Report on Writing Assessment in Electrical Engineering and Mechanical Engineering, 2010

A Project of the General Education Oversight Committee, University of Connecticut

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This report is the latest in a series that began with the 2008 GEOC report *W Course Assessment at the University of Connecticut,* which introduced the philosophy, methods, and findings of a study of student writing in three departments: Art History, Human Development and Family Studies, and Political Science (available online at geoc.uconn.edu/assessment.htm). A 2009 update report focused on writing in Nursing W courses, and this one focuses on Mechanical Engineering (ME) and Electrical and Computer Engineering (ECE). The methods for collecting and evaluating student writing were the same as those employed in the earlier studies, with a few exceptions as noted below.

The following findings from ME and ECE stand out as especially significant:

- Using direct assessment of student reports and a system of double-blind review, 96% of Electrical Engineering sophomore lab reports and 94% of Mechanical Engineering senior design reports were scored as meeting at least minimal proficiency. Given that scorers set high standards for minimal proficiency, these are impressively high percentages.

- Few reports were rated *excellent*, suggesting that while departments are doing a commendable job of bringing students to minimal and moderate proficiency, there is still a good deal of room for improvement.

- For the Electrical Engineering W lab reports, areas of strength were *describing circuit theory, reporting results*, *adopting an appropriate prose style*, and *editing for grammatical correctness*; the weakest areas were *analyzing results* and *using appropriate citation formats*. A point of emphasis for future teaching should be helping students write more sophisticated analysis and discussion sections, which could be partly addressed by introducing informal write-to-learn exercises on data analysis at key moments in the semester.

- For the seniors composing collaborative design reports, the strongest areas were *adopting an appropriate prose style*, *editing for grammatical correctness,* and *writing up the background*; their weakest were *crafting the abstract*, *articulating the design and basis*, *reporting results*, and *including appropriate references and citations*. We also discovered, when we compared mid-year drafts to the end-of-year final submissions, that while the teams performing well at mid-year continued to grow and to revise effectively, the lower performing teams stalled in their engineering and writing development. Two changes to the course could address this and the weak areas: (1) disseminate the rubric developed for this project among faculty and students to establish clear expectations and deliver feedback; (2) set up interim deliverables to ensure earlier formative feedback on sections of the report in process, plus assign student self-assessments when such drafts are due.

- For both ECE and ME, instructor grades were higher than the blind holistic rubric scores (as was the case for other UConn departments), but the correlations between instructor grades and blind scores were statistically significant. (.480 /$p<.05$ for ECE and .669/$p<.001$ for ME). This affirms that instructor grades tracked reasonably well to the criteria in the rubrics.

- Although we saw a pronounced need for students to document sources with more care (*citations* was the lowest scoring rubric item for both groups) and a lack of references especially in ME reports, we discerned very few significant breaches of academic or professional ethics. Academic integrity was sound.

- Findings about W courses in engineering run parallel to findings about W courses in five other UConn departments we have assessed so far: (1) outstanding success in bringing nearly all students across the threshold of writing proficiency appropriate to the discipline and level of course; (2) much less success in bringing a significant percentage of students up to the *excellent* category; and (3) overall strengths in summarizing and editing but lagging growth in higher order concerns such as analysis.

Collection of Writing and Adjustments to Earlier Methods

We collected 70 lab reports from ECE 2001W: Electrical Circuits, a course that enrolls approximately 150 sophomore engineering majors who attend a common lecture but are slotted into lab sections taught by several different instructors. In this course students submit three major lab reports: for the first report students submit two drafts, receive instructor comments, and revise for the final submission; for the second they submit one draft for comment and then a final submission; for the third—one we collected—they hand in only a final submission.

From ME we collected 32 senior design projects, which typically run 15-25 single-spaced pages. Students taking this capstone course work in teams on industry sponsored projects. Faculty from across the department direct those projects but students enroll in a common year-long lecture and the professors for that course coordinate the whole system and teach most of the writing. The reports we scored were submitted in December 2009. By that stage students have received faculty feedback on an earlier draft; however, they are expected to continue writing and revising well into the next semester as they complete, test, and present their engineering projects.

