When Engineering Students Write about Waste Electronics: Trends in how they Think of Global Impacts

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Abstract

The engineer of today requires a wide set of non-technical skills, including the ability to write for various audiences and the capacity to consider the ethics of their work. The issue of waste electronics (including consumer electronics, appliances, and personal computers) is an ethics-laden topic associated with the professional activity of many engineers, particularly computer and electrical engineers. In a pilot study, we evaluated 92 writing samples on the topic of waste electronics from a range of undergraduate engineering students in an introductory circuits class at a large public research institution. We asked students to read a journal article on waste electronics and recycling and then write an essay on what they viewed to be (a) the most important negative impacts of waste electronics on ecosystems and public health, and (b) the engineer’s responsibility in limiting improper disposal of consumer electronics. We then evaluated these writing samples for several types of literacy. Findings showed that students scored better on higher-level literacies than on basic literacies, and that basic literacies were uncorrelated to higher-level literacies, specifically ethical and critical literacies. In other words, even students who wrote poorly were able to express fairly sophisticated ideas regarding ethical issues and the power dynamics associated with waste electronics and stakeholders. Among demographic groups, very few differences were observed, the most noteworthy being that those students who classified themselves as introverts tended to consider their audience to a greater degree than those who classified themselves as extroverts.

Introduction

The need for improvement in undergraduate student writing abilities has been well recognized,[1] and with the added complications of transnational and intercultural communication that globalization brings, even more work remains to be done in preparing students for the real world. Gone are the days when knowledge of basic literacy—e.g., grammar, spelling, structure, etc.—is sufficient for engineering writing. A comprehensive framework for literacy must be learned that considers, in addition to basic literacy, more complex and overlapping literacies, including Rhetorical, Social, Technological, Ethical, and Critical Literacy.[2] Cook defines these literacies as “layered literacies,” describing them as follows: Basic Literacy is the ability to read and write with completeness, consideration, clarity, courtesy, and correctness, through the application of formal rules, principles, and forms with a focus on clarity, precision, and efficiency. Rhetorical Literacy reflects an understanding of the purpose and objectives of writing, the audience for whom a piece is written, as well as an awareness of the author’s own ideological position and the effect it may have. Social Literacy involves the ability to collaborate and work with others and to articulate and even negotiate the purpose or intention of such collaboration. Technological Literacy reflects a working knowledge of communication technologies, including proper use of a word processor and formatting to support the intended communication with the reader. This literacy also covers an awareness of how communication technologies promote social interaction, as well as an ability to research (and critique research about) how users work with technologies, and an ability to then use this knowledge to design documents both with and for users. Ethical Literacy reflects both knowledge of professional ethical standards (e.g., codes of ethics), as well
as an ability to consider all stakeholders involved. Critical Literacy reflects “an ability to recognize and consider ideological stances and power structures and the willingness to take action to assist those in need.”[2]

In this work, we examine student writing samples through the lens of Cook’s layered literacies framework as described above, excluding Social Literacy and the metacognitive aspects of Technological Literacy, as they do not apply to the research context in this study. This framework is particularly useful because it allows us to separate poor writing quality (i.e., problems with Basic Literacy) from other important components not well researched or understood, such as ethical and critical literacies. We used this framework to create an assessment rubric (see Methods section), which we then applied to 92 writing samples from an introductory electric circuits class at a large public research institution. Specifically, we asked students to read a journal article on waste electronics and recycling in China and India, then write a reflection paper that (a) speaks to the most important negative impacts of waste electronics on ecosystems and public health, and (b) provides a personal opinion on what the student believes is the engineer’s responsibility in limiting the impact of improper disposal of consumer electronics. Our findings confirm existing literature showing that Basic Literacy remains a problem. However, our findings also show that despite poor Basic Literacy skills, students on the whole and across most demographics are expressing fairly sophisticated thoughts regarding ethics and other associated critical issues.

Background

Writing is performed for a variety of purposes, for a variety of audiences, and can be taught and assessed in a variety of different ways. In the wider literature on undergraduate writing, others have observed[3],[4] that college faculty fail to agree on how to define good writing and thus on how to promote and assess it. Even within engineering education, faculty do not all share the same view of writing literacy.[5] In the interest of facilitating more a meaningful synthesis, we focus our literature review primarily on the archival literature of the field of engineering education research. Here we find only a modest number of empirical studies seeking to describe or assess the state of engineering student writing abilities. In 2008, Paretti[6] observed that most engineering education scholarship, at least in the area of technical communication in design courses, “has focused on describing course assignments and strategies for integrating communication into curricula, and on providing assessment methods.” This is also true in general for writing in engineering education. Additionally, we have found that what is known about how engineering students write (described below) is primarily in the realms of basic and rhetorical literacy with very little attention to higher-level literacies such as ethical and critical. While no other engineering education researchers have yet employed Cook’s layered literacies framework, we use Cook’s language of these literacies to discuss relevant literature below.

