



## **Work in Progress: Rubric Development for Year-long Civil Engineering Capstone Projects**

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### **Abstract**

Project-based learning pedagogies have been shown to be effective at teaching many of the technical and professional skills desired of engineering education programs. They allow students to engage in more authentic engineering designs, helping to develop the technical and professional skills. This type of approach, however, makes traditional assessment more difficult due to variability in project content, difficulty, and types of deliverables from team to team.

In our engineering program, all seniors engage in year-long, industry sponsored capstone projects with the guidance of both faculty mentors and corporate liaisons. These projects are generally conceived of and sponsored by local engineering firms and oftentimes the results of student work form the foundation for final solutions used by the corporate sponsor. Students work in teams of three to five, developing a project proposal in the first quarter, working through the technical solution towards a final report and deliverables at the end of the academic year. In the past, achieving consistent assessment of student work has been difficult across the civil engineering projects. Since engineering projects include environmental, water resources, general civil, and structural engineering foci, faculty have found it difficult to accurately assess technical content in disciplines outside their expertise. Additionally, faculty perceptions of Likert scales on report elements have remained largely individualized, prone to variation due to personal preference. Finally, not all projects are equally complex; therefore a grading system was needed to account for variability in project difficulty and student performance at that difficulty.

Toward creating more consistency in grading of student proposals and final reports, a new grading rubric is in the process of being developed. The objective in this rubric development has been to normalize grades across faculty members, accounting for disciplinary expertise and project difficulty. The paper presents the in-progress rubric as well as preliminary inter-rater reliability evidence which was developed using faculty reviewers of student project proposals. The aspiration is that this rubric would be useful for many engineering programs that use project-based learning and require some form of final written document from students as a metric for grading.

### **Introduction**

ABET Criterion 5 requires that “Students must be prepared for engineering practice through a curriculum culminating in a major design experience based on the knowledge and skills acquired in earlier course work and incorporating appropriate engineering standards and multiple realistic constraints”<sup>1</sup>. Criterion 3 requires that graduates also demonstrate “an ability to communicate effectively”. Senior Capstone programs address both these criteria within the undergraduate curriculum. Most capstone programs require the teams to submit a final report and in some cases a proposal as part of the senior design requirement. However, evaluating these documents poses difficulty for faculty and other reviewers due to the variability in the types, nature and complexity of projects and the reviewers’ own style of writing and reviewing documents. Developing tools to limit how these variables affect document assessments is difficult, especially while trying to retain flexibility to address a wide variety of project types.

Capstone projects have been the focus of many studies. Studies focused on assessment of capstone projects have looked at teamwork, peer evaluations, presentations, reports, and technical competency<sup>2</sup>. Assessment frameworks<sup>3</sup> and myriad rubrics<sup>4-7</sup> have been proposed. Several of the papers presenting the development of rubrics discussed the need to improve reliability across both internal and external reviewers, and to develop a system that was fair in grading student work. They also discussed the difficulty of developing a tool that could be applied to a wide variety of project types that their capstone programs had<sup>8</sup>. Few studies, however, presented assessment of the tool itself. Most studies presented evidence of student skills or knowledge improvement based upon the rubric results, but few examined if the developed rubrics actually improved inter-rater reliability or were capable of being used across a great diversity of project types.

Similar to many previous studies, this paper describes the evolution of assessment documents for proposals and final reports in the capstone program within the Civil and Environmental Engineering Department at Seattle University. This paper also presents a comparison between two iterations of the assessment rubric, focusing on the goals of improved inter-rater reliability, rank-order reliability, and the breadth of the scale use by reviewers.

### **Program Background**

The Seattle University's senior capstone program has been in existence for the past 28 years. All engineering students complete a team based, year-long, externally funded, real life project under the supervision of a faculty advisor, the design coordinator (i.e. instructor of the course) and a liaison from the sponsoring agency. The Civil and Environmental Engineering (CEE) Department has completed almost 150 projects for 50 different sponsors, ranging from public agencies, private companies, non-profit organizations and universities. Each year the CEE senior class size ranges from 15 to 30 students resulting in the completion of about 4 to 8 projects. The typical team size is 4 students though in certain years some teams have had 3 to 5 students.

The team's main deliverable at the end of the fall term is a written proposal describing the project background, scope of work, plan of implementation with detailed work break down structure and deliverables. The teams work on the project itself in winter and spring terms. At the end of spring quarter the teams deliver a final report to the client describing the methodology, conclusions and recommendations. Depending on the nature of the project, the report may cover a literature review, experimental procedures and results, modeling approach and results, calculations and engineering drawings.

The faculty advisor and the design coordinator provide feedback on both documents throughout their development. The sponsor liaison also provides feedback on both documents once they get to a fairly well developed stage. During the fall quarter a technical writer works closely meeting with each team frequently to provide constructive feedback. The final drafts are sent to a team of practicing civil engineers for review. The teams are required to address the comments of the practitioners and finalize the document.

### **Assessment History**

The assessment of proposals and reports has evolved significantly over the past two decades. During the first few years of the program, the proposals and reports were reviewed by the faculty advisor alone. The advisor gave feedback to the team on areas to improve. The design coordinator reviewed all proposals for consistency and major flaws. No rubric was available for

assessment. Course grades were subjective and decided by the faculty advisor and the design coordinator.

In early 1990's the engineering department faculty members developed a document with the help of an English department faculty member to help the students with the preparation of the proposal. The document described the function, attributes and organization of an effective proposal. It also included sets of guideline/criteria for the faculty advisor to provide feedback to a team. The reader ranked the proposal qualitatively in the following areas: first impression, reader friendliness, evidence of technical mastery, letter of transmittal, introduction, scope of work, and plan of implementation. In addition, the reader provided a holistic score for the proposal.

In early 2000 the assessment document underwent revisions: it was modified into a scoring rubric with numerical ranking (scale from 1 to 6) for the categories used in the previous rubric; substantial effort was included as a category to reflect a team's effort; an equivalent scoring rubric was developed for the report. These scores were used in the final grades of teams. In mid-2000's both the scoring rubrics were revised again to include References and Bibliography, and Figure and Tables. These rubrics, used for proposal and report, are presented in Appendix A.1 and A.2, respectively. These rubrics would hereafter be referred to as "original rubrics." By 2007 all CEE faculty advisors were grading the proposals and reports of all teams and using the scores to decide on the final grade.