Because both the ECE lab reports and ME design projects differ from the kinds of research papers and literature reviews that we collected for earlier W assessments, we had to reconfigure some of the qualitative methods we used in earlier iterations of the assessment project. For other departments we did an exhaustive source check on a random subset of papers (we called it a "deep audit" of sources). However, ME and ECE reports hinged less on finding and integrating sources than on collecting and analyzing experimental data. Therefore, for the ME reports we opted to compare eight reports collected mid-year with the final versions of those same reports, with an eye to evaluating how teams revised between the December and May. For the ECE lab reports we opted to evaluate a subset of reports for the integrity of the raw data and the data analysis.

Rubric Scoring for Electrical Engineering

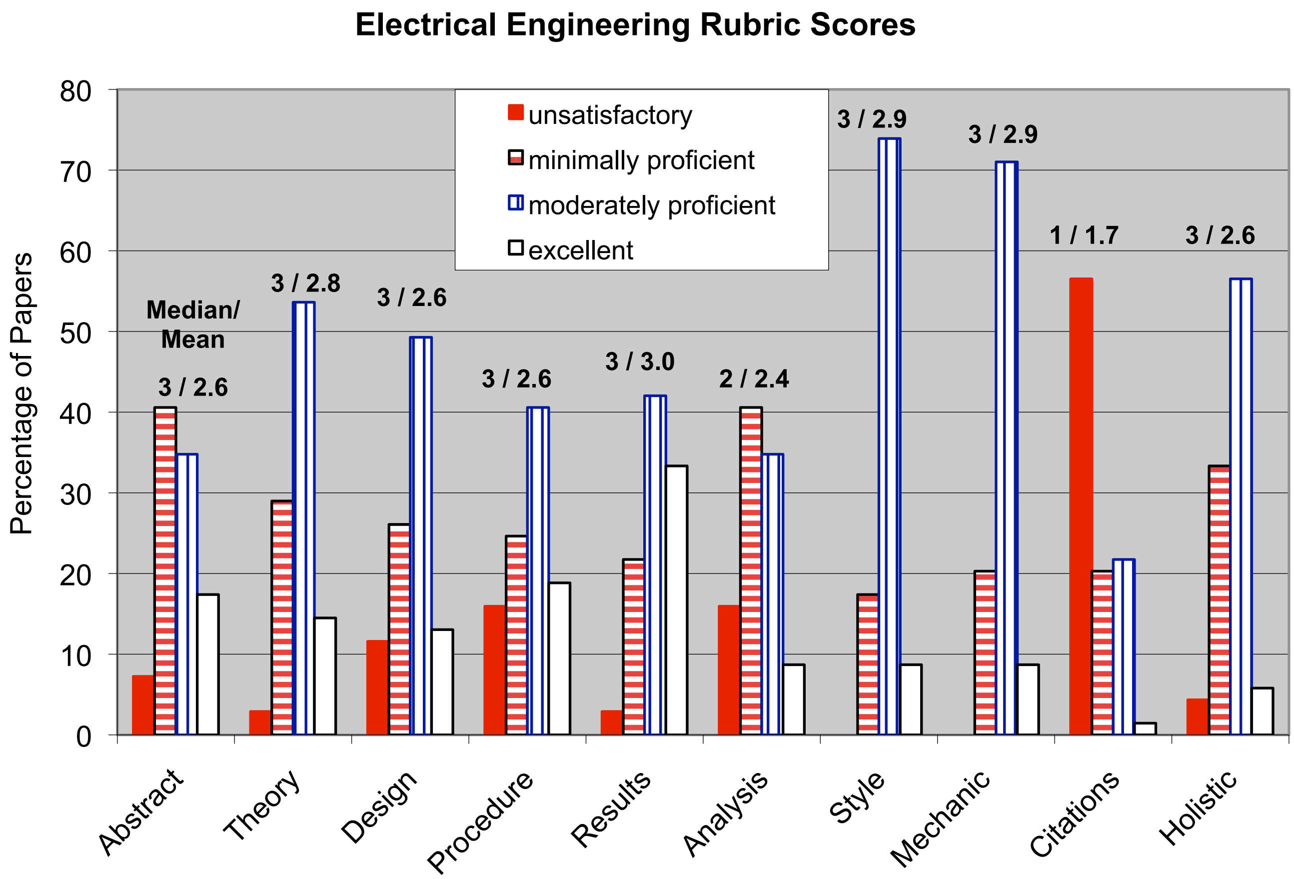
During spring 2010 Professor John Ayers worked with colleagues in ECE to construct a rubric for scoring student lab reports. The rubric, adapted from a grading rubric already in use, featured the four criteria common to all previous rubrics developed for the W assessment project (style, grammar/mechanics, documentation/citation, holistic score) and six criteria that the department judged most important for writing in the discipline. Like earlier rubrics, this one employed a four-point scale: 1=Unsatisfactory; 2=Minimal Proficiency; 3=Moderate Proficiency; 4=Excellent. An abbreviated version of this rubric can be found on the following page; the full version is available in the Appendix.

