15,000 people;
- Assume per capita consumption rate of 50 liters of water per day per person;
- Store water in a reservoir tank with enough capacity for a three-day supply of water;
- Design a self-sufficient pumping station;
- Supply no external power to pump the water to the reservoir tank.

Because the company has limited experience with this type of system, McKim & Creed has instructed you to conduct experiments using different components of the system. Based on experimental results, determine the following:

- Current generated by solar cell;
- Hydrogen production using the solar cell & electrolyser unit;
- Hydrogen consumption by the fuel cell.

The company (instructor) will provide you with details of the experiments used to characterize the behavior of the fuel cells, electrolysers and solar cells.

Draft a memo to McKim & Creed that addresses the following:

- Renewable energy system specifications including dimensions of the reservoir tank, hydrogen and power requirements;
- Recommendation as to the feasibility of the renewable energy system;
- Discussion of design calculations including assumptions;
- Brief explanation of how the fuel cell works and the potential of using hydrogen as energy source.
- Future work to be done or alternative to the design.

Since other engineers in the company will review all designs submitted, include the following supporting documentation as attachments to the memo:

- Systems Diagrams (hierarchical, context and functional flow diagrams)
- Experimental data tables
- Spreadsheet of your design calculations.

TABLE II. GRADING RUBRIC FOR REMOTE PUMPING STATION SYSTEM PROJECT

Dimension	Expectations
Overall Quality of Memo (20%)	• Organized paragraphs • Precise & consistent terminology • Proper use of units and notation; e.g. mL not milliliters
Heading (5%)	• Complete heading according to guidelines • Includes date, recipient, sender (author), and subject line • Precise subject line
Summary Paragraph (15%)	• Concisely addresses readers' questions • Rephrases the primary question as a statement to open the memo, followed by secondary questions/results and important conclusions
Relevant Background (15%)	• Discusses hydrogen as renewable energy source • Explains how fuel cells work • Discusses how system diagrams are used in designing the system • Explains purpose for each experiment conducted • Includes schematic of renewable energy system
Discussion of Design Calculations (20%)	• Explains calculations and relevant equations included in explanation • Identifies assumptions • Summarizes results from experiments and explains how results are used in design calculations
Recommendations (10%)	• Recommendations based on data presented • Comments on feasibility of the renewable energy system • Discusses future work to be done or alternative to the design
Graphs and Tables (10%)	• Tables are organized and summarize pertinent data • Graphs/figures and tables are labeled by number with captions • Captions for tables are above table and captions for figures are below figures
Attachments (5%)	• Includes list of attachments at end of memo • Labels each attachment • References attachments in memo

Overall Grade	Percent	Grade
Technical Memo	50%	
Spreadsheet & Design Calculations	30%	
Experimental Data Used	4%	
Schematic Diagram	1%	
System Diagrams (3 Diagrams, 5 pts. each)	15%	
TOTAL GRADE	100%	

B. Introduction to Modeling of Engineering Systems

All engineering students typically take the Introduction to Modeling of Engineering Systems course in the first semester of the sophomore year. This course has two PITCH assignments emphasizing data presentation. Students are required to submit a memo discussing their work which includes tables and plots of their results. The PITCH outcomes (see Table 1) addressed in this course are 1a, 2a and 2f.

The first assignment required students to develop a model to predict voltage for a fuel cell as a function of current draw. The data provided showed a highly non-linear character to the voltage-current relationship. However, a linear model was needed. Students are asked to partition the data into three regions and provide a linear model for each region. In their memo they must discuss how they chose the cut-off points for the regions as well as the possible error in using the model. Data displays are required to augment the text discussion. In addition to the memo, they are asked to append pages from their spreadsheet, which is also evaluated on the basis of organization and communication effectiveness. The audience for the memo is a technical reader.

The second project requires students to specify a pump and pipe system for transferring water from a reservoir to an elevated storage tank. An optimization is required to determine the pipe diameter that would yield a certain incremental return on investment. Again, a technical memo is required to report results and justify choices made. The memo is to include plots and data tables. The audience for the memo is a person with a business background.

Materials provided to the students include a memo about writing memos, a guideline for plots, and a guideline for data tables (see www.newhaven.edu/engineering/PITCH/482611/).

C. Project Planning and Development

Within the PITCH roadmap, students learn about oral and visual presentations in the Project Planning and Development course. This course is typically taken in the students' first semester and is a foundational course required in most of the engineering programs. The course includes a series of weekly project status presentations that are required for about 6 weeks. In these presentations, the students update the class – the other project teams – on the status of their projects. This is designed to simulate weekly project staff meetings that are standard practice in industry where employees each take turns providing their project status updates to the team. The instructor evaluates the students' presentation effectiveness in a separate meeting immediately following the presentation and subsequently in writing utilizing the rubrics shown in Tables III and IV. The oral presentation assignments in this course address PITCH outcomes 1b, 2a, 2c, 2e, 2f, and 2h.

The assignment is given after lectures on the practice of giving effective presentations. During these lectures, the instructor models effective oral presentations and effective PowerPoint use and engages in discussion with the students.

Students are provided with the advice tables/grading rubrics shown in Tables III and IV to use as they prepare their presentations. The advice tables list a series of expectations for the students along with grading percentages assigned in dimensions shown in the tables. Grading of presentations is done using the same rubrics. The instructor provides comments on how the students can improve their future performances as well as comments on what was done well.

TABLE III. ADVICE TABLE/GRADING RUBRIC FOR ORAL PRESENTATIONS

Dimension	Expectations
Verbal Effectiveness (30%)	• Speak clearly and precisely • Speak using proper volume; person in back of room should be able to hear you and understand everything said • Modulate your volume to provide emphasis of important points • Minimal verbal static: using "um," using "you know," etc.
Non-verbal Effectiveness – Managing Space and Movement (30%)	• Maintain professional posture and body language; both presenter and team members should not speak at the same moment. • Face audience. Use your body language and movement to engage the audience, interact with the audience, and direct their responses. • Do not just read off of the screen. Instead use note cards or similar tool to refresh your memory so you will always be facing the audience. Hint: Do not stare at note cards either. Consider arranging note cards on the desk or podium in a way that you can read them at a glance. You might also create notes in PowerPoint and print those out to replace note cards. • Do not block the screen. Position yourself during the presentation so that the audience can see the screen at all times.
Presentation Organized and Balanced (20%)	• Each person gives about equal part of presentation. • Quick and smooth transitions between speakers.
Management of Time Constraints (20%)	• Delivered within time limits: 2 min +/- 20 sec. • Final presentation will have longer time constraint.

The presentation skills introduced in this course are further developed in second and third year courses and culminate in the senior design courses.

D. *Applied Engineering Statistics*

Many engineering and computer science students take the Applied Engineering Statistics course in their third year, which is required in some programs and a popular elective in others. Of the many assignments in this course, two that focus on presenting, discussing and summarizing data accurately, and persuasively are designated as PITCH assignments. The assignments require planning, designing and producing technical memos. Each assignment consists of an assignment sheet and an accompanying rubric. The assignment sheets capture: (1) the goals of the assignment, (2) assignment tasks, and (3) a checklist for completing these tasks. This course deepens the PITCH outcomes (see Table 1) 1a, 2a and 2f addressed in the Methods of Engineering Analysis course.

The first assignment is cast in the form of a technical memo to provide students a reinforced example of the memo format (see Exhibit II). The second assignment did not include a sample memo. However, the design of tasks in the second assignment required students to initiate a memo. The objective for using a slightly different structure in the second assignment was to assess students' retained knowledge of writing technical memos.

TABLE IV. ADVICE TABLE/GRADING RUBRIC FOR POWERPOINT PRESENTATIONS

Dimension	Expectations
Technical Material Covered (35%)	• Include all elements require by instructor • Status – show percent complete for major project elements
Organization of the PowerPoint Presentation (40%)	• Opening slide – show each team members name and project • Structure presentation in a logical manner following specific directions from instructor • Final slide is questions slide • Make every second count; avoid unnecessary and unrelated material such as jokes and animation
Readability of Slides (25%)	• Minimal use of color – recommend black lettering on white background. If using color, use: background blue colors and foreground contrasting colors • Use same font for entire presentation • Slides readable from anywhere in the room. Rule of thumb: you should be able to clearly read everything on your PowerPoint slide while standing 6 ft. from your own monitor

Both assignments include a grading rubric. Each category in the rubric has grade percentage allocation and requirements specifications. These rubrics were developed to guide students in producing a well-written memo, one that has necessary information in an organized and effective manner. Table V shows a typical grading rubric.

