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

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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.

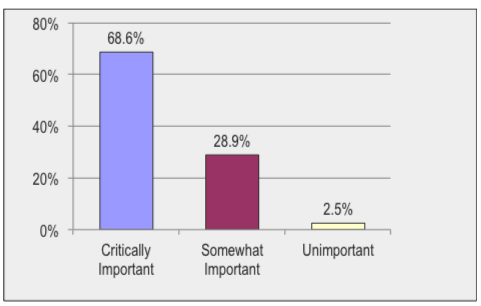

Fig. 1. Response to question: "Within my organization, to what degree are technical communications skills considered in hiring and promotion decisions?" $N = 121$.

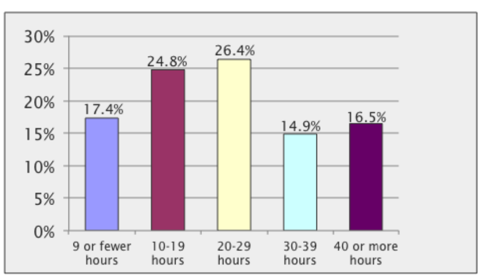

Fig. 2. Response to question: "In a typical work week, I spend about the following number of hours performing technical communication tasks (writing, reading, speaking or listening)." $N = 121$.

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.

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

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.

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.

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