After doing the double-blind scoring process using that rubric, we discovered that students in ECE 2001W are writing at a level expected for sophomore engineering majors. Especially encouraging is the median score of 3 (moderate proficiency) for the holistic score, a measure of overall quality. Sub-areas of strength were *describing circuit theory, reporting results*, *adopting an appropriate prose style*, and *editing for grammatical correctness*.

The only area in which students fell below minimal proficiency was *citations,* which was somewhat understandable because documentation was not emphasized in the assignment or grading; moreover, the assignment focused on collecting experimental data rather than on finding and integrating outside sources, so students may have assumed that citations were not important. Still, this weakness in referencing should be remedied because students, even at the front end of their major, should start appreciating the priority that engineers put on carefully documenting their sources.

The *Analysis and discussion* item crossed the threshold of minimal proficiency but was an area that deserves ongoing attention. More textured explanation of the analytical writing we observed is included in the next section on qualitative findings.

Electrical Engineering Lab Report Rubric	Median	Mean
1. **Abstract** clearly conveys what was done and why; it includes quantitative results.	3	2.6
2. **Theory** is described clearly using equations and circuit diagrams. Equations use appropriate formatting and symbols; all quantities are defined unambiguously. Circuit diagrams are complete and use standard formatting and symbols.	3	2.8
3. **Design** is described in detail, including the overall topology and its justification. Component choices are made to satisfy design specifications and calculations are provided to justify these choices. A complete circuit schematic is provided.	3	2.6
4. **Procedure** is complete enough so a trained engineer could replicate the results. All equipment and measurements are described, and controlled conditions or variables are included. A complete circuit schematic is provided and diagrams are used to illustrate special connections or techniques.	3	2.6
5. Complete **results** are provided, including raw data and derived quantities. Measured data are tabulated with clear headings and engineering units. Results are presented graphically with the independent variable on the abscissa and the dependent variable on the ordinate; axes have titles, labels, and units; controlled conditions or variables are provided in the captions.	3	3.0
6. For the purpose of **analysis and discussion**, measured and theoretical results are plotted together for direct comparison, and significant differences are duly noted. An error analysis is conducted with consideration for component tolerances and the errors associated with instruments and their readings. Departures from the specifications are discussed. Improvements or future work are suggested based on the findings.	2	2.4
7. **Style** is appropriate for an engineering report (past tense, third- person passive voice or first-person active voice, concise, appropriate level of formality); transitions; appropriate figure titles, captions, and labels.	3	2.9
8. **Writing mechanics**: grammar usage, sentence structure, punctuation, and spelling are consistent with standard engineering usage.	3	2.9
9. **Citations** are provided using a standard format (IEEE) and sources are not used without appropriate citation.	1	1.7
10. **Holistic Score:** Overall sense of writing quality based on expectations for sophomores in Electrical Engineering	3	2.6



Qualitative Findings Concerning ECE Lab Reports

We took time for extensive discussions to explore what the rubric scoring may have missed and what patterns the 7 readers—faculty and graduate students both within and outside of the ECE department—discerned in the lab reports. In addition, two advanced graduate students in ECE performed a separate in-depth review for academic integrity.