Both grading of student papers and the feedback provided are based on the rubrics. Each comment is linked to a grading criterion in the rubric to show students the areas in which they are strong and those that they need to improve. Summary comments to capture the overall performance of the assignment are also included. Furthermore, a sample memo for each assignment is provided as a learning resource.

E. *Disciplinary Courses*

Reports documenting experimental or simulation methods and results in disciplinary courses were enhanced to include PITCH outcomes in spring 2014. Guidelines for such reports, advice tables, rubrics and annotated sample reports are being developed.

Developing a common set of guidelines to span civil, mechanical, system, electrical and computer engineering and physics was a complex task. The group charged with working on disciplinary courses had one faculty representative from each discipline. At the outset it was not clear whether a common set of guidelines could be developed for all disciplines. After several weeks of discussion facilitated by the PITCH consultant, the group agreed that the components listed in Table VI are a comprehensive set, with some sections that could be optional depending on the type of document.

In fall 2014 assignment sheets, grading rubrics, advice tables and annotated model reports will be developed for each discipline.

EXHIBIT II. ASSIGNMENT SHEET FOR APPLIED STATISTICS COURSE

This assignment is designed to improve your understanding of descriptive statistics concepts, data organization and visualization, the normal probability model, and normality test. The assignment problem is intended to help you learn to compute and interpret basic descriptive statistics; to construct and interpret visual data displays; and to compute and interpret probabilities from a normal probability distribution.

Submission Guidelines

- Submit your assignment in a technical memo format prepared in word processing software. (**Hard-written assignments will not be accepted)**
- Please specify clearly any assumptions that you make.
- Prepare all visual data displays included in your submission in Minitab.
- Submit your assignment on **Blackboard** by the assignment due date.

Your Assignment

ZMD is an aerospace company manufacturing commercial aircrafts. ZMD's Aircraft_Series_900 design specifications calls for a certain bolt, Bolt_A, with a minimum ultimate tensile strength of 17.4kN. In addition, ZMD's Quality and Manufacturing department requires all supplier parts conform to 99 percent performance level with respect to part specifications.

You are a design engineer at ZMD. Your manager, Lauren Hull, has sent you the memo below. Ms. Hull has to respond to the Purchasing Department by the end of the working day. She will make a recommendation on behalf of the design department based on your report. In your report, you will address the following:

- Test the data set (provided in Assignment5_Data.xlsx on Blackboard course page) for conformance to a normal probability model, and report on your results.
  a) Compute descriptive statistics.
  b) Construct a histogram, and a probability plot.
  c) Draw a conclusion using results of (a) and (b).
- Report on the probability that a selected bolt will not conform to the specifications.
- Finally, report the level of process variation The Best Bolt Company should hold so that 99 percent of the bolts meet the strength specification.

February 17, 2014

TO: ZMD – Design Engineer
FROM: ZMD – Lauren Hull, Design Engineering Manager
RE: Bolt A for ZMD_Aircraft_Series_900

Request for Testing

NutsandBolts Co., our Bolt_A supplier for Aircraft_Series_900, is experiencing frequent production shutdowns due to an internal problem. Our purchasing department must find another Bolt_A supplier to prevent any impact on our production due to delayed Bolt_A deliveries from NutsandBolts Co. The Best Bolts Company is one of the potential suppliers.

The Purchasing Department has to secure the Design Engineering Department's approval before proceeding to a part purchase agreement with the Best Bolts Company.

You must warrant whether the Best Bolts Company parts are acceptable for use in our Aircraft_Series_900 production. The purchasing department has 124 Bolt_A samples from the Best Bolts Company, available for you to test their ultimate tensile strength.

Submit a report on your findings no later than 3:00pm, on February 18, 2014.

TABLE V. GRADING RUBRIC FOR APPLIED ENGINEERING STATISTICS

Component	Specification
Written Report (10%)	• Structure report in a clear, easy to follow format • Use correct statistical terminology • Include data important to discussion within the text; give complete data information in an appendix with a brief note to that effect in the text • Provide references for the source of any information in work that is not yours such as data obtained from other sources • Provide report in one document prepared using word processor software • Prepare all visual data displays included in submission in Minitab
Memo Format (10%)	Include the following structure in memo: • **a heading**: includes the recipient, the sender (author), the subject, and the date • **a summary paragraph**: presents a summary of the entire memorandum, reports the most significant results • **a main body**: provides more detailed results including visual displays • **a concluding paragraph**: includes summary of the major points. • **an appendix**: includes extreme detail such as tables of raw data, the full set of values, etc.
Descriptive Statistics (20%)	• Compute all relevant descriptive statistics • Include computer outputs (if calculated by software) • Include formulas and calculations steps (if calculated manually)
Visual Data Displays (Histogram and Probability Plot) (20%)	• Use clear headings to identify purpose • Label the plot (meaningful title, properly labeled axis including units) • Include meaningful and easy to understand legend if needed • Include a descriptive caption for all visual data display
Probability Calculations (20%)	• Compute all relevant probabilities • Include computer outputs (if calculated by software) • Include formulas and calculations steps (if calculated manually)
Interpretation & Justification (20%)	• Discuss results of data analysis to formulate a conclusion • Provide appropriate numerical summaries and related discussion • Include appropriate interpretation of visual displays • Justify explanations through visual data displays and/or numerical summaries • Specify clearly any assumptions made

F. Senior Design Courses

PITCH activities in the Tagliatela College of Engineering culminate with the senior design experience. The series of technical communication activities in senior design courses follows the general pattern described here with some variation between the various disciplines. These PITCH activities are being or have been developed with input from the six engineering programs and the Computer Science program offered by the college. Since the design activities within the

TABLE VI. COMPONENTS OF LABORATORY REPORTS

Lab Report Component	Component Description
Letter of Transmittal, or Memo of Transmittal a.k.a. memo (Accompanies the report, one page, not technical)	• A transmittal letter (for external audiences) or memo (for internal audiences. These brief formal letters follow an employee (or lab instructor) assigned standard format. Limit to 1 page- as small as 1 paragraph, includes any anomalies that occurred.)
Cover Page	• A single page that normally includes title, author (s) name, names of colleagues, the course name, and the date the work was done and the date the report was written. • The format and content are specified by those requesting the report. • A graphic may be used to show company/university affiliation or to show major lab setups.
Abstract (formal, documents work for archiving)	• Consists of no more than 150-250 words. • States the *major* objectives. Not in physics where research can be very open ended and not goal driven. • Briefly describes the methods and materials employed, especially if they are novel or unfamiliar. For established methods, a name for the technique or key equipment is given. • Summarizes *important* results and conclusions.
Table of Contents	• A list of section titles used in the report, with page numbers to the right.
Executive Summary (strategic document, ~5% of total length of report, at the beginning of report)	• Similar to an abstract but targeted to those who may be making decisions based on the content of the report. Larger audience, external sponsor. • Clear and concise statement of results and conclusions. Length varies.
Introduction	• Lists objectives of the study in order of importance. (Not for more open ended scientific research. The psychological intent of the researcher is seldom mentioned.) • Provides background on the experiment, including relevant theory on which the experiment is based. • Theory may be included, equations are numbered. • Citations and discussion of important previous studies.
Literature Review	• For thesis work where the uniqueness of the research must be established or to provide a broad context for the work. Citing relevant work can allow the report to be searched for through a citation index.