In 2002, Plumb and Scott examined the writing quality of nearly 25% (n=122) of seniors in the College of Engineering at the University of Washington.[7] Trained faculty evaluators rated a significant number of the writing samples as “Not Acceptable” (16% of samples/evaluations), meaning that based on these assessments, (a) the faculty evaluators would not recommend a sixth of the engineering students for a job requiring only basic writing skills, (b) the writing required extensive repair (more than people in the workplace would want to address), and (c) the student would not graduate if graduation depended on writing proficiency. This study also points out that
“a large portion of the ‘Not Acceptable’ papers showed significant non-native speaker issues.” Furthermore, the study indicated that not many writing samples showed “Strong” writing abilities (35 out of 302 evaluations, or 11%), meaning that faculty evaluators would (a) recommend, without reservation, students for jobs that carry a writing load much greater than the average engineering job in the workplace, (b) that students would need very little on-the-job training, and (c) that the writing could be used as a model for other students and for co-workers. The study also indicated specific writing quality problems, including:

1) Several issues related to basic literacy, including: use of proper citation forms (35% of evaluations); punctuation, grammar, usage, and spelling (31% of evaluations); logical progression and the structuring content to represent that logical progression (21% of evaluations)

2) An issue related to the rhetorical literacy skill of clearly stating the purpose and providing an explicit justification for the writing (16% of evaluations)

3) An issue related to the ethical literacy skill of using citations for others’ ideas, including both textual and non-textual materials (36% of evaluations)

In 2006, Drury, O’Carroll, and Langrish[8] reported on an interactive online program for teaching report writing at the University of Sydney. They included in their results the assessment of a cohort of third year chemical engineering students’ laboratory reports. This cohort was comprised of 46 students, 42% of whom were non-native English speakers. Assessment criteria included “academic literacy” based on a diagnostic instrument known as MASUS (Measuring the Academic Skills of University Students – see [9] for more information), which looks at the following four areas related to basic, and rhetorical literacy: “transfer and integration of relevant reference material, use of an appropriate genre structure, academic style and cohesion, and correct grammar.”[8] Unfortunately, findings from this study were not presented analytically, but holistically in the form of single scores (from 0-100%) for “academic literacy” on each of three of the writing samples assessed: practice reports (79.4%), draft reports (74.5%), and final reports (77.6%).

In the same year, Johnson presented a model for assessing writing by scoring students’ online portfolios using an analytical rubric-based approach.[10] The model involved having two independent evaluators rate student portfolios with values of 1 to 6 on each of 16 elements. Specific examples of these elements include “Demonstrates accurate language use (grammar, punctuation, spelling),” “Can adapt content to audience and purpose,” and “Contents of portfolio demonstrate the ability to differentiate between sources and one’s own text”. Here, too, assessment criteria were primarily issues of basic and rhetorical literacy, as well as an optional criterion on textual attribution related to ethical literacy. Using the model for three years (n=61, 50, and 136, respectively) with student portfolios at the New Jersey Institute of Technology, mean scores for all writing criteria (except the textual attribution criterion, which was not reported) were between 7.5 and 9 (on a scale of 2 to 12). The lowest scores occurred for the basic literacy issue of “accurate language use”.

In 2007, Yalvac et al.[11] presented findings from two consecutive years of their study of upper-level biomedical engineering student writing at Northwestern University. They assessed research papers written by teams of 3 to 5 students as part of a writing intervention based on best practices gleaned from the learning sciences. They also employed a rubric-based approach in which papers were scored by two evaluators using scales of 1 to 5 for issues of rhetorical and basic literacy,
including argumentation (e.g., explaining purpose, evaluating/questioning material cited, discussing controversies), organization and formatting, mechanics, style, content clarity and quality, synthesis (e.g., drawing on literature to show understanding, integrating ideas, making comparisons), and visual representations (i.e., charts and tables). Data for both of the years presented (n=9 and 8, respectively) showed insignificant changes in mechanics and visual representation, but significant improvement for all the other criteria.

In 2008, Flateby and Fehr\textsuperscript{[12]} described a rubric-based writing assessment tool called Cognitive Level and Quality Writing Assessment (CLAQWA) based on Bloom’s taxonomy. They reported the results of an analysis of 25 essays written by electrical engineering students at the University of South Florida. The CLAQWA assessment criteria are comprised of sixteen elements related to issues of basic and rhetorical literacy, the following five of which are reported on in the paper: “appropriate audience”, “opening supports main idea”, “reasoning supports main idea”, “accurate word choice”, and “consistent viewpoint”. Each element was assigned a score of 1 to 5 by evaluators, resulting in mean scores between 2.7 and 3.2 with the lowest scores occurring for the basic literacy issues of “reasoning supports main idea” and “accurate word choice”. The paper indicates that a peer review session improved these scores modestly and decreased the degree of their variation.