Qualitative discussions among participants affirmed what the rubric scoring revealed: that this cohort performed well as writers for a sophomore-level course. They knew what they needed to do; they ran their experiments well; they described the theory of experiment well; their organization was sound; they were good at putting experimental and actual results on the graph; and the overall style and editing were fine.

The passable but disappointing quality of student data analysis and interpretation emerged as the major theme. We observed that students could graph the expected and actual results but too often omitted or struggled with *interpreting discrepancies* and *making an argument*; most students assumed that the graphs could speak for themselves. Writers often didn't explain why results were as good as expected and what to do about it; they had trouble with identifying discrepancies and interpreting them; they often overlooked or insufficiently dealt with error analysis (for example, accounting for component tolerances or instrumental accuracy). Because of this, sometimes they resorted to stating "the results where good" or "the results were reasonable" as a proxy for analyzing results.

In the rubric scoring most abstracts were rated as minimally or moderately proficient, but in our later discussions several people noted the need for more effective abstracts.

When the graduate students did their review for data integrity and academic honesty, the results were encouraging, with a few exceptions. Among the 70 reports they discovered 2 clearly troubling cases: one in which two students used the same graph, suggesting that one copied from the other; and another in which the data seem fudged. In addition, they discerned that 3 students had questionably similar data and that all 3 of those did not include the raw data in their appendices, which was suspicious but not conclusively fraudulent.

Recommendations for Electrical Engineering

Because ECE 2001W is already successful in helping students perform as emerging engineers and writers, the structure of the course and its current delivery should be maintained. Still, some incremental changes could address the few problems we discovered:

1. Create a handout that details for students how to handle citations (or that points them to print and online resources on how to do so). Inform students that they are accountable for citing all sources—whether class materials, textbooks, websites, software, or outside research—in proper IEEE format. Distribute this handout with the assignment and support proper citation practices by making it part of grading (but not a big part) or setting a minimal threshold for citation correctness that must be met for a report is to be eligible for grading.

2. Focus more lectures on data analysis and consider including a few in-class, ungraded write-to-learn assignments as part of those lectures. Some studies in engineering education suggest that informal write-to-learn activities in tandem with lectures can improve mastery of concepts and proficiency in writing. The activities should focus on the *interpretation* of data. For example, within a lecture on data analysis students could be given one section (a graph and some text) of a lab report that scored as *minimally proficient* in this study and then be given 5 minutes to assess (and write up) how they might revise it: What needs more explanation? Which variables were not discussed? What alternative interpretations were not explored? How could the analysis be phrased more precisely and clearly? And so on. After writing silently, they would share results one other student. Then the instructor could answer questions and select some exemplary responses to show on the board or screen. Such activities should be timed for shortly before students are scheduled write up their own experiments.

3. Provide several models of successful and unsuccessful abstracts. The graduate students discovered some resources for teaching abstracts that could be used for this course. Professor Ayers has already created an excellent custom writing handbook that he makes available to students; perhaps adding sections on crafting abstracts, writing up data analysis, and doing citations might also be helpful.

4. Revise the assignment sheet to emphasize the points above.

5. Distribute the current rubric to all W lab instructors.

6. Because teaching analysis is so difficult, the department might consider hosting a faculty workshop on pedagogy by an outside consultant who has published in this area of engineering education. The University Writing Center would be willing to co-sponsor such a workshop.