TABLE VI (CONT'D). COMPONENTS OF LABORATORY REPORTS

Lab Report Component	Component Description
Methods and Materials (apparatus, equipment, software) Provides only enough detail to replicate the experiment.	• Methods Identifies by name commonly accepted methods. Lists in order, the procedures performed. • Materials Provides a description of apparatus and its components if readers would not be familiar with it. Often includes a sketch or photograph of the apparatus. • Identifies the materials employed and their relevant properties. (In table format)
Data and Results Presents data and results pertinent to the primary objective or argument from experiments, simulations, models.	• Pertinent data are presented in formats (graphs, tables, diagrams, etc.) that reveal critical relationships (trends, correlations, etc.) • "Raw" (directly measured) data can be presented if they are not too detailed to disrupt the flow of reading
Discussion	• Interpret the data and results in light of what you expected, and/or make comparisons to published information. • Identifies and explains any unusual or surprising results. • Identifies the significant sources of error and assesses the reliability of your results.
Conclusions/ Recommendations	• Restates significant limitations, assumptions or violations of assumptions that qualify the conclusions. • Based upon results and discussion, list conclusions in **order of importance**. • Assess the extent to which each objective has been met. • Provides any recommendations that derive from the conclusions..
Works Cited	• Uses appropriate format (Council of Science Editors, IEEE ...) to list sources. • Includes sources used in designing the experiment, writing the lab report, discussing theory or for citing standard equations.
Appendices	• Provides detailed information (raw data, calculations, etc.) that are too cumbersome to include in the body of the report. These data might interest only a few readers, especially those who verify the validity of results.

college vary from system design to the design of an electrical or mechanical device to the development of software, the PITCH activities need to allow for flexibility in their preparation. All of the PITCH outcomes (see Table 1) are addressed in all senior design courses.

The first PITCH activity involves the preparation of an engineering proposal for the design project. Each student team gains experience in the preparation of a proposal by providing such a document to the project sponsor (the "client"). Guidelines for the preparation of the design proposal have been developed with input from all of the programs in the college and are available at www.newhaven.edu/772778.pdf.

The second PITCH activity associated with the senior design experience is a poster presentation of the project. The poster is presented at the end of the second semester as part of the Senior Design Expo conducted by the college. While this poster presentation has been a part of the design activities for several years, the guidelines for such posters have been lax. Formal guidelines for the preparation of the design posters with an accompanying grading rubric and advice table are currently being developed.

The third PITCH activity associated with the senior design experience is the final design report. The final design report provides a complete record of the design effort along with a description of the design and recommendations. In the past, the relatively lax guidelines provided for the final design report have varied greatly from program to program resulting in wide variability in the reports. Formal guidelines for the preparation of the final design reports are being prepared with input from all engineering programs and the computer science program. These guidelines will allow greater consistency in the final work product. A grading rubric and advice table will be developed to accompany the guidelines and assist students in preparing the final design report. In addition, PITCH sponsors cash awards for the outstanding senior design reports as nominated by faculty and judged by members of the TCoE Professional Advisory Board.

VI. Assessment of PITCH

All graded PITCH assignments for all students starting with the freshman class of fall 2012 are being electronically archived so that a longitudinal assessment of the effectiveness of PITCH can be assessed when the freshman 2012 class graduates in 2016. This assessment will evaluate how effective PITCH is in developing technical communication skills in engineering and computer science students. Prior to 2016, partial assessments will be made on the effectiveness of PITCH in the first few years of each program. In addition to annual reviews of student portfolios, each faculty member teaching a PITCH course completes a self-assessment of their experience in the prior year. These self-assessments identify areas of strength and weakness and include plans for improvements in subsequent course offerings. Once the initial cohort has graduated, the initial survey of faculty, alumni and employers of Tagliatela College of Engineering graduates will be repeated. Since the college is only in the third year of developing and implementing PITCH, it is difficult to make any comprehensive assessment at this time.

Some instructors have made preliminary and somewhat subjective evaluations of improvement in student performance within a single course from one PITCH assignment to another. The general consensus is that the more systematic approaches used in PITCH, including the availability of advice tables, rubrics and sample assignments increases student performance in technical communication from one PITCH assignment to another within a single course. Annotated sample assignments will be developed over the next year for all PITCH courses, and these are expected to further improve student performance.

VII. Conclusions

A Project to Integrate Technical Communication Habits (PITCH) in engineering and computer science undergraduate students at the Tagliatela College of Engineering at the University of New Haven is described. This four-year program, coordinated across seven engineering and computer science programs, is believed to be one of the most comprehensive engineering technical communication programs in the country. Rather than offer special courses in technical communication taught by non-engineering faculty, or focusing on one or two courses taught within a program, PITCH trains engineering faculty to develop technical communication skills in students by implementing technical communication products into existing engineering courses in a systematic and structured manner throughout the program. The technical communication products used and the PITCH outcomes were based on the results of an extensive survey of alumni, employers of students, and faculty. Development and implementation of PITCH began in fall 2012. While it is too early to assess fully the effectiveness of PITCH, it is expected that PITCH will significantly improve the technical communication skills of engineering and computer science students in the Tagliatela College of Engineering. Preliminary reactions from PITCH faculty confirm that this is so.

Acknowledgments

The Davis Educational Foundation funded the development and implementation of PITCH at the University of New Haven. See www.davisfoundations.org/site/educational.asp for more details about the foundation.

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Appendix B

Preliminary Assessment of and Lessons Learned in PITCH: An Integrated Approach to Developing Technical Communication Skills in Engineers

Abstract

The Project to Integrate Technical Communication Habits (PITCH) was recently implemented at the University of New Haven. The goal of PITCH is to develop good communication habits in engineering students. The program is designed to integrate technical communication learning objectives into a sequence of engineering courses, culminating with the senior design experience. Engineering students are introduced to the PITCH program in three courses during their freshman year and the skills they learn are reinforced in each subsequent year of their studies. After three years of progressively more extensive development and deployment, a preliminary assessment of student writing from freshman to junior years was performed.

PITCH teaches students how to report on technical work with an appropriate level of detail and how to effectively present data. As part of the program students prepare laboratory reports, technical memoranda, poster presentations, oral presentations, and senior design reports. PITCH has been integrated into four freshman and sophomore courses taken by all engineering students, as well as two higher level, program specific courses. Engineering faculty teaching these courses were trained through workshops conducted over three summers. A random sample of students across four majors was selected for the assessment. The sample was taken from the first cohort of students that had taken freshman through junior courses with trained instructors.

Four faculty members and an external consultant involved in the development and deployment of PITCH were chosen as evaluators. The student assignments chosen for review were evaluated by a common rubric to determine whether students achieved the PITCH learning outcomes. The evaluations were done with all five evaluators present. Student progress through the first three years of PITCH is quantified and the results demonstrate that student writing improved significantly. The pedagogical and administrative lessons learned by developing and implementing the program are also discussed.

PITCH is supported by a grant from the Davis Educational Foundation.

Background

A key skill desired by employers of new engineering graduates and valued by alumni is the ability to communicate technical content effectively.[1-5] Engineering educators have recognized this need for many years and a variety of efforts have been undertaken at different universities to address it.[6,7] An approach adopted by many engineering schools is to require students to take a technical communications course. However, that approach has not been particularly effective since the course is typically not connected with engineering content and the material is not reinforced in later semesters.[8,9] The development of technical communication skills in engineering students cannot be effectively accomplished in one or two semesters and needs consistent attention over a prolonged period. Facilitated by a grant from the Davis Educational Foundation, the Project to Integrate Technical Communication Habits (PITCH) was begun in the Tagliatela College of Engineering at the University of New Haven in fall 2012 to establish an integrated approach to developing written, oral and visual technical communication skills in engineering students. The project spans all seven ABET-accredited engineering and computer science programs in the college and includes engineering courses across all four years of the undergraduate curriculum. The course sequences within each program that integrate technical communication are depicted in the "roadmaps" available at www.newhaven.edu/engineering/PITCH/roadmaps/. A sample roadmap for the electrical engineering program is shown in Figure 1. In its approach to integrating technical communication instruction within engineering curricula PITCH is a fully developed project modeled after earlier, less extensive initiatives at Michigan State University and The University of Maine.[6,8,10-12] The program contains a number of features that refine and extend the integrated approach:

- PITCH faculty developed a comprehensive set of learning outcomes based on surveys of both the University of New Haven engineering faculty and engineering alumni and employers.
- Communication assignments are based on discipline-specific content and designed to have students achieve stated outcomes in a developmental progression throughout their programs.
- PITCH leverages technology to provide students and faculty with supporting resources.

Further details on the implementation of PITCH can be found at www.newhaven.edu/engineering/PITCH/.