In 2013 the authors decided to revamp the scoring rubric for several reasons which are discussed below with the presentation of the proposed rubric.

### **Research Goals**

Given the wide range of project types, relative difficulties, and deliverables, in addition to the breadth of reviewers from faculty to industry liaisons, this research set out to further refine the proposal and final report grading rubrics. The goals to assess whether the proposed rubric was an improvement over the previous rubric are:

1. Improved inter-rater reliability in scores
2. Improved inter-rater reliability in rank-order
3. Increased scale range used by reviewers
4. Provide a mechanism for the reviewer to provide specific, actionable feedback to students

Goals 1 and 2 address the common measure of reliability, or consistency, across different users of the rubric. Ideally, a rubric would be well defined such that individual preferences or tendencies toward being a "hard" or "soft" grader would be eliminated. Additionally, the goal is that, across different proposals in the same year, reviewers would have increased agreement of the rank-order of the report qualities overall. With respect to goal 3, it was perceived that only the upper half of the previous grading scale was being used. This goal addresses the development of a rubric that is well defined such that reviewers utilize more of the scale in assessing reports as well as examining the previous rubric to find out if, indeed, the full extent of the scale was not being utilized. Finally, the fourth goal was set so that the rubric would be a tool to be used during reviews of drafts and where reviewers could comment specifically to students about why their current efforts received a given score and opportunities for improving those. Examples of how this has been used are given in the results discussion.

## Rubrics

As explained above, the “original rubric” was developed collaboratively through several iterations and was a great improvement from the previous assessment methods. The rubric used to grade proposals (Appendix A.1) contained 12 criteria on a 6-point scale from “very weak” to “very strong”. The rubric used to grade final reports (Appendix A.2) contained 11 criteria, most of which were similar to those used for the proposals. Descriptions of quality performance on each criterion was given, including the elements of the report which contribute to that criterion such as document organization, sentence quality, and paragraph transitions being the attributes of “Clarity of Writing.”

There were five key aspects of the original rubric that the authors wished to improve upon. The first element was to move closer to a traditional rubric by describing criteria attributes at specific levels rather than one single description for each criterion. Having a single description not specific to a number on the scale was believed to allow more room for reviewer interpretations in grading. The proposed rubric describes criterion attributes at specific scores, usually at the ends of the spectrum for criteria on a 6-point scale and all three scores for criteria on a 3-point scale.

Every criterion on the original rubric was scored from one to six. This created two issues that the authors wished to address with the new rubric. The first is that this approach gave equal weight to each criterion, such that the evidence of technical mastery carried the same weight as the bibliography. Secondly, this broad stroke approach gave more discretization to many criteria that didn’t need it, such as the bibliography or tables. The authors felt that criteria such as these didn’t warrant six discrete criteria, but could rather be appropriately assessed with a three point scale instead. The proposed rubric varied both in the scale size (6- and 3- point) and also the values (1-3, 3-5, 1-6) to account for both the number of discrete criteria a criterion could realistically be partitioned into as well as a built in weighting system. Furthermore, a larger weighting system was used, breaking the elements into the Mechanics of the Document, the Proposal/Report Elements, and the Technical Content. All faculty members graded the documents in the first two categories. Faculty members assessed the technical content only if the project fell within their discipline. This removed the discomfort a faculty member felt assessing the technical content of a document outside their area of expertise.

Finally, many of the criteria that were described in the original criteria contained many attributes that could be assessed separately, ideally creating less confusing criteria. For example, the “First Impression—Document Design” item contained sub-elements pertaining to the cover letter completeness, report sections, headings, figure and table labels, and appendices. In the proposed rubric, many of these elements were separated, creating a longer rubric, but one with more direct items.

The proposed rubric that was developed to address these issues is shown in Appendix B. First, it should be noted that neither the original nor the proposed rubrics are true rubrics, in that neither gives discrete definitions for each level of each criteria. It was considered in the proposed rubric to provide descriptions for each level of each criterion, but when this was done, it created a document which was not user-friendly in that it was textually overwhelming. Because of this, a reduced or anchored rubric was used whereby only the extremes were defined and reviewers were expected to employ some form of linear interpolation between the defined scores. The authors realize that this will reduce the reliability of the tool, but, for the sake of usability, this decision was been made.

The proposed rubric has 15 criteria for the proposal and 18 criteria for the final report. All of the criteria for the proposed rubric are collected in Table 1. Criteria are graded on 6-point and 3-point scales, depending on the complexity of the criteria. Additionally, some 3-point items are on a one to three scale while others are on a three to five scale to account for relative importance. For all of the 6-point items, the attributes of a 1, 2 and 5 scores are given in detail. A score of 6 is reserved for exceptional work, which exceeds professional expectations. For most criteria using a 3-point scale, attributes of all three scores are given.

The rubric is organized into three sections, each with its own weight toward the final grade. Fifty percent of the report or proposal grade is attributed to Report Elements which includes criteria such as the cover letter, introduction, methodology, and conclusions. Thirty percent of the grade is attributed to the overall Mechanics of the Document, which include document organization, reader friendliness, grammar, spelling, figures and tables, and references. The final 20% of the grade is attributed to technical content. Developing criteria for this element has been difficult due to the wide range of fields represented by the senior design projects and that each field may have different elements of importance. To date, this section has been one area that is up to the reviewer to define and score.

### **Data Set**

For the original rubric, data from Fall 2010 through Fall 2013 for both proposals (collected in the fall term) and final reports (collected in the spring term) were used. A pilot version of the proposed rubric was used to assess final reports in the Spring 2014 term and a refined version was used to assess proposals in the Fall 2014 term. This produced seven assessment periods for the original rubric and two for the proposed rubric. The number of design teams, number of criteria assessed, the number of reviewers who assessed all team reports, and the number of reviewers who assessed only some team reports (and the number of reports they reviewed) are given in Table 2. In total, 211 independent assessments were conducted using the original rubric over seven terms and 77 independent assessment were conducted using the proposed rubric over two terms.

As noted above, some criteria of both rubrics were unique to either the proposal (fall) or final report (spring). For these criteria, only comparisons between the fall or spring assessments with the original and proposed rubric can be explored. Also, when comparing the rank-order results from both rubrics, only data from reviewers who examined all or all but one team were used.

