# WORKING WORLD PROBLEMS AND COMMUNICATION FOR THE CLASS ROOM

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## Abstract

Engineering problems in the working world can differ from what students encounter in the classroom. The communication of the results also differs. For some engineering problems, e-mail has become the major method of communication.

This paper discusses the differences between the classroom and the working world. The paper also introduces a method to bring working world engineering problems and communication (via e-mail) into the classroom. The goal is to take the students to a higher level of understanding of the material. Another goal is to develop their communication skills.

A pilot study measured the quality of the students' communication skills (i.e., e-mail). In this study, experienced engineers critiqued the students' e-mails about an engineering problem. This study indicates a relationship between e-mail quality and hiring. Additional research is needed to determine if this method actually improves the students' e-mail communication skills.

This paper demonstrates the need and value of writing technical e-mails clearly. The teaching method presented in this paper will help prepare students for industry and may help develop their skills in communicating technical issues.

## Introduction

I, the lead author, am a chemical engineer with 31 years of industrial experience. While preparing to teach thermodynamics and heat transfer, I found striking differences between the textbook problems and working world engineering problems. I also noticed that the students had little or no exposure to the communication needs of industry and businesses. As noted by S. Dillon(13), businesses are spending as much as 3.1 billion dollars annually to improve the writing style of their employees.

In response to these observations, this paper looks at these differences and introduces a method to bring working world engineering problems and e-mail communication into the classroom. A pilot study (completed in April, 2004) of the e-mail portion of this method indicates a relationship between e-mail quality and hiring.

The term "working world" is used because the topics in this paper apply to situations in industry, government, and other business professions. First person and active voice are predominant in this paper because this is what the working world uses, or should use [3][7][10][18][29][33]. This contradicts the preferred use of third person by some references for writing. [3][22]

**Discussion**

A literature review found case studies, term projects, and exemplar studies [14] for the classroom. Miller [23] discusses industry's additional issues (inconsistent data, real vs. theoretical data) that are normally not part of the classroom. Otherwise, a search of the literature revealed nothing that compares how working world engineering problems differ from textbook problems.

Textbook problems differ with the working world in several ways as shown in Figure "A". In the working world the available information may be wrong or misleading. Critical data may not be easily available. The engineer in industry needs an in depth understanding of the problem. He/she needs more than just knowing which equations and parameters to use. Miller [24] points out that industry expects to hire engineers who "can go beyond the numbers" with an understanding of the impact of the technical results.

Another difference is how the results are communicated. In the classroom, the professor receives the calculations on an engineering pad with the answer placed in a box. But in the working world, e-mails are now a major form of communication. Figure B is an outline of these differences in style, intent, and format between the classroom communications and e-mails.

I found discussions in the literature on e-mail etiquette, structure, and audience. One Web page article has a strong focus on what the reader needs to know [1]. The co-authors and I found no literature on the differences in style or format between working world e-mails and classroom reports as outline in Figure B.

In this paper "style" refers to clarity, using simple words, using simple sentences, and only stating what needs to be stated. "Format" is the structure of the communication (abstract, introduction, discussion, analysis, etc.). The "format" or structure of a communication can vary among different organizations. "Style" is the degree of written clarity in the communication.

In rhetoric and composition classes, the focus is on the writer. Students learn to express themselves in their own terms [7] and to demonstrate what they know [29]. In academia, high reading and writing levels are important [29] and can be measured using the Fog Index, a method to measure the grade level required to understand the writing[37][38]. The number of words and sentences in a writing sample are determined. The words that are three syllables or more are also counted. These data are then placed in a formula to determine the Fog Index.

Engineering academia tends to write at a high Fog Index as evidenced in the following example. The Fog Indexes averaged 21.8 for the abstracts (or summaries) of six ASEE articles listed in this paper's bibliography (Figure D). The only criterion is that the abstract be at least 100 words.

