Enhancing Writing Quality in Engineering Capstone Project Documents

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ABSTRACT— *Quality of technical writing in capstone reports is an important attribute to express and communicate the ideas, methodology and results of the technical content of a project. Technical writing expertise for engineering students in general, and for international (non-English) in particular, need improvements in this area. Capstone instructors end up spending significant amount of time in helping student teams in correcting the project documentation for style, grammar, organization and format. This research introduces the concept of bringing in a Technical Writing Assistant (TWA) in to the class room for capstone projects to work with student teams. TWAs conducted sessions with student teams (Onsite and Online) to help with the writing quality of capstone documentations. TWA staff were in addition to the course instructor. This research team used university's writing center expertise to staff TWAs, and they helped in developing a set of metrics/rubrics to evaluate the capstone documents for their technical writing quality. In order to assess the impact of TWAs, this paper analyses and compares capstone project reports done with and without TWAs using the metrics/rubrics. The findings of this evaluation and analysis can lay the foundation for changes, recommendations, and deployment of TWAs in engineering curriculums.*

Keywords— ABET, effect size, accelerated courses, flipped classes, PBL, teaching and learning paradigms, writing quality, written attributes.

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1. INTRODUCTION

Engineers need to write clearly. Engineering students struggle to write; engineering instructors feel ill-equipped or too short on time to effectively teach writing skills [1]. Engineers and scientists are not typically characterized as having excellent communications skills, including in written communications. Some employer surveys support the validity of this perception through their findings that there is a gap between employers' expectations and the actual capabilities of students/graduates of technical programs when it comes to communication skills [2]. The Accreditation Board for Engineering and Technology (ABET), the accrediting body for engineering, engineering technology, computer science, applied science and related programs, has recognized the importance of communication skills – including written communications – and requires that accredited curricula include written communication skills as a learning outcome [3].

The National Commission on Writing in its report referred to college writing as 'The Neglected R. The Need for a Writing Revolution' [2]. Several researchers have done studies on the best approach or methodologies to train students to better or improve their writing skills and methods to assess writing in higher education [4-5]. Sperber in his commentary in the John William Pope Center for High Education Policy notes 'We Must Overhaul College Writing' [6]. Researchers have also documented some serious challenges to teaching academic writing to International students whose first language is not English [7]. One survey asserts that "44% of managers feel writing is the hard skill most lacking among recent college graduates." [8].

Engineering students are heavily trained for detailed analysis of problems and to come up with analytical solutions, but more training is needed for engineers to learn to skillfully write about their work and communicate effectively to both engineering and non-engineering audience [9]. These findings along with the authors' own experiences in teaching, reviewing and assessing capstone project documents (graduate and undergraduate) set the stage for this research with the objective of raising the writing quality of the engineering capstone project documents – the final output of student teams in an engineering program. Use of Teaching Assistants (TA) in higher education to help an instructor with lab classes, grading, and sometimes tutoring - is not uncommon in many major universities in the US and in other higher educational institutions around the world. Other initiatives include 'Writing Fellows' programs, where student fellows work with course instructors to assist students with their writing projects. As part of'Writing Across the Curriculum' programs or writing centers, 'Writing Fellows' programs underscore the need to train students recognize the context, purpose, and audience of each writing situation.This research using TWAs differs from those relying on student fellows in that experienced, profession writing tutors are connected with specific engineering courses where they work with the professors and students on capstone project course writing assignments.

The theoretical underpinnings of this work come from:

1. Writing center theory that asserts the effectiveness of one-on-one conversations about current writing projects.
2. Genre Theory that "stresses the situated nature of all writing, along with the reality that each piece of writing is tailored to a specific audience and has a specific purpose." [10].
3. The 'Writing Across the Curriculum' movement that asserts that the responsibility of teaching of writing does not reside solely with the teachers of a few writing courses.

The approach taken here for engineering capstone project course(s) was to hire an experienced writing tutor from the universities' Writing Center as a Technical Writing Assistant (TWA) to work closely with the student teams and help the student teams with the writing of the capstone project documents. The TWA offered content-specific writing tutoring to help the student teams during the entire course duration. Working closely to set up the methodology and rubrics focusing on the writing quality of the document, the instructor focused on the project course instruction and the technical contents of the project and the TWA focused on the writing quality of the project documents. This combination provides for enhancing the project content quality and improving the written quality of the project documents.

This research was conducted in the School of Engineering and Computing (SOEC) at a university that was established in 2002, and has attracted a current student body of over 1100 in this school, whose profile generally mirrors that of the University itself. This university is the second largest private non-profit university in California, has over 22,000 mainly non-traditional students: students with average age over 30 and heavily weighted with students from traditionally underrepresented groups, including women and minorities. Over 75% of the students are working on master's degrees; in SOEC the number is around 50%. Most students, whether at the undergraduate or graduate level, are reentering an academic environment after having been out in the "working world" for some time. It is not uncommon for these students to be a bit "rusty" in their writing skills. In addition to these typical non-traditional students, SOEC has recently experienced a significant influx of international students. Most of these international students, primarily from India and China, enter the master's programs after just recently completing undergraduate degrees in their home countries. Many of these international students also need to improve their writing skills. The ability to effectively communicate in writing is included as one of university'sInstitutional Learning Outcomes (ILOs), making it an objective for all students in all programs at the university. In addition, every program in SOEC includes written communication ability as a specific Program Learning Outcome (PLO). While writing assignments are not uncommon in many SOEC courses, teaching writing has been mainly confined to specific general education and technical writing courses at the university or elsewhere.