### **Methods**

Toward addressing the first three goals of this research, the following methods were used to compare results from the original rubric to those from the proposed rubric. It should be noted that these results are all preliminary, given the limited data from the proposed rubric, but this process will continue to be used to assess and improve the proposed rubric as more data are collected.

Table 1. Rubric Comparison Results for all assessment criteria

Criteria	Original					Proposed				
	Scale Range	Scale Range Used	Median Score Used	Mean Score	Average % of Scale Used	Scale Range	Scale Range Used	Median Score Used	Mean Score	Average % of Scale Used
Organization of the Document	1-6 <sup>+</sup>	3-6	5	5.14	56%	1-6	3-6	5	4.38	50%
Reader Friendliness	1-6	2-6	5	5.02	67%	1-6	2-6	4	3.99	75%
Grammar	-	-	-	-	-	1-6	1-3	3	2.55	100%
Spelling	-	-	-	-	-	1-3	1-3	3	2.81	100%
Language	-	-	-	-	-	1-3	1-3	3	2.68	100%
Figure/Tables	1-6 <sup>*+</sup>	3-6	5	5.17	57%	1-3	4-5	4	4.41	67%
References	1-6	2-6	6	5.26	62%	3-5	1-3	3	2.55	100%
Cover Letter	1-6	1-6	5	4.89	69%	1-3	3-5	5	4.51	83%
Executive Summary	1-6 <sup>**</sup>	3-6	5	4.90	56%	3-5	3-5	5	4.67	50%
ToC/LoF/LoT <sup>++</sup>	-	-	-	-	-	3-5 <sup>**</sup>	1-3	3	2.64	83%
Introduction	1-6	2-6	5	5.26	60%	1-3	3-6	5	4.43	67%
Methodology	1-6 <sup>**</sup>	3-6	5	5.13	67%	1-6	3-6	4	4.17	67%
Results & Findings	-	-	-	-	-	1-6 <sup>**</sup>	1-5	4	4.19	83%
Recommendations	1-6 <sup>**</sup>	2-6	5	4.97	72%	1-6 <sup>**</sup>	4-6	5	4.44	50%
Conclusions	1-6 <sup>**</sup>	2-6	5	4.97	72%	1-6 <sup>**</sup>	3-6	4	4.33	67%
Appendices	-	-	-	-	-	1-6 <sup>**</sup>	1-3	2	1.50	100%
Substantial Effort	1-6	2-6	5	5.19	64%	1-3 <sup>**</sup>	2-6	5	4.39	83%
Scope of Work/List of Tasks/Deliverables	1-6 <sup>*</sup>	3-6	5	5.05	63%	1-6	3-6	4	4.32	67%
Overall Design Approach/ Design Criteria/ Design Basis	1-6 <sup>*</sup>	2-6	5	4.96	67%	1-6 <sup>*</sup>	1-6	5	4.46	100%
Schedule/ Organization Chart/ Facilities	-	-	-	-	-	1-6 <sup>*</sup>	2-3	3	2.63	67%

\* Criteria for Proposal only (fall)

\*\* Criteria for Final Report only (spring)

-- Not assessed

+ Comprised of two criteria in original rubric

++ Table of Content/List of Figures/List of Table

Table 2. Assessment data sources for original and proposed rubric

Term	Rubric used	No. of design teams	No. of Criteria Assessed	No. of reviewers who assessed all teams	No. of reviewers who assessed some teams (# of teams assessed)	Total no. of assessments
F10	Original	7	12	5		35
S11		7	10	5	2 (1)	37
F11		7	12	4	1 (4), 1 (1)	33
S12		7	10	4		28
F12		6	12	3		18
S13		6	11	2	1 (5), 2 (2), 2 (1)	24
F13		6	12	6		36
S14	Proposed	6	16*	6		36
F14		7	14*	5	1 (6)	41
						Sum = 77

\* Excludes technical content assessment

Cronbach’s alpha with each reviewer as the unit of analysis was used to assess inter-rater reliability for each dimension, at each term. The Spearman-Brown prediction formula was used to adjust Cronbach’s alpha for six raters, the typical number of raters used in recent terms, to compare values<sup>9</sup>. These results were used to assess goal 1. Rank-order reliability was assessed by examining the average of the maximum spread that was seen for a given report in the rank-order determined by reviewers’ total scores. Monte Carlo simulations of 10,000 sets of reviewers were used to determine the 10<sup>th</sup>, 50<sup>th</sup>, and 90<sup>th</sup> percentiles of the distribution of mean spread in rank-orders for sets of six and seven reports, using three to six reviewers (Table 3). These distributions were used to look at the probability that the rank-order mean spreads seen through randomized trials is less than or equal to the observed mean spreads for a given number of reviewers and reports, providing probabilities similar to a p-value.

Table 3. 10th, 50th, and 90th percentiles of distribution of mean spreads from simulated reviewer rank order

# of Reviewers	# of Reports	Corresponding Terms	Mean spread across reports		
			10 <sup>th</sup> Percentile	50 <sup>th</sup> Percentile	90 <sup>th</sup> Percentile
3	6	F12, S13	2.17	3.00	3.50
4	7	F11, S12	3.43	4.14	4.57
5	7	F10, S11,	4.00	4.57	5.00
6	6	F13	3.67	4.17	4.50
6	7	S14, F14	4.43	4.86	5.29



## Results

### *Goal 1: Improved Inter-Rater Reliability in Scores*

The results from investigating inter-rater reliability for each criteria using Cronbach's alpha, with values adjusted to six reviewers, are shown in Table 4. Standard practices for internal reliability thresholds are 0.5-0.6 is 'poor', 0.6-0.7 is 'acceptable', 0.7-0.9 is 'good' and >0.9 is 'excellent'<sup>10, 11</sup>. Because this is a preliminary examination, alphas that show 'acceptable' or greater reliability are highlighted in gray in Table 4. Criterion with an alpha of zero had erratic scores that showed no reliability. The median alpha values for each term are also shown.