In 2012, Fernandez\textsuperscript{[13]} reported a 3-year comparative case study at the Technical University of Lisbon, Portugal of two electronic engineering courses. In both courses, the stated objective was basic literacy, specifically, “writing without spelling and syntax errors”, which was assessed and graded in both courses. Second year undergraduate students attended the first course, entitled Oral and Writing Communication (n=15, 14, and 28 for each of the 3 years for which data was reported). First year Master’s degree students attended the second course, entitled Value of Technology and Innovation (n=14, 24, and 11 for each of the 3 years for which data was reported). A key difference between the two courses (other than age/experience of students) is that, in the undergraduate course, students were specifically taught spelling and syntax rules, whereas in the Master’s course they were not. Results were presented for the evaluation of three types of student writing, each comprised of 20-40 lines (1-2 pages) of text. For the undergraduate course, the assignments were biweekly summaries of (a) journalistic news articles and (b) selected grammar rules from a concise grammar book. For the Master’s course, the assignments were weekly reports (with figures or tables) related to subjects presented in class. For all assignments, the number of errors made (per 20 lines of text) were tabulated and compared both within and between individual course offerings and cross-sectionally for the three years for which data was reported. The study ultimately found that engineering students’ writing skills improved throughout the duration of the course and improved more if students are explicitly taught spelling and grammar rules.

A number of conference papers have also looked at student writing, such as Trotz et al.’s 2010 paper,\textsuperscript{[14]} which employed the CLAQWA assessment tool (see Flateby and Fehr above) to report on a study of civil and environmental engineering student group reports at the University of South Florida. They reported scores for two senior level classes across all 16 elements (issues all related to basic and rhetorical literacy) of the CLAQWA tool. They reported higher scores than Flateby and Fehr, with mean values between 2.6 and 3.7 (out of 5) for one class (n=9) and between 2.6 and 3.9 for another class (n=13). Problem areas are shown to vary depending on the group, but for both classes as a whole, the lowest mean score occurred for the basic literacy issue.
indicating the writing’s “closing synthesizes the elements, supports the main idea and finalizes 
the paper”.

Additional conference papers include Rhoulac and Crenshaw’s 2006 study\textsuperscript{[15]} of 15 technical 
reports written by seniors in civil engineering at Howard University, as well as Poltavtchenko 
and Tingerthal’s 2011 study\textsuperscript{[16]} of 9 group project reports written by construction management 
students at a public middle-sized university in the Southwest United States. In terms of Cook’s 
framework, both of these studies looked at elements of basic and rhetorical literacy. Rhoulac and 
Crenshaw found some encouraging results in their sample with class mean scores of 8.4 (out of 
10) for grammar and syntax, though they do indicate room for improvement in individual student 
writing. Poltavtchenko and Tingerthal found that supplemental project-directed writing 
instruction helps students improve consideration of audience, reporting class median scores of 
22.5 (out of 30) for the first draft of a report and 26.3 for the second draft. Encouraging as this 
might appear, however, generalizations can really not be made based on any of these conference 
papers (and many of the journal papers) due to their small samples sizes.

Thus, from the studies reviewed, it appears that aspects of engineering students’ basic literacy 
still need work, as well, perhaps, as do the various methods of assessment to facilitate more 
meaningful comparisons within, between and across data sets. Regardless, a comprehensive 
framework for assessment is needed. Furthermore, little is known about the higher-level 
literacies of Cook’s framework, including Ethical and Critical Literacy. This study intends to 
begin filling some of these gaps.

\textbf{Methods}

Student writing samples on waste electronics were used to explore how undergraduate 
engineering students feel, think, and propose to act on global issues related to engineering. 
Writing analyzed in this study is from students at a large public research institution in the Pacific 
Northwest, classified as Doctorate-granting RU/VH (Research University, Very High Research 
Activity) according to the Carnegie Basic Classification.\textsuperscript{[17]} Students from a variety of 
engineering majors in a large, entry-level electrical engineering course were provided with an 
article on waste electronics, as well as questions pertaining to the article. Students were then 
asked to write an essay on the article as guided by the provided questions. Students were 
incentivized with extra credit to be applied to their course grades. Ninety-two students 
completed this extra credit assignment and the writing samples were then analyzed using a rubric 
based on Cook’s “layered literacies” framework (see Introduction). The multiple literacies 
present in the rubric (see section \textit{C. Instruments}, below) examine a student’s skill in basic writing 
and grammar, as well as in higher-level literacies including ethical and critical literacies.