Professional prose should not exceed the upper limit of 18 [23]. In technical writing, it is difficult to get a Fog Index below 10, but a Fog Index above 15 will probably be difficult for a reader to follow [10].

For comparison, this paper's abstract has a Fog Index of 12.2. In the working world, written communication should be at the lowest Fog Index that the material allows. This is needed for communication clarity and efficiency.

The differences between academia and the working world showed itself when a co-author (my twin brother and a university professor) and I argued about doing a Fog Index for the student e-mails. The professor wanted the Fog Index because of the curiosity that drives academic research. I didn't want to spend the time because no matter what the results are, there was no potential value relative to this paper. In industry and business, you do not spend time and money just on curiosity; there must be a potential benefit. We did agree that a future study on student e-mails could use the Fog Index to measure the impact of the teaching method discussed later in this paper.

Another important factor is the writer's attitude. The focus is on yourself when you write to express yourself or to show (or prove) your mastery of the topic. With this kind of focus on ones' self, a writer can become close-minded and overstate his or her own knowledge of the topic. This can cause the writer to reach the wrong conclusion or to make an improper recommendation. As discussed later in this paper, some of the student e-mails had statements, conclusions, and recommendations that went beyond what their available data supported.

Writing with the readers' terms and needs in mind requires the author to think from the perspective of others. This perspective leads to a mind open to new and different ideas, thus encouraging better communication.

This paper uses the word "reader" most of the time instead of "audience" as is discussed in the literature [14][29]. This is because "audience" is three syllables and "reader" is two syllables. Burger [7], Freeman [18], and Strunk [33] recommend using simple words, which helps to lower the Fog Index. In addition, e-mails are normally written to a specific person or persons by name, while "audience" normally refers to a group of people the writer may not know.

Communication clarity is critical for time and accuracy in the working world. Words the reader understands are preferred; words only the writer understands decrease reader comprehension. The focus is on the reader. In business and industry, writing at an academically high level (or high Fog Index) is not important. What is important is getting the needed information across to the reader in a clear and efficient way.

Simple words and sentences [23][37] with no excess verbiage [33][35] are the most efficient way to communicate to the widest audience. Quickly addressing the reader's needs in the first paragraph is important in the working world. Occasionally, the addressee only reads the e-mail's first paragraph because of time constraints.

**Teaching Method (E-mail Assignments)**

I developed a teaching method where the students have an assignment of an engineering problem that could occur in industry. For these assignments, the focus is to take the students' understanding beyond just knowing the equations. The other objective is to expose students to working world engineering problems and e-mail communication. I've been using this method for the past four years in my thermodynamics and heat transfer classes.

The e-mail assignments are theoretical scenarios. In the scenario, the student is an engineer who has been assigned a technical problem by his or her supervisor. As does occur in the working world, the scenario contains wrong or misleading information and not all needed data are available to the student.

The calculations needed for the scenario are class homework problems. The assignment's calculations and results are then discussed in class as part of the homework review. Next, the students prepare draft e-mails on the results to the manager, supervisor, or engineer, as stated in the scenario. Actually, the e-mails are sent to me and I play these roles.

The students have instructions to focus the e-mail on what the addressee needs to know and not write to impress or to show the extent of their knowledge. I emphasize the use of simple words and sentences. The e-mail structure is simply a summary and a discussion. The summary states the topic and what the addressee needs to know. The discussion explains the problem, issues, data, the logic used in reaching results, and the justification of recommendations or conclusions.

I then edit the draft e-mails with comments and corrections. The edited drafts are returned to the students for re-submission. This is repeated several times as needed to teach the student what changes the working world requires. For this method, the premise is that good technical writing is a skill best learned by practice (29).

This method is not overly time consuming for me. Each draft takes less than 5 minutes to edit and the final submission is about a half page. The grade is given only to the final submission with no reflection on how many times it was submitted and corrected. Hence, if a student works hard enough he/she will get a "100" on the e-mail portion of the assignment.