For the original rubric, three quarters (S11, S12 & F12) showed good reliability in the median and had 60% or more of the criteria with acceptable or greater reliability. The S12 term had the best results, with 9 of the 10 criteria having alpha values of 0.6 or higher and a median alpha value of 0.84. The other four terms using the original rubric, however, have unacceptable reliability in the median and no more than four criteria with acceptable reliability or better. Both the S13 and F13 terms had the lowest median reliability value at 0.32. 'Substantial Effort' was the most reliable criteria across the terms for the original rubric, having good to excellent reliability in six of the seven quarters it was used. 'Methodology' also had good to excellent reliability in all three terms that it was assessed using the original rubric.

The proposed rubric showed good reliability in the median for the F14 term, but extremely low reliability in the S14 term. For the S14 term, five of the 16 criteria had zero reliability and only five had acceptable reliability. No criteria had alpha values greater than 0.6. In the F14 term, however, only one criterion had no reliability ('Spelling') and ten of the 14 criteria had acceptable reliability or better. 'Substantial Effort' had the highest reliability at 0.92. The low alpha values for the S14 term could be due to this being the first time that faculty had used the new rubric and doing so at the end of the academic year as well. The rubric remained relatively unchanged in the F14 term, which leads the authors to believe that familiarity with the tool led to increased reliability and would do so in future uses. Individual criterion with low reliability, such as 'Scope of Work/List of Tasks/Deliverables' will be examined in the future. Finally, it was encouraging to see that criterion that had consistently good reliability in the original rubric, such as 'Methodology' and 'Substantial Effort', continued to do so in the proposed rubric.

### *Goal 2: Improved Inter-Rater Reliability in Rank-Order*

Inter-rater reliability in rank-order was initially explored by the spread in rank-order for the same document among all reviewers. The maximum spreads in rank-order were explored for each report and each term. For example, if a reviewer ranked a team as the best report (#1 rank order) and another reviewer had that same report as the 5<sup>th</sup> best report (#5 rank order) then the spread would be four. The means of the maximum spread across all team documents for a given term was then calculated. These values are shown in Figure 1. Also shown in Figure 1 is the 50<sup>th</sup> percentile of the distribution of simulated mean spreads with error bars showing the 10<sup>th</sup> and 90<sup>th</sup> percentiles below and above, respectively.

Table 4. Criteria-based Cronbach's alpha values by term – adjusted to six raters for the past nine quarters.

Criteria	Cronbach's Alpha, adjusted to six raters								
	F10	S11	F11	S12	F12	S13	F13	S14	F14
Organization of the Document	0.32	0.50	0.32	0.68	0.76	0.46	0.03	0	0.80
Reader Friendliness	0.71	0.02	0.33	0.95	0.60	0.12	0	0.11	0.67
Grammar	-	-	-	-	-	-	-	0	0.51
Spelling	-	-	-	-	-	-	-	0	0
Language	-	-	-	-	-	-	-	0	0.72
Figure/Tables	0.08	-	0.66	-	0.53	0.88	0.54	0.10	0.58
References	0	0.61	0.82	0.85	0.50	0.27	0.73	0.64	0.74
Cover Letter	0	0.96	0	0.30	0.48	0.61	0.21	0.20	0.79
Executive Summary	-	0.51	-	0.93	-	0	-	0.29	-
ToC/LoF/LoT	-	-	-	-	-	-	-	0.22	0.65
Introduction	0.44	0.70	0.61	0.83	0.72	0.32	0.33	0.15	0.72
Methodology	-	0.76	-	0.83	-	0.95	-	0.68	-
Results & Findings	-	-	-	-	-	-	-	0	-
Recommendations	-	0.87	-	0.74	-	0.32	-	0.63	-
Conclusions	-	-	-	-	-	-	-	0.61	-
Appendices	-	-	-	-	-	-	-	0.64	-
Substantial Effort	0.48	0.90	0.73	0.91	0.87	0.89	0.76	-	0.92
Scope of Work/List of Tasks/Deliverables	0.53	-	0	-	0.88	-	0.51	-	0.43
Overall Design Approach/ Design Criteria/ Design Basis	0.71	-	0.30	-	0.58	-	0.30	-	0.75
Schedule/ Organization Chart/ Facilities	-	-	-	-	-	-	-	-	0.71
Technical Mastery (Content)	0.40	0.83	0	0.90	0.71	0	0	-	-
Median	0.42	0.73	0.34	0.84	0.71	0.32	0.32	0.18	0.72

F = fall; S = Spring

These results show that five of the seven terms with the original rubric had mean spreads that were less than 10% likely to have happened through random assignments. This is an approximation for the degree of agreement between reviewers in rank order. Two terms (F10 and F11), were below the 10<sup>th</sup> percentile, meaning there was a greater than 10% likelihood that the agreement was random. For the proposed rubric, both terms showed mean spreads below the 10<sup>th</sup> percentile.

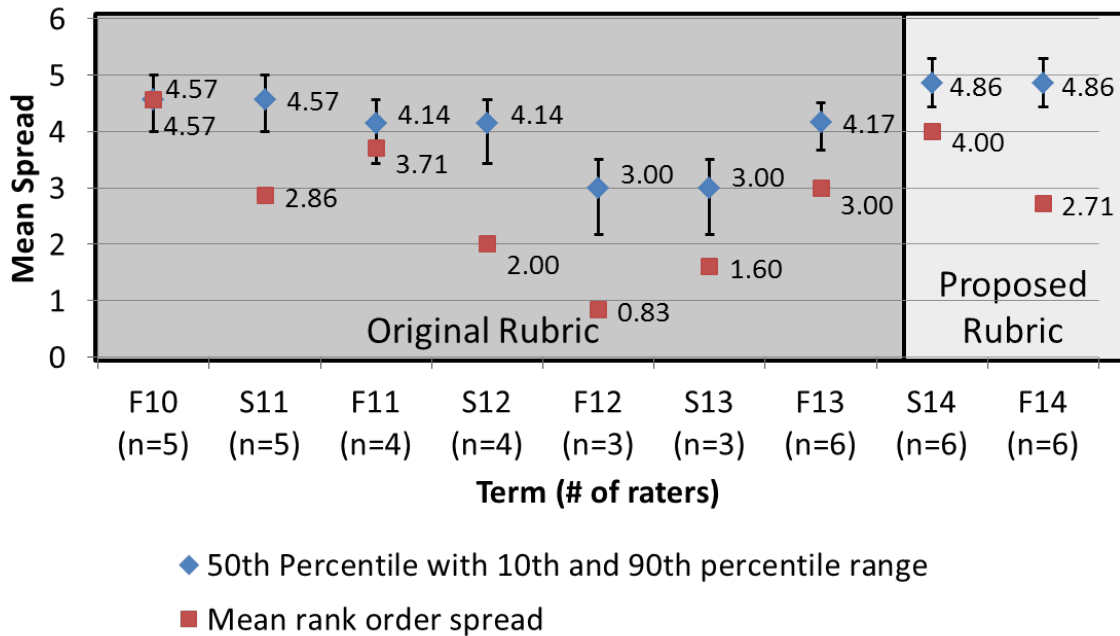


Figure 1. Reviewer mean rank order spread by term as well as 50th percentile of distribution from simulated trials with 10<sup>th</sup> and 90<sup>th</sup> percentiles shown as error bars. “F” denotes Fall quarter, “S” denotes Spring quarter, and “n” denotes number of reviewers who rated all or all less one reports.