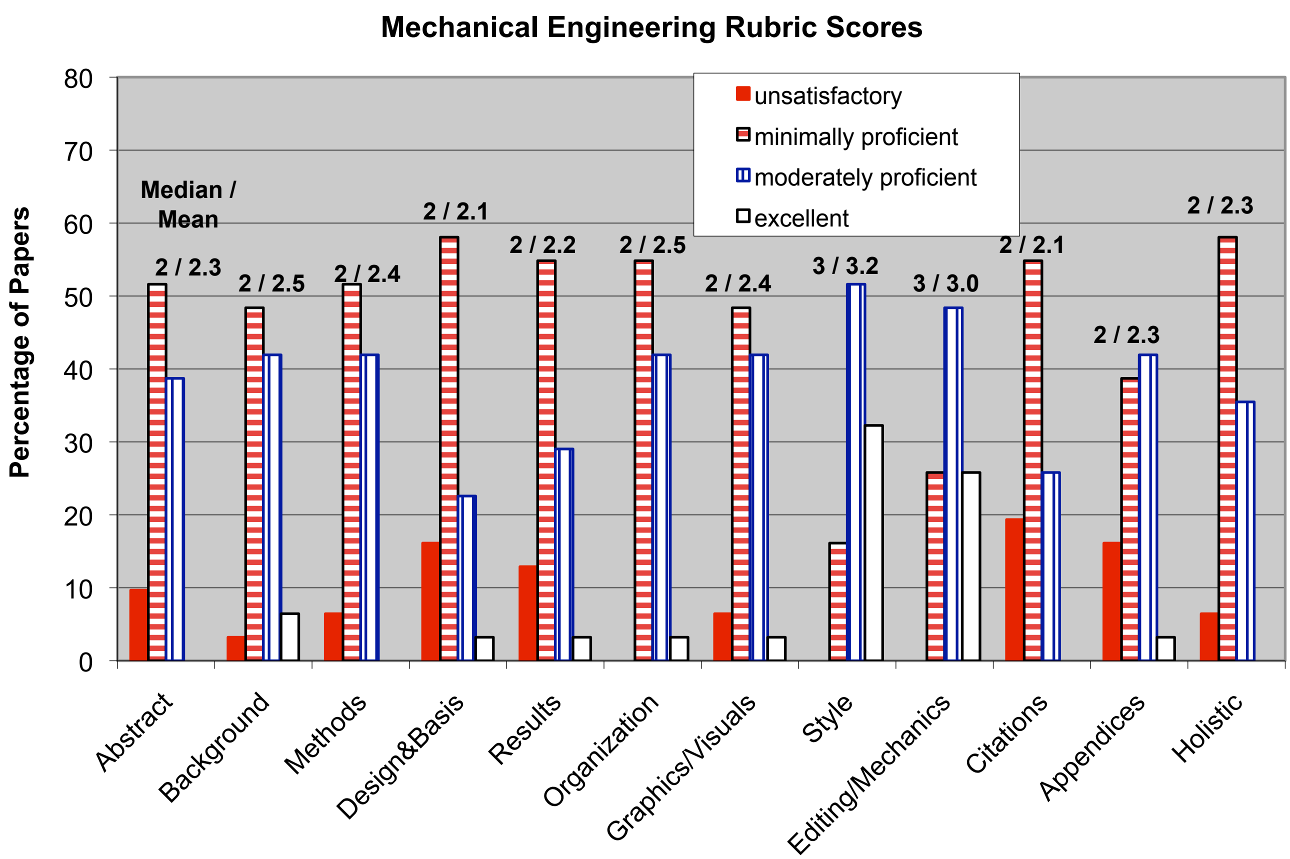
Rubric Scoring for Mechanical Engineering

During spring 2010 Professor Thomas Barber worked with colleagues in ME to construct a rubric for senior design reports. It featured the 4 criteria in rubrics developed for previous W assessments (style, grammar/mechanics, documentation/citation, holistic score) and 8 that the department determined most vital for senior design projects (for the full rubric, see the appendix). The categories of proficiency were the same as those used for ECE (1=Unsatisfactory/2=Minimal Proficiency/3=Moderate Proficiency/4=Excellent) but scoring in ME was adapted to expectations for seniors doing a capstone project—that is, the scales for ECE and ME writing proficiency were not uniform but instead calibrated to their respective contexts, for how engineering students should write at a given stage in their development. Engineering and writing expectations for seniors are, of course, higher than for sophomores.