\textbf{A. Research Questions}

\textit{Research Question \#1: How skilled are undergraduate engineering students in the multi-layered 
literacies of technical communication?}

This research question provides an overview of student ability to both think and communicate 
within each different literacy, as well as provides an opportunity to compare skill level across 
literacies.
Research Question #2: Are basic literacies linked to higher-level literacies?  
This question broadens Question #1, asking if students’ basic grammar and writing skills are associated with their ability to think critically, consider their audience, and write thoughtfully about ethical issues.

Research Question #3: What demographic groups perform best at higher-level literacies?  
This question seeks to illuminate any differences in how students express thought on ethical issues based on demographic groups. Findings from this question will inform further research.

B. Subjects and Procedures

Students for this research were all enrolled in and recruited from an introductory-level sophomore electrical engineering course with a total enrollment of 180. Students majored in a wide variety of engineering fields, but most students were from bioengineering, electrical engineering, or mechanical engineering. All students in the class were invited to complete the essay and also to release their work for this research. Students were fully informed (verbally and in writing) that no student’s grade would be negatively impacted by not providing consent. Details regarding who provided consent and who did not were withheld from the instructor. In total, 101 students completed the extra credit assignment and 92 released their work for research. Demographics of the student population as relevant to the analysis provided in this paper are summarized in Table 1. Personality type was self-declared and did not include a Myers-Briggs or similar test to confirm personality type. No over-sampling was done for minority populations and demographics by gender, ethnicity, and citizenship are comparable to representations at the College (of Engineering) level.

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Type</th>
<th>College of Engineering</th>
<th>This Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>All</td>
<td>4085 (100%)</td>
<td>92 (100%)</td>
</tr>
<tr>
<td>Gender</td>
<td>Men</td>
<td>3105 (76%)</td>
<td>76 (83%)</td>
</tr>
<tr>
<td></td>
<td>Women</td>
<td>980 (24%)</td>
<td>16 (17%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>Caucasian</td>
<td>2696 (66%) estimated</td>
<td>51 (55%)</td>
</tr>
<tr>
<td></td>
<td>Asian</td>
<td>1144* (28%)</td>
<td>28 (30%)</td>
</tr>
<tr>
<td>Citizenship</td>
<td>U.S.</td>
<td>3758 (92%)</td>
<td>76 (83%)*</td>
</tr>
<tr>
<td></td>
<td>Non-U.S.</td>
<td>327 (8%)</td>
<td>16 (17%)</td>
</tr>
<tr>
<td>Personality Type</td>
<td>Introvert</td>
<td>N/A</td>
<td>12 (13%)</td>
</tr>
<tr>
<td></td>
<td>Mixed</td>
<td>N/A</td>
<td>54 (59%)</td>
</tr>
<tr>
<td></td>
<td>Extravert</td>
<td>N/A</td>
<td>26 (28%)</td>
</tr>
</tbody>
</table>

*Includes Asian Americans only; **Includes citizens and permanent residents of the U.S.
Demographics were collected as part of a separate survey administered concurrently with the written extra credit assignment described above. The survey is part of a larger, five-year study investigating connection, community, and belonging among undergraduate STEM students, described in greater detail by Allendoerfer, et al.\textsuperscript{[18]} The demographics noted in Table 1 were collected using the questions outlined in Table 2.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|}
\hline
\textbf{Question} & \textbf{Response Scale} \\
\hline
Gender (circle one) & (1) Female \hspace{1cm} (2) Male \\
\hline
Your Ethnicity (check as many as apply for you) & (1) American Indian/Native American \hspace{1cm} (2) African American/Black \hspace{1cm} (3) Arab/Middle Easterner \hspace{1cm} (4) Asian/Asian American \hspace{1cm} (5) Caucasian/White \hspace{1cm} (6) Hispanic/Latina/Latino/Mexican American \hspace{1cm} (7) Pacific Islander \hspace{1cm} (8) South Asian/South Asian American \hspace{1cm} (9) Other, please specify \\
\hline
What is your status in the U.S.? (check one) & (1) U.S. Citizen \hspace{1cm} (2) Permanent Resident \hspace{1cm} (3) Foreign Student \hspace{1cm} (4) Other, please specify: \hspace{1cm} \underline{____________________} \\
\hline
Which of the following best describes you? & (1) Introvert (being around people typically diminishes my energy) \hspace{1cm} (2) Mixed Extravert/Introvert \hspace{1cm} (3) Extravert (being around people adds to my energy) \\
\hline
\end{tabular}
\end{table}

\textbf{C. Instruments}

1. Assignment
The writing assignment consisted of three components: a scholarly article, writing directions, guiding questions, and a consent form. The article students were to read and write about was a 14 page scholarly article entitled “A review of the environmental fate and effects of hazardous substances released from electrical and electronic equipment during recycling: Examples from China and India”.\textsuperscript{[19]} This article discusses the presence of poor waste electrical and electronic equipment (WEEE) recycling techniques in China and India and also discusses the impact these practices have on a variety of stakeholders. Along with the article, students were provided written instructions to write at least one page of text in response to the following prompts:
1. What part of Waste Electronics Recycling in Figure 1 [in the article] concerns you most? Why?