These values cannot be compared directly, however, because simply examining the mean of the rank order spread does not account of the number of reports or raters. In order to compare rank-order reliability across quarters and rubrics, the probability of the simulated mean spreads being less than or equal to the observed mean spread was examined. These results are given in Table 5 and show that only two of the quarters (F10 and F11) with the original rubric showed high probabilities that the observed values were similar to randomly generated values (probabilities greater than 0.01). One quarter for the proposed rubric showed the same. For the quarters with a low probability, these results show that the F14 quarter with the proposed rubric performed equally as well (to three digits) as the S11, S12 and F12 quarters with the original rubric.

Table 5. Probability of simulated mean spread values being less than or equal to observed data for each quarter, given same number of reviewers and reports.

Quarter	Original Rubric							Proposed Rubric	
	F10	S11	F11	S12	F12	S13	F13	S14	F14
Observed Average	4.57	2.86	3.41	2.00	0.83	1.60	3.00	4.00	2.71
Probability of simulated values being less than or equal to observed values	0.408	0.000	0.159	0.000	0.000	0.010	0.002	0.236	0.000

Fi = Fall; Si = Spring

### *Goal 3: Increased scale range used by reviewers*

The breadth of each scale used by reviewers was examined across all assessments, looking at the difference between the highest score given on an item and the lowest score, as well as the median and mean scores using all assessment with each rubric. The average range used was divided by the scale size to give the average percentage of each scale used. These values as well as the median and mean values are shown in Table 1.

The results from the original rubric showed that, on average, 55%-72% of the scales were being used. Median values were all 5, except for “References” which was a 6. Mean values were between 4.89 and 5.26, skewed toward the upper half of the scales. These results could be interpreted several ways. Some scales could be unnecessarily large (all of which are six point) and reviewers never needed lower values. This could be the case for “Figures/Tables”, and “Executive Summary” where only scores of three to six were used and the average percentage of the scale used was 57% and 56%, respectively. Another interpretation could be that, by the time that these reviewers saw either the proposal or final report, the documents had been through internal and external reviews and therefore they were, in general, refined to the upper portions of the scales. Perhaps using these rubrics for draft versions would show that a larger portion of the rubric could be used at intermediate stages.

Examining results for the proposed rubric showed many of the median values shifted one point lower than the original rubric (when comparing criteria with 6-point scales) and, generally, lower mean values across all criteria. For example, “Reader Friendliness” had a median values of 4 and 5 and mean values of 4.38 and 5.02 for the proposed and original rubrics, respectively. This is most likely a result of shifting the scales such that a score of 6 is reserved for extraordinary work and a score of 5 meets expectations. Additionally, for that criterion, a higher average percentage of the scale was used; 75% as opposed to 67%. Changing the scales from 6- to 3-point scales for many criteria makes a comparison difficult with the original rubric. All but one (“Figures/Tables”) of the criteria with 3-point scales had the full scale used, and the average percentage of the scale used for five of them was 100%. One criterion with a 6-point scale (Overall Design Approach/ Design Criteria/ Design Basis) also had the entire scale used.

Three of the criteria with equal scales had lower average percentage of the scales used for the proposed rubric compared to the original rubric (“Organization of the Document”, “Recommendations” and “Conclusions”). The latter two only had one term of assessment data (S13), so perhaps using the scale in future quarters would provide more information.

### *Goal 4: Mechanism for feedback*

The fourth goal of this research was to provide a mechanism by which reviewers could provide direct justification for the score they chose to students and suggestions for how they could improve their report and therefore their score. This type of mechanism didn’t exist in the original rubric in any formal way. This is achieved in the proposed rubric by only using anchoring definitions in the rubric and by leaving the middle ranges blank for most items. For items on the proposed rubric on a six point scale, only attributes of the bottom (1), top expectations (5) are given. If a reviewer gives an intermediate score (2-4), the blank space in the rubric allows them to highlight which elements or mistakes led them to choose that scores, providing students with evidence of their grade and directed areas for improvement. Ideally, reviewers would go further to explain what a higher score would be in their opinion, further guiding the students.

As an example, a practicing civil engineer reviewed the near-final draft of one teams' proposal in the Fall 2014 term using the proposed rubric. For one of the overall document criteria, "Organization of the Document", the reviewer gave the team a score of 4 and wrote in the blank space under that score:

"Visually, the proposal is well done. Information is organized well using outline format, a tried and true standard, and perhaps a little boring. Proposal flowed in logical manner with all pertinent information present. Would have given a 5 if writing was more consistent and complete. Would have given a 6 if it were that plus visually stunning."

This kind of feedback, given across all criteria, would provide students with a greater understanding of the score they earned and how they can improve element of their document for the final submittal. This reviewer points out the current strengths ("well organized" "flowed in logical manner"), but highlights ways in which it could be improved ("more consistent and complete (writing)", "visually stunning") and how the reviewer would have adjusted the team's score accordingly. This depth of feedback and accompanying scores could also provide a way to track the improvement of a document through the drafts and to the final product, which could be beneficial for grading as well.