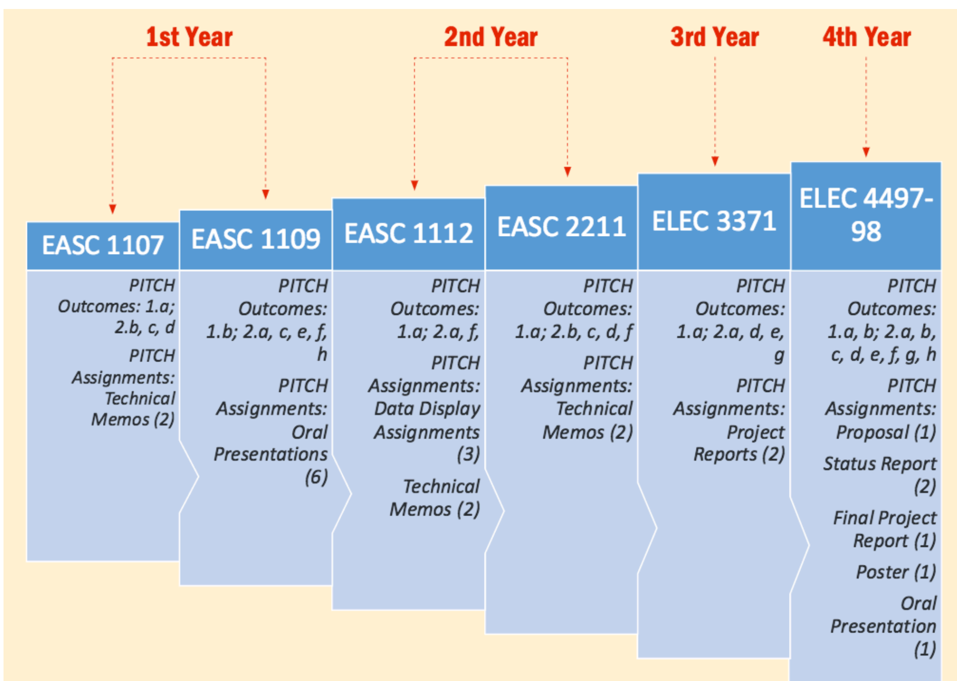

Figure 1. A roadmap of PITCH outcomes and assignments for electrical engineering

PITCH Assignments

Examples of assignments that were evaluated are included in the appendix and other examples of PITCH assignments were included in earlier publications.[13,14] These assignments address PITCH goals by requiring students to respond to workplace scenarios that incorporate decisions about purpose, audience, levels of detail and specific reporting goals within those scenarios. Such an assignment structure allows students to experience the kind of reporting demands they would face in a professional setting. The structure also allows PITCH faculty to continue refining assignments by changing variables and evolving grading rubrics that reinforce the desired characteristics of these reports. Table 1 presents a summary of PITCH activities in the electrical engineering program. Similar activities exist in other programs.

Table 1. Summary of PITCH activities in the electrical engineering program

Course and Level	**Assignment Types**	**Examples of Assignments**
EASC 1107: Introduction to Engineering – Freshman, Fall	2 technical memos reporting on projects done in course. Projects introduce students to the design process and the importance of engaging customers in design.	Optimize, construct and test a bridge design. Design, fabricate and test a puzzle, by engaging customers in the design process.
EASC 1109: Project Planning and Development – Freshman, Fall	6 weekly oral presentations reporting on project status. The project involves the construction and programming of robots to simulate a manufacturing floor.	Build a robot to be used in the class manufacturing floor simulation. Program robot using LabVIEW. Report out weekly via oral presentations and at project end via a technical memo.
EASC 1112: Methods of Engineering Analysis – Freshman, Spring	3 technical memos reporting on projects done in course. Projects involve developing a computer solution for an engineering problem, often an open-ended problem involving some design thinking.	Calculate hydrogen storage and flow for a fuel cell powered vehicle. Design optimal pipe insulation for a steam pipe. Develop a spreadsheet to illustrate the concept of terminal velocity as a tool for a high school science teacher.
EASC 2211: Introduction to Modeling of Engineering Systems – Sophomore, Fall	2 technical memos reporting on projects done in the course. Projects involve the development of a model for an engineering situation. Some decisions are required to develop the model or use the model to optimize a design.	Develop a model to predict voltage as a function of current for a fuel cell, with highly non-linear behavior. Design a pumping system to fill a rooftop water storage tank, optimizing pipe size with economic constraints.
ELEC 3371: Computer Engineering Lab Course – Junior Year, Fall	2 project reports documenting project work done in course. Projects involve microcontroller interfacing.	Interface microcontrollers for serial communication and interrupt based timer.
ELEC 4497: Capstone Design Course – Senior Year, Fall	Collaboratively authored engineering design proposal in the fall. Collaboratively authored engineering design report and a poster in the spring.	Design audio amplifier, quad-copter, wireless power transmission, robot arm, fire-fighting robot, 3-D advertisement board, etc.

Assessment

A preliminary assessment of the program was performed in late 2015. Student work from four PITCH courses was evaluated to measure students' progress in their technical communication skills. The four courses that were evaluated are listed in Table 2. One assignment per course was selected for the study and the specific assignments chosen from each course are shown in Table 3. The 16 students selected for the study were randomly chosen from a group that had taken all four courses with trained instructors. Four faculty members and an external consultant involved in the development and deployment of PITCH performed the assessment.

Table 2. Four PITCH courses included in the assessment

Course Number	Course Title	Year
EASC 1107	Introduction to Engineering	Freshman (Fall)
EASC 1112	Methods of Engineering Analysis	Freshman (Spring)
EASC 2211	Introduction to Modeling of Engineering Systems	Sophomore
One of: CHME 3311 CIVL 3323 ELEC 3371 MECH 3315	 Chemical Engineering Lab Mechanics and Structures Lab Computer Engineering I Mechanics Laboratory	Junior

Table 3. PITCH criteria and the five-point rubric scale used to assess student work

PITCH Outcomes	Overall Assessment of Progress*					
	Poor (1)	Below Average (2)	Average (3)	Above Average (4)	Excellent (5)	Total
Use appropriate format and content						
Exhibit clear, precise and logical expression						
Demonstrate appropriate organization, level of detail, style and tone for a given audience, situation and purpose						
Demonstrate appropriate syntax and correct usage of grammar and spelling						
Highlight or identify critical information						
Present, discuss, and summarize data accurately and persuasively						
Write thoughtful and persuasive conclusions and recommendations						

*Scale: The five-column rubric has become a standard practice in PITCH courses as well, with two blank columns to allow for flexibility in applying specific descriptors.

1. Poor: Shows little or no progress in achieving PITCH outcomes. Little or no progress in mastery of products or habits.
3. Average: Shows evidence of progress in achieving PITCH outcomes that reflect a merely acceptable level of mastery of both products and habits.
5. Outstanding: Shows evidence of progress in achieving PITCH outcomes that reflect superior mastery of both products and habits.

The assignments were evaluated simultaneously (with reviewers in one room) using the rubric shown in Table 3. Student progress was quantified and the results are discussed in the following section.

The 16 students were from four engineering majors and the number from each major was a close representation of enrollment distribution in the mechanical, electrical, civil and chemical engineering programs. In each collective assessment setting, student work was evaluated based on seven criteria (a subset of PITCH outcomes) using the five-point scale shown in the rubric in Table 3. The maximum score a writing assignment could receive was 35 points. Each evaluator reviewed each writing assignment; therefore, each assignment received five ratings.

Statistical Analysis

Before further analysis of assignment ratings, the equal variance test was performed to see if any differences existed among the evaluators' assessment of student work in each course. The equal variance test is used to determine whether the variances of two or more groups are similar; when the p-value obtained from the test is larger than the significance level chosen, the conclusion is that the variances are not different. The equal variance test at the significance level $\alpha = 0.05$ was performed for each course with the five evaluators representing the different groups tested. The test results with p-values of 0.59, 0.68, 0.74, and 0.59 for each course indicated no difference in variance between the evaluators, suggesting that rating variation between evaluators was not a factor impacting the total variance observed in student ratings.

Table 4 shows the descriptive statistics of these writing assignments for each of the four courses. The standard deviations for each course were similar and suggest that the variation among student work observed in each course was similar. An equal variance test, similar to the one described above, at the significance level $\alpha = 0.05$ was performed on the assignment ratings, this time with the four courses representing four different groups. The p-value = 0.41 obtained supported the observation that there were no significant differences in variation among student work in each course.

Table 4. Descriptive statistics for four PITCH courses – Comparison of assignment ratings

Variable	N	Mean	Std. Dev.	Minimum	Maximum	Median
EASC 1107 Rating	54	14.9	4.9	7	27	14.5
EASC 1112 Rating	75	16.2	5.9	7	26	16
EASC 2211 Rating	80	16.8	5.4	8	30	16
3rd Year Course Rating	65	23.6	5.1	11	35	24

Note: N is the number of ratings assigned by the evaluators for student papers in that course. One assignment was used for each course with each evaluator submitting ratings for each student. Assignments were missing for some students in each course; hence the N value differs across the courses.