Developing the rubric itself was an important outcome and should prove immediately useful for the department. Senior design student teams are supervised by a wide range of faculty but until now those faculty did not have a well-articulated rubric to guide writing assessment. The new rubric will be useful for delivering both formative feedback on drafts in December and summative evaluations of final submissions in May.

After doing the double-blind scoring process using that rubric, we discovered that students are writing at a level expected for senior engineering majors. The means and medians for the holistic score and all the sub-criteria crossed the threshold of minimal proficiency. The strongest areas were *adopting an appropriate prose style*, *editing for grammatical correctness,* and *writing up the background*; the weakest areas were *crafting the abstract*, *articulating the design and basis*, *reporting results*, and *including appropriate references and citations*.

Mechanical Engineering Design Report Rubric	Median	Mean
1. ABSTRACT: Includes introduction, objective, approach, what was accomplished, summary of most relevant results, and recommendations, if appropriate.	2	2.9
2. BACKGROUND: Brief introduction on company and product, need, problem statement, specifications, constraints.	2	2.5
3. METHODS: Basis of using software and or hardware and validation of use of software and hardware	2	2.4
4. DESIGN & BASIS: (a) Theory: Clearly describes relevant theoretical background with a complete list of assumptions. Related equations are typed and numbered with variables clearly defined. (b) Preliminary and final design: The details of the design are presented with the specifications and constraints in mind. (c) Procedures: procedures are clearly stated and itemized in a way that others can reproduce the work.	2	2.1
5. RESULTS: Analysis of raw data and derived outcomes. Comparisons between theoretical and obtained results. Discussion of any discrepancy between theoretical predictions and actual results. Draws conclusions based on evidence presented.	2	2.2
6. ORGANIZATION/NAVIGATION: Reader-based organization that anticipates audience needs (rather than a writer-based order, like chronological, that requires readers to do more work). Formatting enhances navigation with table of contents and appropriate titles, headings and subheadings, bullets and lists.	2	2.5
6a. GRAPHICS/VISUALS: Use of figures and tables to support analysis and discussion; visuals strategically placed and distinctly labeled, including figure number, title, source, and description; consistent engineering units; articulation of relevant variables (in legend); appropriate assumptions, equations, and/or error bars included as necessary.	2	2.4
7. STYLE: Appropriate nomenclature, syntax, formality, and technical style; helpful transitions; third-person perspective; mostly active voice; concise.	3	3.2
8. EDITING/MECHANICS: Grammar, usage, sentence structure, punctuation, and spelling are consistent with standard engineering usage.	3	3
9. REFERENCES/CITATIONS: Appropriate, accurate and consistent use of references, citations, and bibliography in ASME journal style. All references must be cited, including software and personal communications.	2	2.1
9a. APPENDICES: Includes related supporting contents, such derivations, drawings (if any), codes (if any), etc.	2	2.3
10. HOLISTIC SCORE: Overall sense of writing quality based on expectations for seniors in Mechanical Engineering	2	2.3



Qualitative Findings Concerning ME Design Reports

Qualitative discussions of the ME reports added depth to our understanding of the rubric outcomes. On the positive side, most teams demonstrated that they understood the engineering problem that was the focus of their work. They described it well and in an appropriate technical voice. The reports were organized fairly well; headings and subheadings guided readers; graphics were adequate; basic paragraph structure was fine; word choice and transitions and language were appropriate; and students generally did good sentence-level editing (with some irksome exceptions). The reports looked professional.