### **Discussion**

The results comparing the original rubric to the proposed rubric across the four goals established by the authors was mixed. With more years to examine, we could go deeper into the behavior and trends of the original rubric than was yet possible for the proposed rubric. From both the inter-rater reliability and the rank order examinations, it was clear that the reliability of the original rubric was highly variable from year to year. Some years (F12 and S13) showed significant reliability across many of the criteria as well as strong agreement for rank order. Other years (F10 and F11), however, showed little reliability across criteria and large mean spreads in rank orders among reviewers, suggesting a volatile tool. Many of the reviewers across all seven of the terms for the original rubric were the same, removing the possibility of poorly trained reviewers as a reason. One possible explanation could be the differences between grading a proposal (Fall) and a final report (Spring), though this would not account for the positive rubric reliability in F12. Furthermore, examining the percentage of the scales used with the original rubric showed that reviewers tended to stay in the upper half of the scale, supporting what the authors originally suspected. This variability in results for the original rubric made it difficult to know if it should be replaced or not.

The proposed rubric had the same variability in the two terms that it was used, with generally poor performance in S14 and good performance in F14. The poor performance in S14 could be attributed to that being the first time the faculty reviewers had ever used this tool and there was a necessary adjustment period. Many of the S14 reviewers were the same as the F14 reviewers, so perhaps their familiarity with the tool increased the accuracy. Future assessments using the proposed rubric would support or reject this hypothesis. Beyond statistical measures, the proposed rubric, with its built in weighting system and some reduced scales, provided a measure that more accurately aligned with the faculties' perspectives of the relative importance of each criterion. Additionally, the proposed rubric provides a mechanism for reviewers to give feedback to students, which may prove useful in draft versions of both the proposals and the final reports.

A brief note, however, about the challenge of usability. In its current state, the proposed rubric is a long and potentially overwhelming document. For each term, the rubric formats to a four page document whereas the original rubric fit neatly on two pages. This creates an appearance of being more work for faculty reviewers, which they were resistant to.

### **Future Work**

One main limitation at this point is that the proposed rubric has only been used twice, with the inaugural run perhaps being skewed due to the unfamiliarity of reviewers with the tool. This work sets up a roadmap from which future assessments with the proposed rubric can be added to see if it proves to be a more stable instrument than the original rubric. Side by side comparisons using the two rubrics on the same report may be effective in assessing whether the proposed rubric improves reliability over the original rubric. In addition to examining reliability of the tool, it would be useful to assess whether the usability of the tool could be improved such that reviewers are not initially off put by the length of the rubric. Furthermore, it would be worth polling, even qualitatively, if reviewers with several years of experience found that the proposed rubric took more time to use, and, if so, how that may be improved. Finally, there needs to be more work done by the authors and other reviewers to further develop the measures of technical content among reports. Given the wide range of topics and project difficulty, this would need to be developed iteratively with feedback from many reviewers over many project types.

### **Conclusion**

This paper has presented a brief history of the evolution of assessment rubrics for documents in an engineering senior capstone class. The authors set out to improve upon the most recently developed rubric, desiring to improve 1) inter-rater reliability in scores, 2) inter-rater reliability in rank-order, 3) the extent of the scales being used, and 4) to provide a mechanism for feedback to students. The proposed rubric that was developed used a system where attributes of the ends of each scale were defined for each criterion and the middle values were left blank. Data from seven terms with the original rubric were compared to data from two terms with the proposed rubric.

The results for inter-rater reliability were mixed. Some terms with the original rubric performed well in both measures, while other terms performed poorly. Similarly, one term with the proposed rubric performed well, while the other term performed poorly. Reviewers generally used a wider range of the scales in the proposed rubric, which achieved one of the four goals set by the authors. The proposed rubric also provided a mechanism for the reviewer to provide feedback, meeting a second goal. The proposed rubric will continue to be assessed and improved, taking into account both statistical performance, as well as reviewer feedback on the usability of the instrument.

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## Appendix A: Second Iteration Capstone Rubric (“Original Rubric”)

### A.1 - Reader’s Feedback Sheet For Project Proposals

**First Impression--Document Design:** *[Follows Project Center manuscript guidelines; has cover page, letter of transmittal and signed by all members (ok if not signed for drafts), title page, TOC (and list of figures/tables), Introduction, Design approach/assumptions/literature review, Scope of Work and Plan of Implementation through describing Task Break down and Deliverables; headings in TOC match headings in body; figures and tables are correctly labeled and referenced in text; appendices are clear and easy to follow]*

Very Strong						Very Weak
6	5	4	3	2	1	

**Letter of Transmittal:** *[Makes good first impression; summarizes problem and team's design approach; creates confidence in team's professionalism]*

6	5	4	3	2	1
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**Introduction:** *[Opens with summary of project's purpose; states problem clearly; shows understanding of the problem from a technical standpoint; specifies sponsor-provided parameters/criteria that must be met; shows problem's significance to company; provides needed background]*

6	5	4	3	2	1
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**Scope of Work, List of Tasks and Deliverables:** *[Clearly defines the scope of work; explains how the team will accomplish the scope of work by breaking the work down into tasks and lists deliverables at the end of each task]*

6	5	4	3	2	1
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**Overall Design Approach/Design Criteria/Design Basis:** *[demonstrates that the team understands the plan of implementation of the project by describing the following, as appropriate: literature review, design basis, design assumptions, design codes and design parameters to be used and justification, design basis behind software to be used]*

6	5	4	3	2	1
---	---	---	---	---	---

**Reference and Bibliography:** *[References used in the preparation of the proposal are listed; the format follows a consistent pattern either chronological or alphabetical; references include author, name of publisher, year and volume whenever appropriate; personal communications and websites and properly referenced; reader can track down all references, if needed.]*

6	5	4	3	2	1
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**Reader Friendliness:** *[Reader energy stays focused on content rather than structure; clear organization; parts in right place; parts clearly related to whole; follows old/new contract; sentences are grammatically correct and coherent; absence of noise; reader seldom gets lost]*

6	5	4	3	2	1
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**Clarity of Writing:** *[the document is organized in a clear manner; individual sentences are clear with no ambiguity; paragraphs transition logically]*

6                    5                    4                    3                    2                    1

**Figures:** *[arranged sequentially and referred to in the text; placed close to the paragraph where figure is referenced; captions appear below; have good resolution; are self-explanatory and can stand alone; there is enough white space around; captions describe the contents clearly; sources are cited, when appropriate; legends and labels are clear when copied in black & white]*

6                    5                    4                    3                    2                    1