Student progress was evaluated by comparing the average rating for each of the four courses. The mean value for the first freshman year course, EASC 1107, was used as a baseline. As shown in Table 4, the mean values for the next two courses, EASC 1112 and EASC 2211, increased by approximately 11%, indicating that student proficiency in technical communication skills had modestly increased after completing their first semester. A significant improvement in quality (an increase of 37% in mean score) was observed in the third year.

Ratings of student assignments were also analyzed using a randomized block design ANOVA (analysis of variance). This statistical test is an extension of the paired t-test for three or more samples. In this study, students were treated as blocks to preserve the pairing of ratings for a particular student across the four courses. The ANOVA test results are shown in Table 5.

Table 5. ANOVA table (main factor: course, block: student)

Source		DF	F-Value	p-Value
	Course	3	39.6	0.000
	Student	15	7.4	0.000
Error		255		
	Lack-of-Fit	36	4.1	0.000
	Pure Error	219		
Total		273		

Before interpreting the results of the ANOVA test, the assumptions implicit for the ANOVA were verified. These assumptions are that the data is normally distributed and homoscedastic (i.e., has uniform variance over its range). To test normality, normal probability plots were created on all four groups and are shown in Figure 2. A normal probability plot is a graphical technique for assessing whether or not data is approximately normally distributed. The data is plotted against a theoretical normal distribution in such a way that the points should form an approximate straight line. If the assessment data is normal, the data points should fall along the middle straight line in each plot in Figure 2. The curved upper and lower lines in each plot show the 95% confidence margins. All four lines observed in Figure 2 are reasonably straight except in the tails. Furthermore, *p*-values, similar to the one described in the equal variance test above, can be used to derive a conclusion about normality. Although results for one of the courses (EASC 1112 with *p*-value = 0.012) suggest non-normal data, the *p*-value is not significantly low, and the ANOVA method is fairly robust against departures from the normal distribution, especially for larger samples. The results of ANOVA with a *p*-value = 0.000 at the 95% confidence level agree with our preliminary observations based on the mean student rating for the four courses. The change in ratings from course to course shown in Figure 3 suggests a conservative increase in the first three courses, and a significant leap in the last course in the sequence.

The ANOVA test shows only whether there was a difference in the means of two or more groups tested, but does not reveal which ones are different. The paired t-test was used to evaluate the hypothesis that the students' skill level was higher in each successive course compared to the previous one. With the EASC 1107 mean of 14.9 as the baseline, the test results presented in Table 6 indicate that the students achieved considerable growth in their technical writing ability as they finished their second course in the sequence (EASC 1112). There was no significant

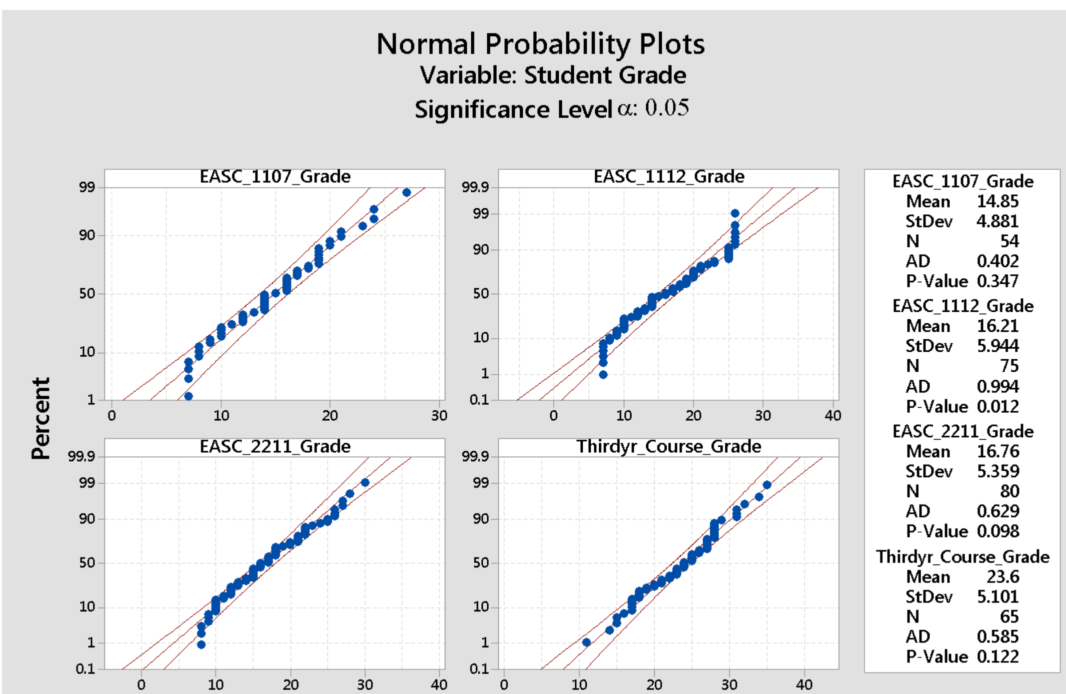

Figure 2. Results of tests for confirming normal distributions of data

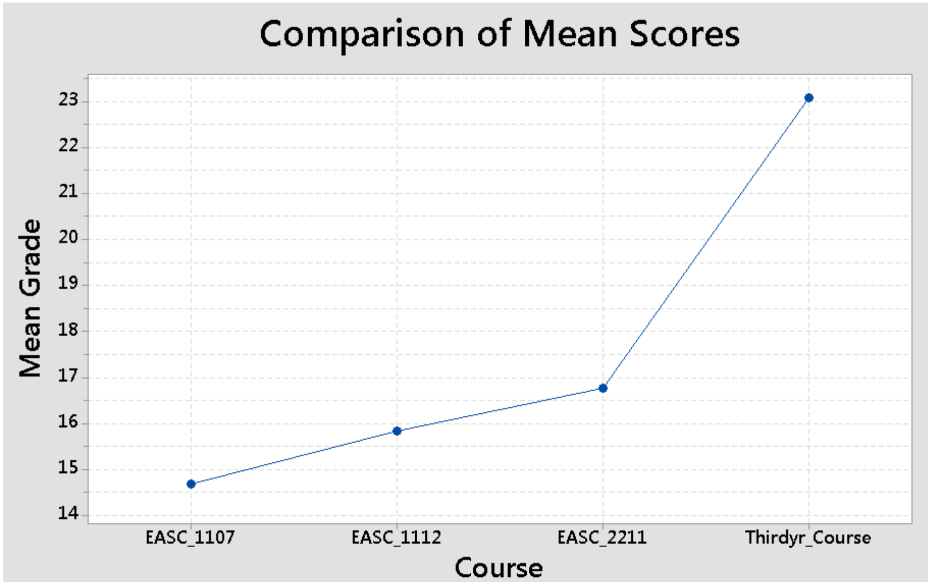

Figure 3. Change in rating of student writing from course to course

Table 6. Pairwise comparison of improvement in student work in two consecutive courses

Comparison of Progress (Course 1 to Course 2)	Mean Rating 1	Mean Rating 2	Percent Improvement	p-value	Statistical Significance
1st Year Fall to 1st Year Spring	14.9	16.2	9%	0.037	Significant
1st Year Spring to 2nd Year Fall	16.2	16.8	3%	0.088	Not Significant
2nd Year Fall to 3rd Year	16.8	23.6	41%	0.000	Significant
1st Year Fall to 3rd Year	14.9	23.6	58%	0.000	Significant

difference observed between the second and the third courses. During the review of these results, one of the instructors of the third course indicated that one possible reason for not being able to observe improvement might be attributable to the timing of the writing assignment that was reviewed. The assignment due date coincided with another assignment for that class, and furthermore, was very close to finals week. Therefore, the work students provided for this particular assignment may not have been the best example of their work. Despite this, the average assignment scores were somewhat higher than in the previous semester's course, though not statistically significant.

The paired t-test indicated that there was a significant improvement observed in students' writing skill in their junior year. There may be several factors contributing to this result. Naturally, the level of student maturity increases as they move into their junior and senior years. In addition, they continuously practice their writing through many assignments in their courses. The assignments in the third year courses were also collaboratively authored, while those in the first year were individually authored. Nevertheless, we believe that the continuous emphasis on PITCH and its expected outcomes is a significant factor in improving student's technical writing skills, and that the other factors support these skills.