Most of the editing is to remove unnecessary words and replace with simple words. Whole statements are removed that "go without saying" or contain information the addressee (as stated in the scenario) already knows. Also removed are excessive details and unnecessary information (7)(18)(29)(33)(35).

These assignments require the students to have an in-depth understanding of the concepts and technical issues. In one assignment the students compared the design of two walls relative to heat transfer. Calculating the rate of heat transfer for each design is a simple textbook calculation. But an in-depth understanding beyond textbook equations is needed to explain why one design is better than the other even though the thermal conductivities are the same for the materials in both designs.

I noticed that the students have a difficult time adjusting to this kind of assignment. They tend to write what they think I want to hear and not what the scenario says they need to communicate. The students also tend to follow the textbook and not what the scenario and calculations show.

Some students became frustrated when they compared two refrigerants (R-134a and R-744) for an assignment. They thought that R-134a should have a higher convection coefficient than R-744. The students apparently thought that the R-134a should have a higher convection coefficient that R-744 because my present job in industry deals with R-134a. They couldn't imagine that I would give an assignment that shows that R-744 is better than what I make. They did not trust their own calculations. I informed the students that their calculations are correct for the given conditions; R-744 has a higher convection coefficient than R-134a.

One e-mail assignment requires the students to compare the Coefficient of Performance between refrigerants R-134a and R-744 in a car air conditioner. Two students stated in their e-mails that the pressure in the scenario is too high for the R-744 condenser. The pressure is above the critical point where condensation will not occur. They recommended that the R-744 condenser operate at a lower pressure for condensation to occur. The students essentially followed the textbook on how an air conditioner works rather than what is really needed for an air conditioner to work.

I pointed out that the R-744 would not work in a car air conditioner at their recommended pressure because the temperature is too low. The R-744 is above its critical point at the car air conditioner's required pressure and temperature. This means there is no condensation with R-744. The students expected condensation because that is how the textbook explained is how an air conditioner works. The students had to determine on their own that the R-744 condenser is simply a regular heat exchanger (or gas cooler) operating above the R-744 critical point. This is the kind of thought process that working world engineering problems require.

A drawback to this method is that the students learn, by way of edited drafts, my e-mail writing style and structure. The editing is very subjective based on my judgment and is specific to my own experiences. Special care is needed not to edit simply because the style is different than mine. I must refer to the many references [7][18][23][33][35] on effective writing and not edit based on my own writing style. Because of these concerns, a pilot study was completed where experienced engineers evaluated the students' e-mails.

## Pilot Study

The pilot study's objective is to develop a protocol to score the student e-mails in a way that reflects the working world. Driskill [14] and Miller [25] discuss various assessment methods on communication and point out that "these methods do not specifically consider the audience" or in the case of this paper the e-mail addressee. I therefore had to develop a new approach for assessment.

Working world engineers are the best judges of their understanding of an e-mail sent to them. Five engineers, each with more than 20 years experience, agreed to be Technical Reviewers and to evaluate the students' e-mails. Three of the Technical Reviewers work in industry, one for a government agency, and one is a consultant.

The differences between academia and the working world again became clear during the authors' discussion of how to describe the engineers who would evaluate the student e-mails. One academic co-author recommended the term "Professional Engineering Evaluators". I wanted to use "Technical Readers" for simplicity based on my experience in industry. We compromised with "Technical Reviewers".

The assignment's scenario (based on an actual experience of mine) casts the student as an engineer for a car air conditioner manufacturer. In the scenario the supervisor was in a meeting where there was a heated debate on which refrigerant (R-134a or R-744) has the higher convection heat transfer coefficient in the condenser. One argument is that R-134a has a higher coefficient because of the higher velocities. The other argument is that the R-744 is better because it has a higher thermal conductivity.

The supervisor asked the engineer (i.e., the student) to determine which has the higher convection heat transfer coefficient in the condenser. For this scenario, I told the students to just look at the condenser inlet conditions where one must deal with gases only. Condensation was not included because condensation is beyond this course.