**Tables:** *[arranged sequentially and referred to in the text; placed close to the paragraph where it is referenced; captions appear above table; self-explanatory and can stand alone; there is enough white space around; captions describe the contents clearly; sources are cited, when appropriate; foot notes are included when appropriate; column headings are separated from data; appropriate significant digits]*

6                    5                    4                    3                    2                    1

**Evidence of Technical Mastery:** *[Quality and depth of work; adequacy of design process; good understanding of technical issues; evidence of both creative and analytical thought; professional thoroughness]*

6                    5                    4                    3                    2                    1

**Substantial Effort:** *[Evidence that the team has put in substantial effort in completing the proposal]*

6                    5                    4                    3                    2                    1



6                      5                      4                      3                      2                      1

**Reference and Bibliography:** *[All references used in the project and in the preparation of the report are listed; the format follows a consistent pattern; references include author, name of publisher, year and volume whenever appropriate; personal communications and websites and properly referenced; reader can track down all references, if needed.]*

6                      5                      4                      3                      2                      1

**Figures and Tables:** *[Figures are visually appealing and easy to read; have effective labels, legends, and unique captions; stands-alone from text, refers to all pertinent dimensions of the graphic (both axes, legends). Tables: column headings are separated from data; don't run into multiple pages. Table captions above & Figure captions below. Figures and tables have units and appropriate significant digits.]*

6                      5                      4                      3                      2                      1

**Substantial Effort:** *[Evidence that the team has put in substantial effort in completing the project]*

6                      5                      4                      3                      2                      1

**Appendix B: Proposed Rubric**

**Sr. Design Proposal Grading Rubric – Reader’s Feedback Sheet for Proposal**

Reviewer \_\_\_\_\_ Design Team \_\_\_\_\_ Date \_\_\_\_\_

Category	6	5	4	3	2	1
<b>Proposal/Report Elements (50%)</b>						
<b>Cover Letter</b>		<ul style="list-style-type: none"> <li>• Clear and concise.</li> <li>• Formatted properly for a cover letter.</li> <li>• Directly addresses the purpose of the report and findings.</li> <li>• Refreshing to read.</li> </ul>	<ul style="list-style-type: none"> <li>• Body of the letter addresses some components of the report, but lacks others.</li> <li>• Formatting may have some errors.</li> </ul>	<ul style="list-style-type: none"> <li>• Minimal content provided regarding the purpose of the report and the results.</li> <li>• Poor letter formatting (addresses in wrong place, dates are wrong, names are wrong, no signatures, etc.)</li> </ul>		
<b>Executive Summary (Final Report Only)</b>	<ul style="list-style-type: none"> <li>• Meets all requirements of ‘5’, but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>• Describe the problem</li> <li>• Provide brief approach</li> <li>• Explain main deliverables for the client</li> <li>• Provide a summary of results/conclusions/recommendations</li> </ul>			<ul style="list-style-type: none"> <li>• Poor logical flow through the project and results.</li> <li>• Don’t provide a clear description of the problem, approach or results and recommendations.</li> </ul>	<ul style="list-style-type: none"> <li>• No executive summary is provided</li> </ul>

Category	6	5	4	3	2	1
<b>Table of Contents, List of Tables, List of Figures</b>				<ul style="list-style-type: none"> <li>● Page references are correct.</li> <li>● Titles, headings, and captions match those within the body of the proposal</li> <li>● Formatting is consistent</li> </ul>	<ul style="list-style-type: none"> <li>● Formatting is inconsistent.</li> <li>● Page numbers are wrong.</li> <li>● Titles, headings, captions don't match proposal or there are missing headings/sub-headings</li> </ul>	<ul style="list-style-type: none"> <li>● No ToC, LoT, or LoF are provided</li> </ul>
<b>Introduction</b>	<ul style="list-style-type: none"> <li>● Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>● Clearly demonstrates that the team understands the client's problem and provides their overall approach.</li> <li>● Opens with summary of project's purpose.</li> <li>● shows understanding of the problem from a technical standpoint.</li> <li>● specifies sponsor-provided criteria that must be met.</li> <li>● shows problem's significance to sponsor</li> </ul>			<ul style="list-style-type: none"> <li>● Does not provide adequate context for the problem or lack of understanding of the problem.</li> </ul>	<ul style="list-style-type: none"> <li>● Introduction is missing.</li> </ul>

Category	6	5	4	3	2	1
<b>Methodology (Final Report Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Clearly explain the team's approach to solving the problem. The approach is logical and presented sequentially.</li> <li>Assumptions are stated if appropriate.</li> <li>(From 2015 onwards: Clearly defines the scope of their project, including elements which may be outside of their scope but central to a complete solution to their problem)</li> </ul>			<ul style="list-style-type: none"> <li>The approach taken by the team remains unclear after reading the Methodology.</li> <li>The steps don't seem to be logically ordered, or necessarily related to each other; there is no logical 'building' of ideas for results.</li> </ul>	<ul style="list-style-type: none"> <li>No methodology is given</li> </ul>
<b>Scope of Work, List of Tasks and Deliverables (Proposal Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Clearly defines the scope of work</li> <li>Explains how the team will accomplish the scope by breaking down into task and deliverables at the end of each task.</li> </ul>			<ul style="list-style-type: none"> <li>the scope of work is described vaguely</li> <li>Lists the tasks but does not explain them clearly</li> <li>Deliverables are either not listed or not meaningful.</li> </ul>	<ul style="list-style-type: none"> <li>Tasks and deliverables are missing</li> </ul>
<b>Overall Design Approach/ Design Criteria/ Design Basis (Proposal Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Demonstrates that team understands the plan of implementation through appropriate research of one or more of the following: literature review, design codes/manuals, design criteria</li> </ul>			<ul style="list-style-type: none"> <li>Literature review, design codes/manuals, and design criteria are included in a superficial manner.</li> </ul>	<ul style="list-style-type: none"> <li>The following are missing in the proposal as appropriate for the project: literature review, reference to design codes/manuals, and design criteria</li> </ul>