This preliminary assessment provides an indication that PITCH positively impacts students as intended. We note, however, that the study was done with a small sample and without data on student performance before PITCH was implemented. Future work will include a more comprehensive study spanning the full four years of the PITCH curriculum with a wider range of measures and a larger number of students to better assess the impact of the PITCH initiative.

Lessons Learned

Lessons learned during the course of developing and implementing PITCH and strategies for addressing these are as follows:

1. So far instructors have not spent significant class time discussing technical writing, but only referred students to related written guidelines and instructions that were developed as part of PITCH (see www.newhaven.edu/engineering/PITCH/482611/). The relatively modest improvements discussed herein are a result of this practice. However, we feel that considerably greater improvement in student writing can be obtained if formal instruction on technical writing can be provided in the context of the courses included in PITCH.
2. Obtaining consistent grading of writing by the many instructors of the engineering courses and course sections in which PITCH is implemented has been difficult. Although most instructors have been trained through PITCH workshops, their ability to assess technical writing and provide effective feedback varies widely. This limits students' potential improvement.
3. Engaging a sufficient number of engineering faculty to commit to advancing technical communication is a challenge. Strong leadership and support at the college and institutional levels, a partnership with a technical communications consultant or faculty member, and a sufficient number of core faculty members who believe in the value of effective technical communication are required for a project like PITCH to be successful. It is also difficult for an institution to bear the cost of developing a project like PITCH; external grant funding is vital during the development phase. Once developed, implementation and continuation are feasible through institutional support.

Conclusions and Future Work

The work to date has verified the potential for PITCH to improve students' technical communication abilities. The key features include the establishment of consistent guidelines across all four years, the integration of writing assignments into engineering courses which use these guidelines, training instructors to be more sensitive to communication skills and giving writing assignments more weight in course grades. Further improvements will require providing formal technical writing instruction to students, further training of faculty to achieve more consistent grading, and having people strong in writing provide support to other faculty.

The assessment of PITCH will continue as more student data is collected. The first cohort of students who would have experienced PITCH in all four years will graduate in spring 2016. At that time, we will have an opportunity to do a comprehensive before and after PITCH assessment between students who have not experienced PITCH and the ones who went through the four years of PITCH training. Senior design reports of both groups will be compared in this planned assessment.

Furthermore, PITCH core faculty are currently developing three online modules to address the issues raised above. Students will take these in their freshman, junior and senior years in conjunction with EASC 1112, junior laboratory courses, and senior design courses. The intent of these modules is to engage students with writing exercises that will prepare them for the specific PITCH assignments in target courses (i.e., technical memos, laboratory reports and senior design proposals, reports and posters). Students will also benefit from feedback provided by the online technical writing instructors as well as peer review using the EliReview® software system.[15] The online modules are being developed now and implementation is expected to begin in fall 2016.

Acknowledgements

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Appendix – PITCH Assignments

EASC1107 – Introduction to Engineering Assignment:

Customer Awareness Project

During a marketing meeting, your company has decided to explore new markets for generating revenue and have targeted the toy industry. Preliminary research has shown that puzzles like the Rubik cube seem to appeal to all ages. You have been asked to lead a team to first identify a market and then develop a puzzle cube that can compete in that market. There is limited time since your company would like to introduce this product to the market in time for the holiday season. You are not expected to do a Cost-Benefit Analysis at this time; however, specifying a selling price is expected. In three weeks, you need to pitch your team's idea to your boss, Mr. White, so that he can make a recommendation to the company's investors.

Listed below are the design criteria for the puzzle cube. To expedite the design process, each member of your team will design a puzzle cube based on the listed criteria. Your team will collect data for each before choosing which design to pitch to Mr. White. Design requirements and action items appear below.

Design Requirements

- Each puzzle design must have a specific theme with a target audience, age group and time to completion.
- Each cube is made from 27 individual ¾ inch wood blocks.
- Pieces should interlock so that the puzzle cube is self-supported when assembled.
- The puzzle must be easy to ship.

Action Items:

- As a team, design a brief survey to determine who your target audience will be for the puzzle cube. Collect data from at least 12 individuals; e.g. 3 people per team member. The survey could include questions related to a theme for the puzzle cube, level of difficulty and price someone would be willing to pay. Create the survey using the free download version of Survey Monkey. The suggested length of the survey is 1 page.
- Upon analyzing the survey results, each member of the team will sketch, design and build a puzzle cube according to the design requirements above. Students will then produce a computer model of their sketch using a 3-D solid modeling program, such as Inventor.
- Team members will evaluate their individual puzzle design by testing it out on 10 prospective customers using a survey provided by your instructor.
- Based on KT Decision Analysis, choose the optimal design for the team using the results from your surveys.

Mr. White has informed your team that each member must first take no more than 30 seconds to pitch their own individual design, before the team leader is asked to pitch the team's choice. Remember to include selling price as part of the pitch.

Technical Memo and Oral Presentation Requirements
Each student will submit a technical memo and pitch your cube design to the class. **Each instructor will set the deadline for the Technical Memo and cube presentations.**

EASC 1112 – Methods of Engineering Analysis Assignment:

TO: March 27, 2013

FROM:

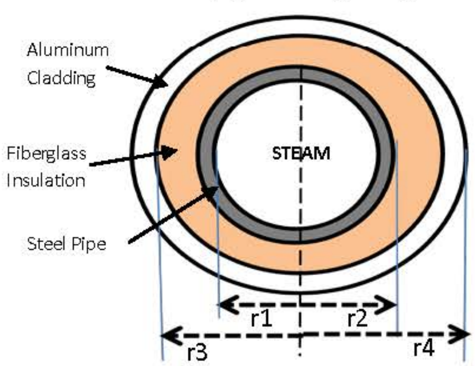
Subject: Project 2, Optimum Pipe Insulation

A long pipe is to be installed to transport steam from a boiler to another part of the plant. Insulation is needed on the pipe for both safety and economic reasons. You are to develop a spreadsheet to calculate the surface temperature of the insulated pipe and to model the heat loss to the surrounding air as a function of the thickness of insulation on the outside of the pipe. Your model should allow for variation in the key parameters to explore the effect of various changes. Using data generated by your model, select the best insulation thickness to maximize the present value of net savings in comparison to an un-insulated pipe. Provide appropriate plots and data tables to support your decision and to show the financial penalty for using a different insulation thickness.

Heat Loss Calculation

The steam pipe is to be made from schedule 40 steel with a diameter in the range of 2 to 3.5 inches (nominal pipe size). The pipe will be encased in fiberglass insulation with an aluminum sheet cladding to protect from weather. Heat loss for this case can be modeled using a combination of convection and conduction heat transfer rate equations. Heat from the steam is transferred to the inside wall of the pipe by forced convection, then through each of three layers by conduction (pipe wall, insulation, cladding) and finally from the outside of the cladding to the surrounding air by natural convection. The governing equations are shown below to calculate heat transferred per unit length of pipe:

View of pipe looking along axis



Q_S = rate of heat lost by steam to inside pipe wall

Q_1, Q_2, Q_3 = rates of heat transferred through pipe wall, insulation, aluminum cladding, respectively

Q_A=rate of heat lost to air

Heat Transfer Rate for Each Layer
- per meter length of steam pipe

$$Q_S = h_s(2\pi r_1)(T_s - T_1) = C_1(T_s - T_1)$$

$$Q_1 = \frac{k_1(2\pi)(T_1 - T_2)}{\ln(r_2/r_1)} = C_2(T_1 - T_2)$$

$$Q_2 = \frac{k_2(2\pi)(T_2 - T_3)}{\ln(r_3/r_2)} = C_3(T_2 - T_3)$$

$$Q_3 = \frac{k_3(2\pi)(T_3 - T_4)}{\ln(r_4/r_3)} = C_4(T_3 - T_4)$$

$$Q_A = h_a(2\pi r_4)(T_4 - T_A) = C_5(T_4 - T_A)$$

The heat transfer rate equations include constants for the thermal conductivity of the materials and heat transfer coefficients for the convective situations. Values for these will be fixed for the analysis.