The students had to research the physical properties for R-744 because this data are not in their textbook; R-134a is in the textbook. The students could refer to either the ASHRAE reference document or the NIST web page. The goal is to help develop ".... skills to locate, retrieve, evaluate and use information regardless of format" [12].

The scenario's calculations show that the Reynolds numbers are about equal for the two cases and that the R-744 convection coefficient is about twice that for the R-134a. The students had to explain in their e-mails why R-744 has the higher convection coefficient because of the dispute between the supervisors as to which one has the higher coefficient. In a situation like this, a clear and decisive explanation of the results is needed.

The students' first drafts, with no editing from me, were sent to the Technical Reviewers along with the scenario description and the evaluation sheets (Figure C). The Technical Reviewers played the part of the supervisor in the scenario. The ten e-mails were randomly identified with numbers between 1 and 20 to maintain objectivity.

A five-point Likert Scale was used to measure the Technical Reviewers' opinion on the e-mails' quality [19]. The evaluation sheet has five questions for the Reviewers to rate by selecting Strongly Disagree (SD), Disagree (D), Neutral (N), Agree (A), or Strongly Agree (SA) for each question.

The Reviewers then returned the evaluations to me. Each response was rated with a numerical value: Strongly Disagree (-2), Disagree (-1), Neutral (0), Agree (+1), and Strongly Agree (+2). Each student had 25 data entries (five Reviewers with five questions each) that ranged from –2 to +2. The mean rating for each student was calculated and reported in Table 1. A limitation with this method is that the classification data are converted to a numerical value. The assumption is that the differences in magnitude between the choices are equal in the Likert Scale.

The Technical Reviewers were asked if they would hire the student based on the student's draft e-mail. This was done as a separate question to obtain the overall Reviewers' opinion of the student. This also provided a reality check for the students on what to expect in the working world. The fraction of those Reviewers who said yes on hiring is included in Table 1.

TABLE 1
OVERALL TECHNICAL REVIEWER RESULTS

| STUDENT | DISAGREE/AGREE FREQUENCY | | | | | MEAN. | HIRE |
|---|---|---|---|---|---|---|---|
| I.D. # | SD | D | N | A | SA | RATING. | FRACTION |
| 2 | 0 | 4 | 4 | 15 | 2 | 0.60 | 0.55 |
| 3 | 1 | 1 | 5 | 14 | 4 | 0.76 | 0.75 |
| 4 | 1 | 2 | 5 | 13 | 4 | 0.68 | 0.25 |
| 5 | 2 | 7 | 6 | 8 | 2 | 0.04 | 0.25 |
| 6 | 2 | 3 | 4 | 9 | 7 | 0.64 | 0.33 |
| 7 | 0 | 3 | 2 | 14 | 6 | 0.92 | 1.00 |
| 8 | 1 | 3 | 2 | 9 | 10 | 0.96 | 0.75 |
| 11 | 2 | 5 | 7 | 6 | 5 | 0.28 | 0.33 |
| 12 | 2 | 2 | 3 | 12 | 6 | 0.72 | 0.50 |
| 14 | 1 | 6 | 4 | 12 | 2 | 0.32 | 0.33 |
| | | | | | | Pearson R = 0.754 | |
| | | | | | | P < 0.012; N = 10 | |

TABLE 2
STUDENT #12; TECHNICAL REVIEWER RESULTS

| TECHNICAL | DISAGREE/AGREE FREQUENCY | | | | |
|---|---|---|---|---|---|
| REVIEWER | SD | D | N | A | SA |
| A | 1 | 0 | 1 | 3 | 0 |
| B | 1 | 0 | 1 | 3 | 0 |
| C | 0 | 2 | 1 | 1 | 1 |
| D | 0 | 0 | 0 | 5 | 0 |
| E | 0 | 0 | 0 | 0 | 5 |

## Pilot Study Results and Observations

The maximum expected rating is 1.0 (i.e., everyone "agreed") rather than the theoretical 2.0 that is possible if everyone "strongly agreed". This is because the Technical Reviewers have different styles and opinions. No two reviewers can have opinions exactly alike.