2. From the part of [the] Waste Electronics Recycling process you chose in Question 1, what is the impact on humans? On ecosystems? (address air, water, or food quality as needed)

3. What do you think modern engineers producing these electronic technologies should do as an "ethical" response to the waste electronics recycling dilemma? Comment specifically on how far in scope engineers should go to limit the waste electronics recycling impact.

Students were provided one week to complete the assignment. Submitted assignments were separated by consent, and essays that had corresponding consent were forwarded to research assistants for evaluation, described next.

2. Evaluation

Two research assistants evaluated the writing samples using a rubric based on Cook’s “layered literacies,” a theoretical framework for technical communication pedagogy, developed for purposes of assessing these and similar written essays and described in the Introduction above. For each of the “layered literacies” in the rubric, students were graded as “Novice,” “Developing,” “Competent,” or “Exemplary” based on an explicit set of criteria described in the rubric. These literacies, their descriptions and example criteria (for evaluation) can be found in Table 3. All essays were graded on a 4-point scale in each literacy category (1 = Novice; 2 = Developing; 3 = Competent; and 4 = Exemplary). In general, a rating of “Novice” meant that the student achieved at least one of the evaluation criteria in that category; a rating of “Developing” implied that the student achieved at least two of the evaluation criteria, and so on for “Competent” and “Exemplary” ratings. Before assessing student essays, the research assistants removed all identifying information from essays so as not bias their assessments. Neither of the research assistants knew the students personally, also minimizing potential for bias in the assessment. The research assistants were frequently trained through reviewing and discussing how they understood each item in the rubric and they frequently graded a certain number of samples to ensure consistency. Literacy grades discussed in this paper, however, are based on only one research assistant’s grades. At this time, inter-rater reliability analysis is in process.

3. Data Analysis

Evaluation scores were collected, aggregated and analyzed statistically. Descriptive statistics, including mean and standard deviation (SD) were tabulated for each literacy category, and comparisons of the sample means for different demographic groups were evaluated through one-way analysis of variance (ANOVA), the results of which were identical to a t-test when only two groups were involved in the comparison. Statistical significance was evaluated at 0.05 and 0.01 levels. The significance of these levels includes a correction (Tukey’s honest significant test, or Tukey’s HSD) to account for Type 1 error in multiple group comparisons. Tukey’s HSD compares all possible pairs of means and is based on a distribution similar to the t-test that produces a conservative confidence level when unequal sample sizes are involved in the ANOVA. Associations among various literacy levels were analyzed using Pearson correlations.

Qualitative analysis was also conducted, in order to further understand the findings from the quantitative analysis. After identifying certain significant scoring patterns in the quantitative
data, all writing samples demonstrating those patterns were coded with a focus on the targeted scoring patterns. This process confirmed the prevalence of the identified patterns and provided deeper insight into how these patterns were manifested in students’ writing.

**Table 3: Evaluation Rubric for Writing Samples**

(adapted from Cook\(^2\))

<table>
<thead>
<tr>
<th>Literacy</th>
<th>Description</th>
<th>Example Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Literacy 1</td>
<td>Understanding of grammar, spelling and word usage</td>
<td>- Correct grammar</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Correct spelling</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Consistently correct sentence structure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Consistently correct word choice</td>
</tr>
<tr>
<td>Basic Literacy 2</td>
<td>Understanding of essay components</td>
<td>- Clear organization</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Good introduction and clear thesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Quality conclusion restating thesis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Well-constructed and clear sentences</td>
</tr>
<tr>
<td>Rhetorical Literacy</td>
<td>Understanding of audience and ability to effectively communicate a point of view</td>
<td>- Mention of a counterpoint</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Author seems aware of own position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Author clearly articulates position</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Essay is genre-appropriate</td>
</tr>
<tr>
<td>Technical Literacy</td>
<td>Working knowledge of technical communications</td>
<td>- Polished essay format</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Consistent formatting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Professional font, spacing &amp; title placement</td>
</tr>
<tr>
<td>Ethical Literacy</td>
<td>Knowledge of ethical standards and ability to consider all stakeholders involved</td>
<td>- Relevant ethical standards are noted (e.g. IEEE, NSPE)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Identification of multiple stakeholders</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Discussion of ethics associated with technology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Author discusses the ethics behind his/her argument</td>
</tr>
<tr>
<td>Critical Literacy</td>
<td>Recognition and consideration of ideological stances, relevant power structures, and a willingness to take action to assist those in need</td>
<td>- Recognition of power dynamics involved in waste electronics issue</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Author understands and expresses the need to give stakeholders a voice in changing the situation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Proposition of a realistic alternative to the current situation</td>
</tr>
</tbody>
</table>
Results

**Research Question #1:** How skilled are undergraduate engineering students in the multi-layered literacies of technical communication?