The temperatures of the steam and the air will be fixed values, but the temperatures at each surface will be dependent on the thickness of insulation and size of the pipe. The subscripts used for the temperatures correspond to radial distances from the center of the pipe. The radii values will be fixed for a particular case of pipe size and insulation thickness, but will be varied as part of the optimization work. The intermediate temperatures, to be found by simultaneous solution of the equation set, are:

T_1 = temperature of the inside wall of the pipe, at distance r_1 from the pipe center axis

T_2 = temperature of the outside pipe wall and the inside of the insulation, distance r_2

T_3=temperature of the outside of the insulation and inside of the aluminum cladding, distance r_3

T_4 = temperature of the outside surface of the cladding, exposed to the air, at distance r_4

Average steady-state conditions will be used for the analysis of each case, thus the rate of heat lost from the steam must equal the rate of heat transferred through each layer and ultimately the rate of heat lost from the outside cladding to the air. Thus four linear equations can be obtained by setting $Q_A = Q_1$, $Q_1=Q_2$, etc. The resulting equations can be solved using matrix techniques to find the unknown temperatures. Any one of the heat rate equations can then be used to find the heat loss rate. The constants (h's , k's, π and numbers) and the parameters (radii values) become the coefficients, and are shown in the equations above as C1 through C4. For a given case, these will be easily calculated. Terms containing the steam and air temperature are also constants (shift to the right side of equation). For example, setting $Q_S = Q_1$ and $Q_1 = Q_2$ results in the following:

$$\begin{array}{lll} \text{Steady - State Heat Flow} & & \text{Rearranged for Matrix Solution :} \\ Q_S = Q_1 & C_1(T_S - T_1) = C_2(T_1 - T_2) & (C_1 + C_2)T_1 + (-C_2)T_2 = C_1 T_S \\ Q_1 = Q_2 & C_2(T_1 - T_2) = C_3(T_2 - T_3) & (C_2)T_1 + (-C_2 - C_3)T_2 + (C_3)T_3 = 0 \end{array}$$

Similar equations result from setting $Q_2 = Q_3$ and $Q_3 = Q_A$.

Your spreadsheet should have a data section for setting the pipe diameter and insulation thickness along with values for the constants, such as steam and air temperatures, thermal conductivity values, cost information, etc. Develop the model such that entry of a pipe diameter and an insulation thickness results in determination of the 4 temperatures and the rate of heat loss for the full pipe length.

Analysis of Insulation Thickness

Using your model, determine the optimum insulation thickness for different pipe diameters to achieve a maximum net present value of savings. Savings here is defined as the dollar value of energy NOT lost as a result of the insulation. To calculate this you must first determine the heat that would be lost if the pipe was not insulated. Simply subtract the heat loss for a particular insulation thickness from the bare pipe heat loss to determine the energy savings. The cost to insulate the pipe includes both the material cost and the installation labor. A net installed cost is found by multiplying the material cost by an installation factor to account for labor and other installation expenses. Data is provided at the end of this memo for physical properties, cost information etc.

Optimization work requires an objective to be maximized or minimized. In this project the "objective function" is the present value of savings over a 5 year period using a specific interest rate with monthly compounding. The installed cost of insulating the pipe occurs at time zero (present) and is negative, so this is subtracted from the present value of 5 years of savings. Varying the insulation thickness will affect this value, so you can determine if there is an optimum which maximizes the present value. You should also be aware of safety concerns associated with a long run of steam pipe. In particular you should assure that the outside surface temperature is no higher than 50°C.

Report Requirements

At present, the diameter of the steam pipe has not determined, but it will be between 2 and 3 ½ inch schedule 40 steel pipe. Dimensions for standard steel pipe are available in the literature and should be used in this project. After creating the spreadsheet model, you should run simulations for cases in which you vary the insulation thickness from 0.1 to 6.0 cm. Prepare plots showing surface temperature, installed cost, annual savings and net present value as a function of insulation thickness. Create other plots as you deem necessary to justify your design decisions regarding the insulation thickness. A full analysis of this type should be performed for one pipe diameter. In addition, you should determine the optimum thickness and required thickness to achieve an acceptable surface temperature for all pipe sizes in the range given above. Note that nominal pipe sizes in this range are incremented in ½ inch steps. For each pipe size, recommend an insulation thickness.

Your memo should give an overview of the project, discuss your approach, present results and discuss methods used and assumptions made. Tables and plots should appear in the memo to with explanation to make your points. Your concluding paragraph should include a discussion of what you learned in doing the project. Your spreadsheet should, of course, be well-documented and well-organized to show clearly how the work was done. The spreadsheet should include the following features:

- List of pipe diameters using the data validation methods
- Retrieval of dimensions for pipes from a table keyed to the selected pipe size (use Vlookup)
- Scroll bar to set the insulation thickness
- Use of Solver to vary thickness to maximize present value of net savings
- Check box to select either scroll bar or Solver for varying the insulation thickness
- Use of a button to run solver
- A Sub to copy key results to a table, attached to another button
- Any additional <u>functional</u> features you wish to include to make the simulation tool more useful

The project is due Wednesday, April 17, 2013, with a paper submission of the memo and attached printout of the spreadsheet. The spreadsheet should also be submitted via Blackboard. Required data is found on the next page.

Input data for use in project

Properties of pipe, insulation and outer cladding material				
Item	Material	k, thermal conductivity	density	cost
		W/m-C	kg/m^3	$/kg
Pipe	steel	43	7800	NA
insulation	fiber glass	0.055	64.1	30
Outer Layer 0.5 mm thick	aluminum	206	2700	40

Financial Analysis Parameters			
*Install Factor	Energy cost	Annual Interest Rate	Period of analysis
$/$	$/kWh	percent	years
5	$0.04	3.0%	5
		Per month	months
		0.25%	60

* Installed cost = (total material cost) x installation factor

Heat Transfer Coefficients $\frac{W}{m^2\text{-}^oC}$		Other Parameters		
From steam to inside pipe wall	From outside pipe cladding to air	Steam Temperature	Air Temperature	Pipe Length
h_S	h_A	C	C	Meter
50	5	150	10	50

Properties of Standard Steel Pipe			
Schedule 40	Pipe Diameters		Wall thickness
Pipe	OD, cm	ID, cm	cm
2	6.033	5.25	o.39
2.5	7.303	6.271	0.52
3	8.89	7.792	0.55
3.5	10.16	9.012	0.57

EASC 2211 – Methods of Engineering Analysis Assignment:

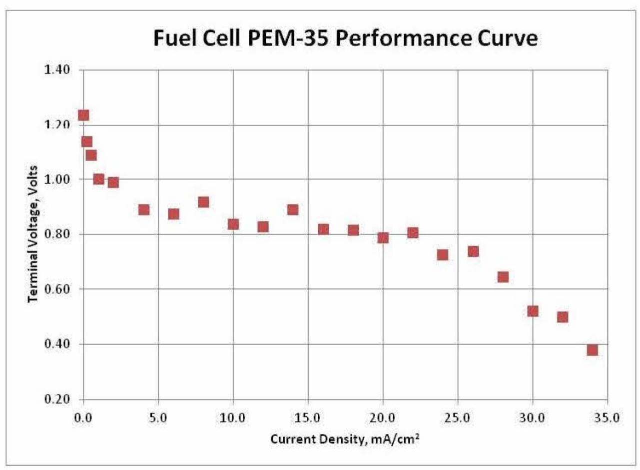
EASC2211 Introduction to Modeling of Engineering Systems Fall 2013

TO:
FROM:
RE: Project 1 – Recommendation for a Fuel Cell Model
Date: October 29, 2013

You work in the development department of a fuel cell company that is working on a small fuel cell to be used home applications. A set of data has been obtained on the performance of the latest prototype. You are asked to use the performance data to derive a model that can be used to predict the voltage delivered by the fuel cell at different current loads. The work should be summarized in a technical memo, due Thursday, November 7, 2013.

The form of the model should be similar to that used in class to model batteries, a constant voltage source (V_S) in series with an internal resistance (R_S). This model will be used by the Applications Department to determine the ability of the fuel cell to operate various home appliances. Engineers in that department will analyze circuit models that incorporate various loads with your model representing the source. In addition, the model of the voltage/current behavior will also be used to find the best configuration for cells arranged in series and parallel to deliver the necessary voltage and current.

