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

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Ron Harichandran is Dean of the Tagliatela College of Engineering and is the PI of the two grants entitled "Project to Integrate Technical Communication Skills" and "Developing entrepreneurial thinking in engineering students by utilizing integrated online modules and experiential learning opportunities." Through these grants technical communication and entrepreneurial thinking skills are being integrated into courses spanning all four years in seven ABET accredited engineering and computer science BS programs.

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Michael A. Collura, professor of chemical engineering at the University of New Haven, received his B.S. in chemical engineering from Lafayette College and M.S. and Ph.D. degrees in chemical engineering from Lehigh University. After several years in industry, he moved to the academic world, where he has taught engineering for more than 30 years. He is currently the Buckman Professor of Chemical Engineering in the Tagliatela College of Engineering. His professional interests include the application of computers to process modeling and control (particularly for energy conversion processes), engineering education research (student self-assessment, developing conceptual understanding, multidisciplinary learning models), and reform of engineering education.Currently he is chairing the shared Department of Engineering and Applied Science Education at the University of New Haven.

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Jean Nocito-Gobel, Professor of Civil & Environmental Engineering at the University of New Haven, received her Ph.D. from the University of Massachusetts, Amherst. She has been actively involved in a number of educational initiatives in the Tagliatela College of Engineering including KEEN and PITCH, PI of the ASPIRE grant, and is the coordinator for the first-year Intro to Engineering course. Her professional interests include modeling the transport and fate of contaminants in groundwater and surface water systems, as well as engineering education reform.

David J. Adams, Technical Communications Consultant

David Adams has more than 23 years experience working in, developing and directing technical communication initiatives within engineering curricula. Prior to his consulting with the Tagliatela College of Engineering, he had worked with similar projects at engineering colleges at Cornell University, Michigan State University and the University of Maine. He is the author of COPE: a Technical Writing Guide for Engineers, 3rd. ed. 2014. University of New Haven. He was also a Senior Member of the Society for Technical Communication (STC).

Dr. Amanda Simson, The University of New Haven

Amanda Simson was appointed Assistant Professor of Chemical Engineering in August 2015. Her research focuses on using heterogeneous catalysis in applications like emissions control and alternative energy technologies. Amanda received her Ph.D. from Columbia University's Department of Earth and Environmental Engineering in May of 2013. Simson's work at Columbia focused on developing more efficient hydrogen production processes for PEM fuel cells and her work was sponsored by BASF. Before joining the staff at UNH she spent two years developing hydrogen production technologies for Watt

Fuel Cell in Port Washington, NY. Dr. Simson is very interested in improving educational opportunities for students in STEM. Prior to her PhD studies Dr. Simson taught middle school for three years as part of the Teach for America program and helped found the first Democracy Prep Charter School. She has developed several programs for students including a series of math competitions for NYC middle school students and a chemistry card game called Valence.

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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/.