Overall, engineering students performed better at higher-level literacies (Rhetorical, Ethical, and Critical) than lower level ones (Basic and Technological), as summarized in Table 4. A dominant majority of students (over 40%) scored in the lower half of the evaluation rubric with regard to basic writing quality (49% “Novice” in Basic Literacy #1 and 42% “Developing” in Basic Literacy #2). Despite struggles associated with the correct choice and expression of written English, students scored much higher in the professionalism and format (Technological literacy) of their essays; 48% scored in the “Competent” category and 35% scored as “Exemplary.” In the higher-level literacies, an overwhelming majority of students scored better than in Basic literacies. In Rhetorical Literacy, over 79% of students scored “Competent” or “Exemplary.” In Ethical Literacy, 88% of students scored “Competent,” and in Critical literacy, over 80% of students scored “Competent” or “Exemplary.”

<table>
<thead>
<tr>
<th>Literacy</th>
<th>Novice</th>
<th>Developing</th>
<th>Competent</th>
<th>Exemplary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Literacy #1</td>
<td>49% (45)</td>
<td>27% (25)</td>
<td>23% (21)</td>
<td>1% (1)</td>
</tr>
<tr>
<td>Basic Literacy #2</td>
<td>34% (31)</td>
<td>42% (39)</td>
<td>24% (22)</td>
<td>0% (0)</td>
</tr>
<tr>
<td>Technological Literacy</td>
<td>3% (3)</td>
<td>14% (13)</td>
<td>48% (44)</td>
<td>35% (32)</td>
</tr>
<tr>
<td>Rhetorical Literacy</td>
<td>2% (2)</td>
<td>17% (16)</td>
<td>49% (45)</td>
<td>32% (29)</td>
</tr>
<tr>
<td>Ethical Literacy</td>
<td>1% (1)</td>
<td>9% (8)</td>
<td>88% (81)</td>
<td>2% (2)</td>
</tr>
<tr>
<td>Critical Literacy</td>
<td>2% (2)</td>
<td>14% (13)</td>
<td>61% (56)</td>
<td>23% (21)</td>
</tr>
</tbody>
</table>

The fact that 88% of students were evaluated as “Competent” in the Ethical Literacy category is noteworthy. This result suggests that the criteria for evaluating this level of literacy were insufficient to discern meaningful differences in Ethical Literacy among students. Thus, a more discerning rubric is needed and is under development as part of the next phase of this study. The new rubric divides ethical considerations into separate rating criteria that consider relevant codes of ethics from the National Society of Professional Engineers, affected stakeholders (those impacted by waste electronics), affecting stakeholders (those who are able to influence waste electronics management and regulation) and similar criteria. Although a full evaluation under these new criteria was not available at the time of this writing, it is noteworthy that only 2 of 92 students (2.2%) cited a code of ethics in considering the waste electronics, and no students differentiated between personal morals and professional ethics. This is consistent with Cook who points out that technical communicators typically rely more strongly on personal morals and values than professional ethics codes when discussing and making ethical decisions.\[2\]
Research Question #2: Are basic literacies linked to higher-level literacies?  
Pearson correlations (Table 5) present associations between the lower level literacies (Basic and  
Technological) and higher-level literacies (Rhetorical, Ethical, and Critical). Surprisingly, our  
results show that no significant links occur between a student’s basic writing ability and his or  
her ability to express higher-level ideas regarding audience, ethics, and power struggles among  
stakeholders.

Table 5: Associations between Basic Literacies and Higher Level Literacies  
(Pearson Correlations)

<table>
<thead>
<tr>
<th>Literacy</th>
<th>Rhetorical Literacy</th>
<th>Ethical Literacy</th>
<th>Critical Literacy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Literacy #1</td>
<td>0.123</td>
<td>-0.099</td>
<td>0.038</td>
</tr>
<tr>
<td>Basic Literacy #2</td>
<td>0.055</td>
<td>0.160</td>
<td>0.094</td>
</tr>
<tr>
<td>Technological Literacy</td>
<td>-0.061</td>
<td>0.042</td>
<td>-0.033</td>
</tr>
</tbody>
</table>

Note: none of these correlations were found to be statistically significant

The finding that lower level basic writing ability does not necessarily interfere with the  
expression of higher-level literacy skills is further illustrated in excerpts from student writing  
samples. For example, the following excerpts are from three different essays that scored low on  
Basic Literacy #1 and #2, yet scored high on Ethical Literacy:

Excerpt 1:

“We all know that less than 1% of the water on the earth is available and 98% of them  
are groundwater. It grows our food, it is the water we drink, and it contributes our rivers.  
Because we drink it, lots of toxic in water may cause human disease. For example in  
China, there is a report that in a little town, lots of people get cancer the reason is  
electrical factory nearby egest the waste directly in to the river. Also, the groundwater  
grows our food. Which is used for agriculture and aquaculture represents a major health  
threat to the local community. Lots of toxic substance in the river may cause the disease  
of Aquatic organism people eat them may also get disease or food poisoning. Moreover,  
pollution of water may also affect the soil; in this case, the soil of that area cannot  
contribute to crops.”