Category	6	5	4	3	2	1
<b>Results/Findings (Final Report Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Results are presented in a logical order, paralleling the methodology.</li> <li>Results presented meet the expectation of the client, as stated in the introduction. Any deviations should be explained.</li> <li>Tables/Figures/Drawings are used appropriately to present the results either in the report or referenced in appendices or both.</li> </ul>			<ul style="list-style-type: none"> <li>Results are incomplete, without acknowledgement on why it is missing.</li> <li>No reference to supporting documents/evidence (tables, figures, appendices, etc.).</li> <li>No clear logical flow or presentation of results.</li> <li>Many tasks as stated from the methodology remain unaddressed in the results.</li> </ul>	<ul style="list-style-type: none"> <li>No results or findings are given</li> </ul>
<b>Recommendations (Final Report Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Results are used to provide clear, concise recommendations.</li> <li>Justification is provided for the selected recommendation, based on results.</li> </ul>			<ul style="list-style-type: none"> <li>Recommendations are provided, but unsupported by the results presented previously</li> </ul>	<ul style="list-style-type: none"> <li>No recommendations are provided</li> </ul>
<b>Conclusions (Final Report Only)</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards.</li> </ul>	<ul style="list-style-type: none"> <li>Clearly summarizes the problem, process, results and recommendations.</li> <li>No new material is introduced.</li> </ul>			<ul style="list-style-type: none"> <li>Conclusion does not relate to the introduction/problem statement provided earlier.</li> <li>New material, unseen elsewhere in the report, is presented or discussed.</li> </ul>	<ul style="list-style-type: none"> <li>No conclusion is provided</li> </ul>

Category	6	5	4	3	2	1
<b>Schedule, Organization Chart, Facilities (Proposal Only)</b>				<ul style="list-style-type: none"> <li>• Team provides a Gantt chart or equivalent.</li> <li>• Provides an organizational chart and explains it with text.</li> <li>• Facilities they have and need are described clearly.</li> </ul>	<ul style="list-style-type: none"> <li>• Gantt chart does not provide enough details or is illegible</li> <li>• organizational chart is presented with no explanation.</li> <li>• Facilities do not provide any details</li> </ul>	<ul style="list-style-type: none"> <li>• Lacks 2 or more of the following: schedule, organization chart, facilities.</li> </ul>
<b>Appendices (Final Report Only)</b>				<ul style="list-style-type: none"> <li>• Descriptive titles</li> <li>Calculations should start with assumptions and clearly state what is being calculated.</li> <li>• Logical progression of appendices</li> <li>All necessary supporting documentation is provided.</li> </ul>		<ul style="list-style-type: none"> <li>• No appendices were provided, even though they were required/necessary to support the work provided in the report.</li> </ul>



Category	6	5	4	3	2	1
<b>Document Mechanics (30%)</b>						
<b>Organization of the Document</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards through novel approaches, creativity, or extreme clarity through superb organization.</li> </ul>	<ul style="list-style-type: none"> <li>Visually, the document presents in a professional manner.</li> <li>Dates, names, etc. are correct.</li> <li>Formatting is consistent throughout the document.</li> <li>Paragraphs are appropriate in length.</li> <li>Headings and subheadings are used appropriately to organize the proposal.</li> <li>Headings/Subheadings are descriptive; orienting the reader to the subject of the section</li> <li>Topics flow logically from the beginning to the end.</li> <li>Has a smooth ending to the proposal through a summary or concluding paragraph</li> </ul>				<ul style="list-style-type: none"> <li>Lack of organizational system (i.e lack of headings/subheadings, long paragraphs, etc.)</li> </ul>
<b>Reader friendliness</b>	<ul style="list-style-type: none"> <li>Meets all requirements of '5', but also exceeds professional standards. Document is enhanced through superb language usage, sentence structure, and organization – creating a document that is exceedingly approachable and understandable.</li> </ul>	<ul style="list-style-type: none"> <li>There is a global introduction, explaining the organization of the document.</li> <li>Sections have introductory and concluding paragraphs. Paragraphs have introductory and concluding sentences such that the document reads well and flows logically.</li> </ul>				<ul style="list-style-type: none"> <li>Many run-on paragraphs, and run-on sentences.</li> <li>Lack of introduction to content within chapters, sections, and paragraphs.</li> <li>Information seems to be abruptly presented with little context before or conclusion afterward.</li> </ul>
<b>Grammar</b>				No grammatical errors	1-4 grammatical errors	> 5 grammatical errors

Category	6	5	4	3	2	1
<b>Spelling</b>				No spelling errors	1-4 spelling errors	>5 spelling errors
<b>Language</b>				<ul style="list-style-type: none"> <li>• Uses professional language, appropriate to the proposal content and context</li> </ul>		<ul style="list-style-type: none"> <li>• Uses colloquialisms often. Uses technical language inappropriately.</li> <li>• Abbreviations are not spelled out in the first use. Uses contractions often.</li> </ul>
<b>Figures/Tables</b>		<ul style="list-style-type: none"> <li>• Figures/Tables clearly present information. They are self-contained, such that they could be removed from the proposal and still understood.</li> <li>• Proper units and labels (axes or headings). Appropriate significant figures.</li> <li>• Images are clear and elements are labeled appropriately.</li> <li>• Sources are cited where appropriate.</li> </ul>		<ul style="list-style-type: none"> <li>• Graphics are overly complex and difficult to understand or visually unappealing – poor resolution or too dark.</li> <li>• Incomplete captions. Figure/Table could not stand alone outside of the proposal and be understood.</li> <li>• Figures or Tables are overly crowded by text above/below or around.</li> </ul>		

Category	6	5	4	3	2	1
<b>References</b>				Meets Professional/ Journal Standards (or no bibliography was needed and therefore is not present), including in-text citations	Some references are incomplete, or reader wouldn't be able to find them due to lack of info; references not formatted according to any professional standard; some in-text citation appear to be missing	Incomplete, missing references, or no bibliography at all when there should be one
<b>Substantial Effort</b>	<ul style="list-style-type: none"> <li>Document exceeds expectations of student effort, demonstrating substantial effort in both understanding and communicating the project objectives and approach.</li> </ul>	<ul style="list-style-type: none"> <li>Document demonstrates a substantial effort given by the team in their aims to understand and communicate the purpose of the project and their approach to finding a solution</li> </ul>				Document demonstrates a lack of effort by the team to fully explain the project and their approach. A proposal that lacked substantial effort would most closely mirror initial documents given to the students and show little team effort to expound.

**Technical Content (20%)**

**Note: Please add characteristics that you were looking for under technical content. And the features of a strong technical proposal (score of 6) vs. a weak one (score of 1).**