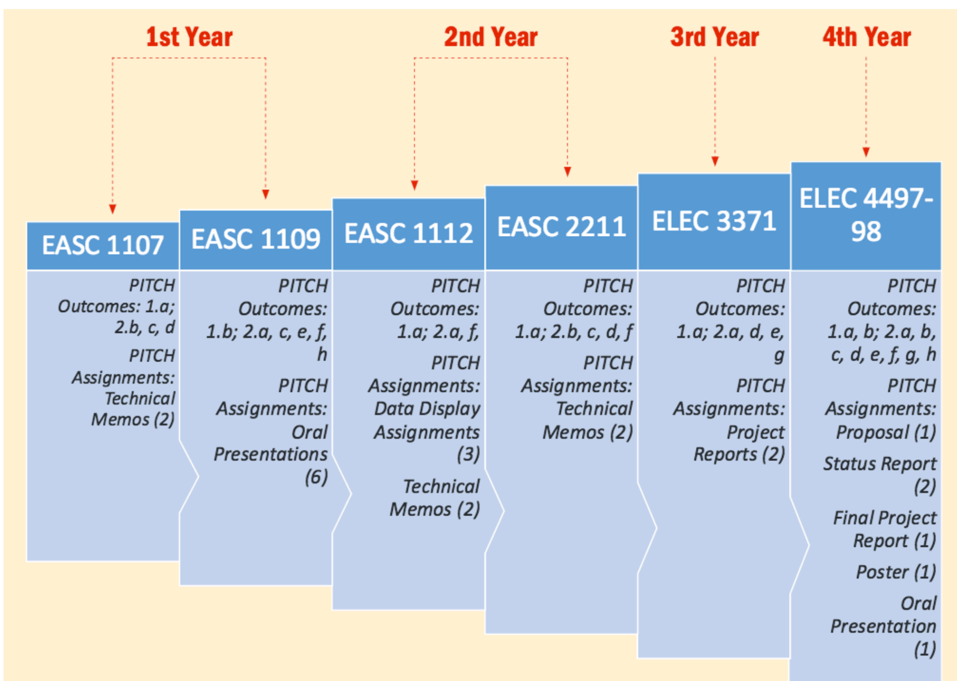

Figure 1. A roadmap of PITCH outcomes and assignments for electrical engineering

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

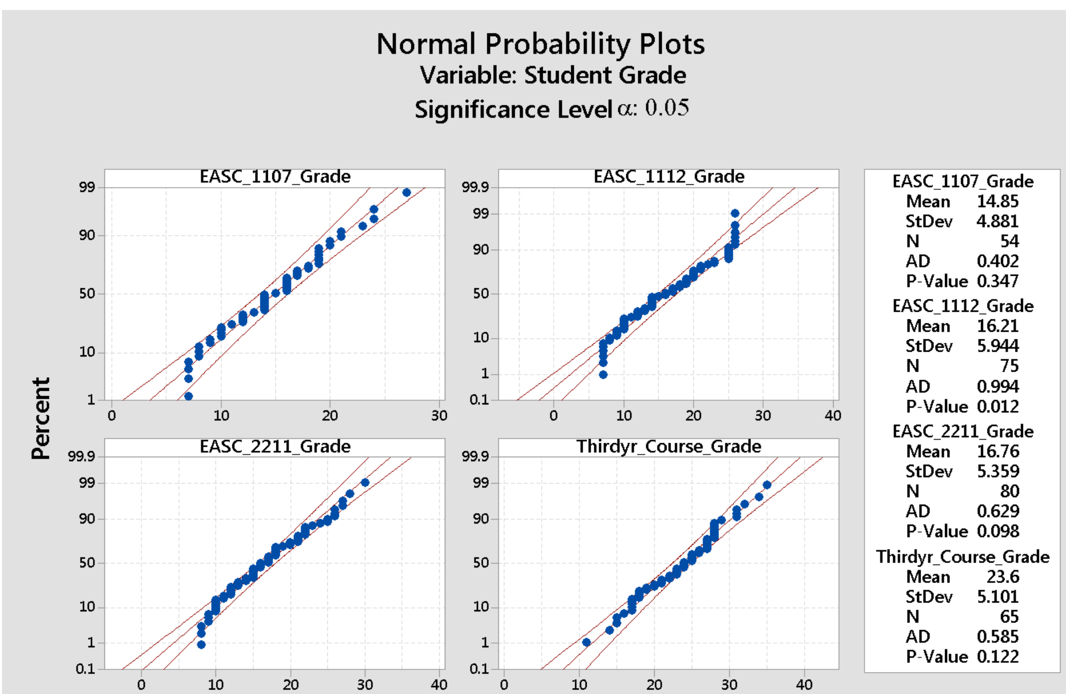

Figure 2. Results of tests for confirming normal distributions of data

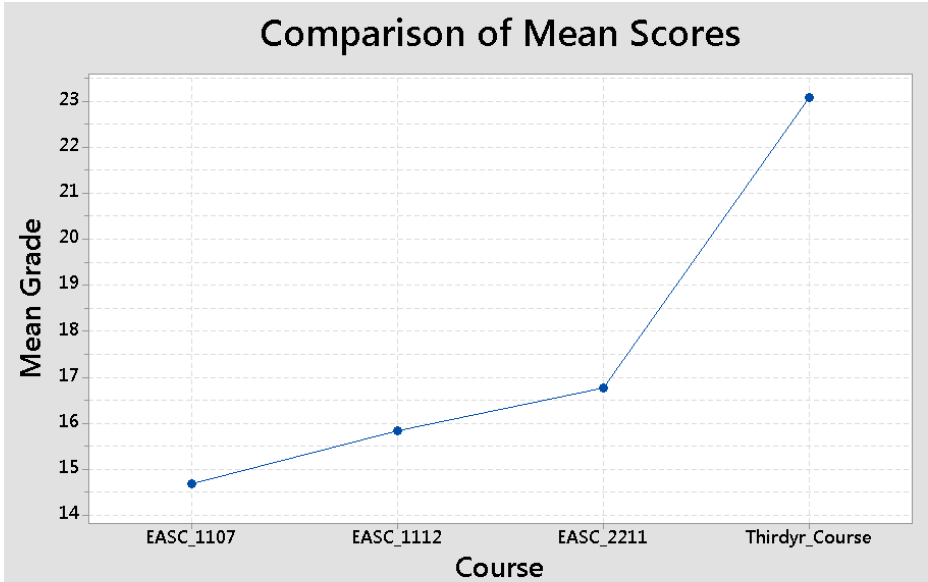

Figure 3. Change in rating of student writing from course to course

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:

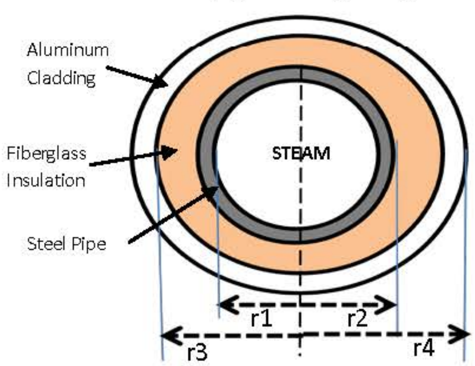
Subject: Project 2, Optimum Pipe Insulation

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:

Steady - State Heat Flow		Rearranged for Matrix Solution :
$Q_S = Q_1$	$C_1(T_S - T_1) = C_2(T_1 - T_2)$	$(C_1 + C_2)T_1 + (-C_2)T_2 = C_1 T_S$
$Q_1 = Q_2$	$C_2(T_1 - T_2) = C_3(T_2 - T_3)$	$(C_2)T_1 + (-C_2 - C_3)T_2 + (C_3)T_3 = 0$

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^{o}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 $\frac{W}{m^2 \cdot {}^oC}$		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:

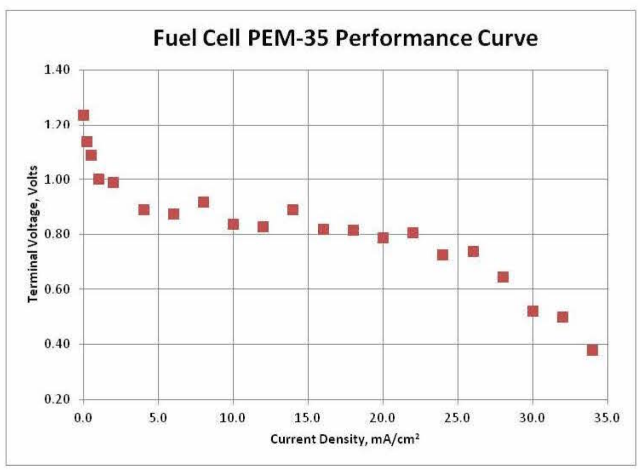
EASC2211 Introduction to Modeling of Engineering Systems Fall 2013

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)