Excerpt 2:

“As I stated above, water is the most impact on our human and ecosystem through the  
wasting electronics recycling circle. Water is the root of everything on the earth besides  
of air. Animals, plants, even our human being are grown with water. Water is the main  
character that is carried along the ecosystem chain. If the water has been polluted, it will  
bring all the leachates and effluents into the surface water. Then, the water will be  
spread out by watering plants, feeding marine life, and evaporating into air. These three  
substances are the directed materials related to human being every moment. It could cost  
a big disaster if we do not consider it correctly. Therefore, water is the most effective  
affect our human lives in any moment.”
Excerpt 3:

“Uncontrolled dumping causes huge impact to humans’ daily lives. One of the most important impacts is that the uncontrolled dumping is influencing our health. According to the previous part, we already know that many diverse kinds of pollutant and toxic chemicals are being produced and released during every process. For instance, dust is produced during dismantling and fumes are produced during burning. Since those pollutants are able to enter the water system and soil, which means that they can pollute biota of plants and terrestrial animals, also poison the biota of marine life. According to food chain, we are consumer, and those plants and animals are producers. Since the biota is polluted, those creatures that live at there will also be influenced and poisoned. Therefore, after we ate them or even approach them, we will also be influenced. Thus, it shows that how the uncontrolled dumping causes impact on ecosystems then influence humans at the same time.”

Although these excerpts show challenges with basic writing skills, these students were still able to convey a relatively high level of Ethical Literacy, for example by identifying multiple types of stakeholders and discussing the larger picture of the targeted issue.

Similarly, the excerpts below are taken from three essays that scored low for Basic Literacy #1 and #2, but scored high for Critical Literacy:

Excerpt 4:

“I don’t think people will put all blame on engineer, because engineers always put their effort on development or innovation. But most of pollution is come from companies or factories, who simply want to reduce the cost. They reduce the cost on disposing, but in this world we have some many factory we cannot make sure everyone to use formal method. So for me, I think we need government to make more policy to punish those informal factories to warn the others.”

Excerpt 5:

“Finally, the issue of whose responsibility is this recycling mess. There is only so far that engineers can carry the burden of e-recycling. They can design recycling-friendly products, use environmentally conscious components, and propose recycling programs, but their companies have to support them in these endeavors. All of these steps cut into an electronic companies bottom line. Competition is tight, and many companies worry that they might lose their edge if they ‘waste’ money on electronic waste. We cannot continue exporting our waste and keeping an ‘out of sight, out of mind’ attitude. I believe that responsible engineers, responsible companies, and effective, enforced federal laws are all required to effectively govern the e-waste nightmare.”

Excerpt 6:

“In conclusion to this is the impact that engineers can have to reduce the WEE dilemma. As always providing more information to the companies making these devices and parts that the implications of waste management stretches far beyond than when that product leaves the assembly line or factory. Most of the time its people knowing that electronics recycling is useful but not having the resources on hand to provide solutions. First and
foremost is an engineer realizing that recycling of electronic waste affects everyone. ... 
Along with recognition of the dilemma is looking for alternatives to recycling these electronic parts. Perhaps reusing them so to not have to recycle them or using alternative materials to make these devices. Many other alternatives could be implemented and researched so that waste of electronic devices is better implemented to protect not only the environment but those living in it.”

Even with low level basic writing skills, students can demonstrate relatively high levels of Critical Literacy, as seen here in students’ discussions of the complexities and competing interests involved in solving problems associated with waste electronics.

It is important to point out that, although several of the essays identified as demonstrating the above two patterns happen to have been written by non-native English speakers, these patterns are by no means restricted to this group of students. Nearly half of the essays with these scoring patterns were written by native English speakers. The examples chosen for inclusion here were simply the clearest illustrations, regardless of the students’ language backgrounds.

Certainly, low-level basic writing skills can complicate one’s communication with others. However, our findings indicate that simply having low level Basic Literacy does not determine the level of one’s other literacy skills. As illustrated here, it is quite possible for students with poor basic writing skills to demonstrate higher-level literacy skills in their writing.