Table 2 is the ratings of the five Technical Reviewers for Student #12 and shows the difference of opinions between the Reviewers. This is in contrast with Miller [24] where two Reviewers had the same rubric score. This variability in opinion indicates a need for an overall average of several Technical Reviewers to measure the quality of the student's e-mail.

The Technical Reviewers emphasized that the students need to use the "spell checker". Misspelled words are very detrimental. They also commented that some e-mails did not have supporting data or show a good comparison of the data. Some e-mails included statements that were not required and gave conclusions beyond what their study covered.

Several e-mails recommended a switch to R-744 because its convection heat transfer coefficient is twice as high as the R-134a. However, the students were not asked for a recommendation or conclusion as to which is better for the car air conditioner. The question was: Which has the higher convection heat transfer coefficient? There are other parameters besides the convection heat transfer coefficient that need to be considered before making a recommendation.

I pointed out that those who said that R-744 provides 2X the heat transfer capacity are wrong. Granted, the R-744 convection heat transfer coefficient is twice the R-134a and the R-744 does provide additional heat transfer capacity. However, the R-744 increase in heat transfer capacity is less than 2X. This is because the overall heat transfer coefficient is 80% dominated by the resistance on the exchanger's air side [6].

Two of the Technical Reviewers commented that the question on hiring is inappropriate when there is just one e-mail to review. Hiring decisions are made with more information on the candidate than just one e-mail. One Reviewer did not answer the hiring question on any evaluation sheet because of this issue. The reviewers suggested that the question be changed to "would you schedule a job interview with this person based just on this e-mail". This would be in line with what actually happens in the working world.

Besides the one reviewer who did not answer the question on hiring, several other evaluation sheets had this question blank. Either the reviewers just could not decide on the particular student or the reviewers may have missed it. For the hiring data that are available, there is a correlation of Pearson $R= 0.754$ between hiring and the Likert score with $p< 0.012$ using a two tailed test ($N = 10$).

I prepared an e-mail like the students and included it with the package to the Technical Reviewers. This was done to baseline my writing style for the pilot study. The results show that

I, student #7, had one of the highest ratings by the Technical Reviewers and everyone who answered said they would hire me.

**Conclusions**

The differences between academia and the working world need to be recognized and understood. Academia should include experienced professionals from industry and businesses as part of a college program to provide a well-rounded education.

E-mail assignments are recommended for technically intense courses to challenge the students' understanding and skills to explain complicated technical issues.

**Future Research**

The expectation is that the students' e-mail communication skills and in-depth understanding of engineering problems will improve by seeing the edits and comments on their drafts. However, the effectiveness of this method is not yet proven. Chenoweth [9] found little or no improvement in the writing skills of their students during a study of an English writing course.

Further study is needed to determine if this teaching method improves the students' e-mail communication skills. A larger number of Technical Reviewers from the working world should be used because of the variability among Reviewers. More Reviewers will improve the correlation statistics between the Likert questionnaire rating and the final question on scheduling a job interview.

FIGURE A.

DIFFERENCES BETWEEN CLASSROOM AND
"WORKING WORLD" ENGINEERING PROBLEMS
(As observed by the lead author)

| TEXTBOOK | WORKING WORLD |
|---|---|
| Straight forward problem or question. | The real problem or issue may not be obvious. |
| All needed data or information are available in the textbook. | Needed data or information not readily available. |
| Simple answer, normally a calculated value on an engineering pad. | Complex results that have to be communicated and explained. |
| All provided data and information are correct. | The available information or data can be wrong or misleading. |
| Just have to state the simplifying assumptions in the calculations. | Can use simplifying assumptions, but need to fully understand the impact on the results. The assumptions can impact what is reported in the results. |
| The engineering calculations and results are for a grade. | The engineering calculations and results can impact costs and safety. The results could make the difference if a company stays in business. |
| There are no extraneous factors to deal with. | Have extraneous factors: safety, government regulations, budget, available equipment, etc. |
| Submission is for the professor to grade. | Submission is what the reader needs or want to know. |
| Partial credit is sometimes given if the calculations demonstrate that the student understands the material; i.e., a simple arithmetic error. | There is no partial credit. Either the results are correct or they are wrong. Simple arithmetic errors are no excuse. |

FIGURE B.