On the negative side, too many reports were thin on theoretical background and featured inadequate validation (these observations are echoed in the relatively low “Design and Basis” and “Results” rubric scores). As one reader reflected, many teams “seemed to forget their four years of education by not selecting, supplying, and explaining the fitting theory to match their design problems.” The weaker teams seems to be thinking and writing like students just trying to complete an assignment; the stronger teams operated as creative problem-solvers who understood the needs of both academic and industry audiences.

Another reader noted, “They don’t seem to used to making arguments based on quantitative evidence.” Too few students understanding the *rhetorical* nature the design report writing, that design reports need to be both informative and persuasive. This could use more emphasis as seniors are making the transition from being students to becoming professionals.

Two readers thought that quality of using sources and referencing was the biggest single predictor of overall report quality. Few reports cited peer-reviewed research; there were likewise gaps in citing software versions and the vendors and costs for materials. Those students who understood the need to cite their sources tended to demonstrate more critical thinking and care with the rest of the report; the converse was also true: incomplete documentation correlated with less critical thinking and care in other areas of writing and engineering.

As with the ECE lab reports, abstracts were weaker than they should be, but this seemed more important for the ME reports not only because these reports were longer and more complex but also because the quality of the abstract was often a good predictor of the quality of the rest of the report. The quality of the methods section was also a fairly reliable predictor of the overall quality of the report.

Especially revealing was an in-depth assessment of student team revision practices. Assistant professor in residence Yen Lin Han and ME graduate student Stephen Stagon compared December and May versions of reports submitted by 8 teams and discovered that the teams that had the stronger reports at mid-year accelerated their gains by revising substantially; in contrast, the teams that submitted the weaker reports at mid-year stalled and showed little progress with revision during the spring semester —they added material but didn’t address the most pressing higher order issues, even when those concerns were pointed out by their professors. In other words, the teams that submitted weak early drafts in December tended to stall in later writing and engineering progress; the teams that submitted strong early drafts tended to accelerate their later writing and engineering progress. Strategies for addressing the problems evident in early weak draft teams are discussed in the Recommendations section that follows.

Recommendations for Mechanical Engineering

The senior design teams take up complex, real-world engineering challenges, and the long reports they compose present many writing challenges: authoring collaboratively, applying theory to a new circumstance, exploring alternatives, dealing with unpredicted complications over the span of a year, balancing the needs of faculty and industry audiences, deciding what to include and exclude, integrating graphics and text, supplying appropriate references, and so on. While at the end of their ME majors, the students are still at the beginning of their careers and have little experience writing in teams or constructing long reports. The following recommendations should provide scaffolding to help students build on their strengths and address their weaknesses:

1. Distribute the new rubric to both faculty and students, making expectations clear to all and building a common vocabulary for talking about writing.

2. Set up a series of interim deliverables, especially for the fall semester. One or two sections can be due, and receive instructor feedback, so that students can adjust before the full mid-year draft is due in December.

3. Change the writing and grading processes to include more interim deliverables (in not just fall but also spring); require a student revision plan/team-assessment/self-reflection; and build in safeguards against students dodging revision as well as incentives for encouraging substantial revision. The current process of having students submit a draft in December may not encourage teams to revise in January because the grade is already in. Faculty should instead require a full December draft *along with a substantial self-assessment and revision plan* (students could score themselves on the rubric, plus write a memo that provides a synopsis their progress so far and plans for revision). Faculty could likewise use the common rubric to assess the December draft. All teams could receive an "incomplete" grade for the fall semester, pending revisions; or they could receive a grade based on the quality of *both* their draft and their revision plan.

4. In January or February the lower-performing teams should be required to submit a revised draft along with a memo explaining how they revised using faculty and industry feedback. This could interrupt the pattern of weak teams ignoring mid-year faculty feedback.

5. Incorporate new topics into lectures, especially on why precise sourcing and referencing are so important and on how to write up more robust design, basis, and validation sections.

6. Create a small set of online and/or print writing resources for senior design students. This should include access to the ASME style guide for citations and a set of exemplary past student reports. In time, a brief guidebook of the sort Professor Ayers has created for ECE W labs could be developed

Appendix: ECE and ME Scoring Rubrics