The data for the fuel cell are shown in Table 1 and Figure 1. At low current draw the voltage drops steeply from the open-circuit value (zero current), but then drops more gently over the middle range of current. At high current loads the voltage again begins to drop as the fuel cell reaches its limit.



In order to model this highly non-linear behavior you will need to develop 3 separate models:

- Model for low current density region, $V_{S\text{-}low}$, $R_{S\text{-}low}$
- Model for medium current density region, $V_{S\text{-}med}$, $R_{S\text{-}med}$
- Model for high current density region, $V_{S\text{-}high}$, $R_{S\text{-}high}$

Using regression techniques with data in each region, you should be able to obtain V_S and R_S values that best fit the data in that region. You will need to exercise judgment in deciding the cut-off points for each region. I suggest you overlap the data used in each region by one data point – that is the low and medium region will both use the data point that separates the regions.

Table 1					
Fuel Cell PEM-35 Performance Data					
Current Density	**Voltage**	**Current Density**	**Voltage**	**Current Density**	**Voltage**
mA/cm^2	**Volts**	**mA/cm^2**	**Volts**	**mA/cm^2**	**Volts**
0.0	1.24	8.0	0.92	22.0	0.80
0.2	1.14	10.0	0.84	24.0	0.73
0.5	1.09	12.0	0.83	26.0	0.74
1.0	1.00	14.0	0.89	28.0	0.65
2.0	0.99	16.0	0.82	30.0	0.52
4.0	0.89	18.0	0.82	32.0	0.50
6.0	0.87	20.0	0.79	34.0	0.38

Experimental data for single cell unit of PEM-35 measuring terminal voltage under varying loads. Note that the data here is organized into 3 sets for convenience in the table. This should not be used as a grouping of the data for modeling purposes.

Report your results to Ms. Tristan Modelz, Director of Applications Department, in a technical memo, no longer than 3 pages. The memo should include a presentation of your results along with a discussion of how you selected the regions for each model with summary tables and figures to justify your choices. Do not include all data in your report, but select values to show in small tables and figures to make your case. For example, you may show a table with the average error (absolute value) between experiment and model for each region, rather than the error for every point. Attach 1 or 2 sheets from your workbook to show all the results, including comparisons between the experimental data and the model predictions.

Students may work in pairs to develop the models, but each student must write and submit his or her own memo. The memo is due Thursday, November 7, 2013.

Third Year Courses:
CHME 3311 Chemical Engineering Thermodynamics

Chemical Engineering Thermodynamics
CM 311
Spring 2015
Simulation Assignment #2

A: Project Overview
Our solvent assessment project is now at the final stage where we will investigate the phase behavior of some binary liquid mixtures, which contain each of our test components. Here, we wish to investigate the performance of both fugacity and activity coefficient models (phi-gamma approach) in predicting VLE for liquid mixtures containing each of our test fluids.

B: Problem Statement
Our task is to predict isothermal vapor-liquid equilibrium (P-x,y diagram) for the assigned mixtures using activity coefficients models for the liquid phase and fugacity coefficient models for the vapor phase (phi-gamma approach).

You should compare models with each other and with the attached experimental data. Again, it would be useful to know how well different models predict the binary VLE over the entire composition range and over a range of temperatures. Be particularly aware of any peculiar behavior of the data (e.g., prediction of liquid-liquid phase splitting, etc.). Each group member is asked to construct P-x,y diagrams using several models and make a critique of the results for the assigned mixtures. You may wish to propose your selection of models with A. S. Gow (Project Leader) prior to conducting any simulations.

C: Presentation of Results
You should prepare a brief critique/analysis of the simulation results obtained. Graphs showing experimental data points along with calculated profiles for the bubble and dew point curves for each particular model would be extremely useful. Also, a summary table with model results and a conclusion column with a brief statement (i.e., good or bad and why) would be particularly useful in presenting these results. Please prepare a brief report of approximately five pages (including graphs and tables) summarizing your findings. The deadline for submission of your report will be announced in class.

D: Simulation Mixture Assignments

Group Member	**Mixture**

Third Year Courses:
ELEC 3371 Computer Engineering Lab Course

Sanderling Electronics, Inc.
4590 Quinopolis Dr.
Dump Duck, CT. 09383

To:
From:
RE: Project Report on Microcontroller Timer Program
Date: 10/21/14

You are a new engineer in the Laboratory Equipment Division of a large electronics firm. You have been assigned to a team that will develop one component of a new product that will control one aspect of an automated assembly device. Specifically, you will determine, using C language programming, whether the TIMER and INTERRUPT capability of the microcontroller will be useful in the new product. The new product needs a timer with the precision of 1/100 of a second which can go up to 99.99 seconds with display capability for the time. In addition an operator must be able to start, stop, and reset it. Since the software component you develop will be part of a larger software piece you must use "interrupts" for updating the time to make sure that your program will not consume the entire CPU time. Also, we need to examine the interrupt and non-interrupt capability of the microcontroller in stopping, resetting, and restarting the time.

To make this determination, you will complete the following tasks:

- Use TIMER1 and its associated interrupt capability to display the time in 4 digits (XX.XX) on four 7-segment displays with least significant digit (7-seg display) displaying the hundredth of a second.
- When the pushbutton RC0 is pressed the timer must stop and the last value on the 7-seg displays must remain unchanged.
- When the pushbutton RC1 is pressed the time must resume from where it was stopped and 7-seg displays must be refreshed accordingly.
- When the pushbutton RC2 is pressed the display must reset to "00.00" and start when you release it if the time was running. It should remain "00.00" if the timer has been stopped by pushbutton RC0 and until RC1 pushbutton is pressed again.
- Pressing RB0 must generate an interrupt which will pause the displays but not the time in the background.
- Pressing RB6 pushbutton must generate an interrupt which refreshes the 7-seg displays with the actual time (not resuming from the last figure that 7-seg displays show). Notice that the function of RB0, and RB6 is different from RC0, RC1, and RC2.
- The above mentioned tasks must be repeated continuously.
- Notice that your interrupt service routine can only execute for 1/100 of a second because it is the time interval between the Timer interrupts. It means that you must try to do most of the tasks outside the interrupt service routine (ISR). The execution time for the ISR cannot be more that .01 second.
- Try to implement your program step by step. For example first get the timer and timer interrupt to work and display the time before you implement RB0/INT and then the mismatch interrupt.
    - ✓ Create a flowchart for this process.
    - ✓ Write the corresponding program.
    - ✓ Download your program to the board, run it and record the results.

- Each group (2 in a group) must come up with a plan for doing this project and specify the tasks assigned to each member of the group. All these steps must be explained in the group report. Once you have submitted your report, you must be prepared to present a demo of your program.

Follow the guidelines provided on BB9 for writing a formal report for this project. Bear in mind that your report needs to technically accurate and be clearly understood by both engineers and non-engineering members of other teams on the product development effort.

Time is critical in this project. Your formal report is due to me on XXXX. *The company must have an accurate and complete report that is submitted on time so that we can make a decision on your program.* Therefore I have provided a checklist on the following page that you should review before submitting your work.

Checklist for Project Report on Microcontroller Timer Program

Report Requirement	Advice
Cover Page	✓ Must contain all elements exactly as specified in the guidelines for writing a formal report. Do not leave anything out; do not add anything extra.
Body of report	✓ Follow the guidelines for writing a formal report. ✓ Include the purpose of your project, the steps and equipment involved in completing it, a summary of results or running the program, and conclusion about whether the results indicate your project can work in the larger product.
Program Flowchart	✓ Must be electronically produced using appropriate flowchart symbols. ✓ Must contain accurate labels and process explanations.
Program Code	✓ Must be reproduced in clear and easily read format. ✓ Must include comments in correct and clear English that will help explain the operations of your program, including subroutines or tasks.

INITIALIZATION FOR PROJECT 4:

1. Load TIMER1 with the value you need for .01sec.
2. Clear TIMER1 overflow flag (PIR1,TMR1IF)
3. Enable TIMER1 overflow interrupts (PIE1,TMR1IE)
4. Enable TIMER1, set prescaler to 1:8, and turn off oscillator (T1CON)
5. Enable PORTB pull ups and set the rising edge for RB0/INT(OPTION_REG)
6. Define ports A, B, and D as outputs and write 0 in all of them.
7. Configure RB0, RB6, and PORTC as input.
9. Enable all unmasked interrupts, peripheral, interrupts, RB0/INT interrupt, and PORTB change interrupt for RB4 through RB7(INTCON)