Research Question #3: Which demographic groups perform best at higher-level literacies? Literacies among different demographic groups were evaluated and the results are summarized in Table 6. Very few differences were found among the demographic groups considered in this work. In fact, no gender differences whatsoever were found among the literacies evaluated. Within ethnicity, only Caucasian and Asian students were present in sufficient numbers to evaluate statistical differences. Differences in literacy scores only become significant within the Basic Literacy #1 category where Asian students (whether U.S. citizens of foreign students) scored significantly lower than Caucasian students (who were predominantly U.S. citizens). These differences were similar for U.S. citizens vs. foreign students, where U.S. citizens tended to score higher in both levels of Basic Literacy than foreign students. Interestingly enough though, despite these expected differences in the use of the English language, no significant differences were found among ethnicity or citizenship among the remaining literacies except a potential emerging difference in Ethical Literacy where Asian students seemed to consider ethical issues more than Caucasian students.

The most distinct differences were between self-identified introverted and extraverted groups of students. Introverts were generally able to express themselves better in the English language and were also better able to consider their audience, as indicated by statistically higher scores for both levels of Basic Literacy and the one score for Rhetorical Literacy.

Discussion

These findings help us begin to understand how engineering students feel, think, and act in regard to the global impacts of issues like waste electronics. This study confirms that many engineering students have challenges with basic writing skills; however, it is encouraging to see
that students are generally stronger in higher-level types of literacy, such as Ethical and Critical Literacy. These higher-level literacies are particularly relevant since they are associated with how students feel, think, and potentially act. Our findings also indicate that Basic Literacy skills do not determine other types of literacy. In fact, several of our participants were able to convey fairly high levels of Ethical and/or Critical Literacy despite low Basic Literacy skills. To further understand our students’ literacy, it is interesting to see that almost no significant differences can be seen among demographic groups. Introverted students were found to have higher levels of Basic and Rhetorical Literacy than extraverted students; however, these personality-type distinctions are found within all demographic groups. Therefore, demographic-based generalizations that faculty may hold about students’ writing and thinking are not supported by this data.

These findings taken together suggest the need for careful reading of students’ writing assignments, ensuring that basic writing skills are not the only metric used for evaluation. Although Basic Literacy is clearly important, it does not give a full picture of how students are thinking about ethical issues. Good writers may have novice levels of Ethical or Critical Literacy, while poor writers may express exemplary ideas about ethical issues. In order to support the development of engineering students’ ethical thinking, it is important to look beyond how they are writing and also examine what they are writing. Defining literacy in a multifaceted way, such as the multi-layered rubric used in this study, can be a useful starting point for using students’ writing as a means for understanding their ethical thinking.

**Concluding Remarks**

From the above findings, we conclude that examining samples of student writing can be useful in understanding how students feel and think about ethical issues, regardless of their Basic Literacy skills. Using writing samples as a vehicle through which we may better understand students’ ethical thought processes is particularly helpful because the writing process allows students to express themselves in their own words. With these types of writing samples, we can also begin to anticipate how students might act on these ethical issues in the future, though, of course, we would not be able to make any concrete conclusions in this regard. Future research may, however, address such limitations. Modified writing assignments may also take a deeper look at how students would act in an ethically trying situation. Additional limitations of the study include the usual sampling issues associated with self-selection and the use of incentives: specifically, the possibility exists for self-selection bias toward those students who, compared to those who chose not to participate, were (a) more interested in the subject matter and/or (b) more motivated by the incentive (extra-credit). In practical educational research settings, there is often little that can be done about such biases other than using non-optional assignments as data (pending IRB approval and participant consent).
<table>
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<th>Category</th>
<th>Type (N)</th>
<th>Mean (SD)</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
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</tr>
<tr>
<td>All</td>
<td>All</td>
<td>1.76 (0.84)</td>
</tr>
<tr>
<td>Gender</td>
<td>Men (76)</td>
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<td></td>
<td>Women (16)</td>
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<tr>
<td>Ethnicity</td>
<td>Asian (28)</td>
<td>1.14** (0.36)</td>
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<tr>
<td></td>
<td>Caucasian (51)</td>
<td>2.08** (0.85)</td>
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<td>U.S. (69)</td>
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<td>Non U.S. (16)</td>
<td>1.06** (0.25)</td>
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<td>Mixed (54)</td>
<td>1.74* (0.81)</td>
</tr>
<tr>
<td></td>
<td>Extravert (26)</td>
<td>0.58* (0.81)</td>
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</table>

BL1 = Basic Literacy 1; BL2 = Basic Literacy 2; TL = Technological Literacy; RL = Rhetorical Literacy; EL = Ethical Literacy; CL = Critical Literacy

Differences found in Demographic Group at *p< 0.07 (emerging); and **p < 0.05
Bibliography