DIFFERENCES BETWEEN CLASSROOM & "WORKING WORLD" COMMUNICATION
(As observed by the lead author)

| CLASSROOM | | WORKING WORLD |
|---|---|---|
| Lab Reports | Term Papers | E-Mails |
| Abstract | Summary or Abstract | Summary |
| Introduction | Introduction | Discussion |
| Procedures | Discussion | Attachments |
| Discussion | Conclusions | |
| Results | Appendix | |
| Conclusions | | |
| Appendix | | |
| Demonstrate a mastery of the material. | | Communicate needed data or information. |
| Research a topic and then summarize what found. | | Summary states what addressee needs to know. The discussion is to explain the problem, logic used in reaching results, justification of recommendations, etc. |
| Written for the professor to grade. | | Written to the addressee for transfer of information. Addressee could be a supervisor, manager, an engineer, accountant, field technician, salesman, etc. |

FIGURE C

# TEXAS A&M – CORPUS CHRISTI
# ENTC 3320

## TECHNICAL REVIEWER
## E-MAIL EVALUATION

STUDENT _____________ DATE________

Please first read the e-mail assignment. Then read the student's e-mail and circle below how well you agree with the statements.

| STATMENTS | STRONGLY DISAGREE | DISAGREE | NEUTRAL | AGREE | STRONGLY AGREE |
|---|---|---|---|---|---|
| Easy to Understand | X | X | X | X | X |
| There are no excess words | X | X | X | X | X |
| E-mail is well organized | X | X | X | X | X |
| Stated what I needed to know. | X | X | X | X | X |
| Has adequate supporting information/data | X | X | X | X | X |

| OVERALL IMPRESSION | YES | NO |
|---|---|---|
| Based solely on this e-mail would you hire this person? | X | X |

COMMENTS (OPTIONAL):_______________________________________________________

_____________________________________________________________________________

FIGURE D

FOG INDEX OF ASEE PAPERS

| PAPER | White, White, & Willette | ASEE Paper | ASEE Paper | ASEE Paper | ASEE Paper | ASEE Paper | ASEE Paper |
|---|---|---|---|---|---|---|---|
| NUMBER OF WORDS IN ABSTRACT | 192 | 157 | 139 | 172 | 187 | 183 | 204 |
| NUMBER OF SENTENCES IN ABSTRACT | 13 | 5 | 6 | 7 | 9 | 7 | 5 |
| NUMBER OF BIG WORDS (3 SYLLABLES) | 35 | 36 | 39 | 43 | 36 | 57 | 66 |
| AVERAGE SENTENCE LENGTH | 17 | 31 | 23 | 25 | 21 | 26 | 41 |
| PERCENT OF BIG WORDS | 17 | 23 | 28 | 25 | 19 | 31 | 32 |
| ADD LENGTH TO PERCENTAGE | 34 | 54 | 51 | 50 | 40 | 57 | 73 |
| FOG INDEX (0.4x OF ABOVE) | **12.5** | **22** | **21** | **20** | **16** | **23** | **29** |
| | | | | | | | |
| NUMBER OF PARAGRAPHS IN ABSTRACT | 4 | 1 | 1 | 1 | 3 | 1 | 2 |
| AVG. NUMBER OF WORDS IN PARAGARPH | 48 | 157 | 139 | 172 | 62 | 183 | 102 |

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**Acknowledgements**
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