2. RESEARCH DESCRIPTION

Capstone projects supports an additional pedagogical importance for engineers by preparing them to become more professional in the work place in the way of written communication. The written material for project proposal (and other documents) needs to address the concerns and questions of the potential audience [11]. For effective engineering project reports, both structure and written quality comprehension of the content are important to answer questions about assumptions, process, implementation, verification of the expected results along with risks.

From a project document structure perspective, in a survey the following overall quality attributes were identified as key to the quality of the output [12]: addresses the objectives, uses an appropriate and logical structure, is consistent in style and application of formatting, presents findings in a clear and succinct manner, using plain English, provides relevant context around statistical findings, focuses on findings that are of statistical and practical significance, is free of errors, meets the brief, uses tables, graphs and text appropriately and incorporates client feedback where appropriate.

The goal for the study is achieve the above with the help of TWA. The objectives of this research are threefold:

- To implement a process that ensures TWA's role to help student teams to enhance the written quality of the capstone project documents to be higher than similar prior project capstone documents.
- Process to be flexible so it can be applied to both online and onsite (live class) capstone courses.
- Apply both qualitative and quantitative analysis to measure the final writing quality. This paper presents the findings and recommendations of this research.

3. RESEARCH METHODOLOGY

The pilot project for this research was introduced to two graduate level capstone courses (one online and one onsite) and one undergraduate level (onsite) in the SOEC.Student-team members were responsible to the write the project document – TWA reviewed, gives feedback on the areas to improve, how to improve and why; TWA were not be responsible to write the project document.

3.1 Three Phase Methodology

The following three phase methodology was implemented for this pilot to have TWA tutor student-teams, namely Initiation, Execution and Analysis. This is shown in Figure 1. Each phase is further discussed below.

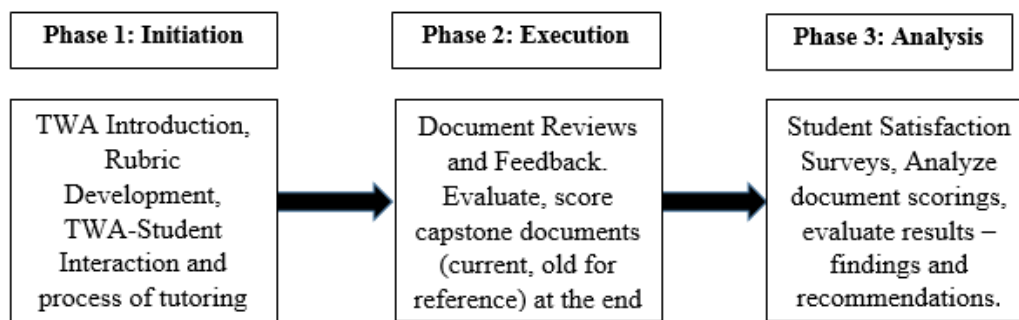| Phase 1: Initiation	Phase 2: Execution	Phase 3: Analysis
TWA Introduction, Rubric Development, TWA-Student Interaction and process of tutoring	Document Reviews and Feedback. Evaluate, score capstone documents (current, old for reference) at the end	Student Satisfaction Surveys, Analyze document scorings, evaluate results – findings and recommendations.

Figure 1: A 3-Phase Methodology for the TWA Pilot

Although the university has a writing center to help individual students or student teams, the focus and objective here are different. In order to achieve the objectives stated earlier, the TWA needs to be an active participant in the class interacting with the student-teams and in helping to develop the quality metrics/rubrics to measure the writing quality. The student-teams need to understand clearly the role of the TWA and that the first and foremost reason for the TWA is to help and raise the program capstone project document's writing quality. This allows more time for the instructor to concentrate on the project's technical content quality.

3.2 Initiation – Phase 1

The first step in the initiation process was to hire the right TWA with experience in reviewing and editing technical writing, in addition to tutoring experience. It was decided to partner with University's writing center and to tap some experienced writing tutors. Several such tutors were interviewed by instructors and two were selected. The entire process needed to be a collaborative process between the instructor and the TWAs to adapt to online and onsite teaching. The full process is shown in Figure 2.
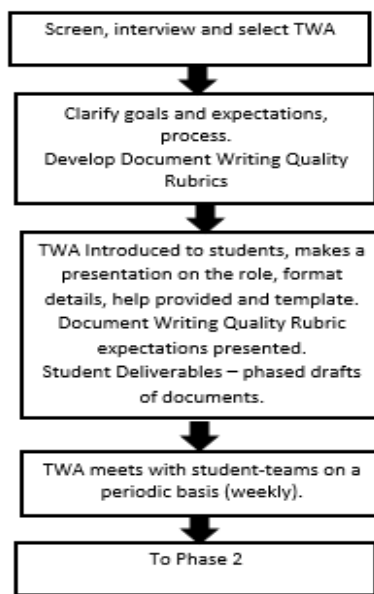
Figure 2 – Phase 1 Initiation Process Diagaram

Two important tasks of this initiation process was to develop the rubrics to evalauate/score the final capstone project doucments, and the details of interaction between the student-teams and TWA. TWAs helped develop the first draft of the rubrics which were reviewed by the instructors and approved. TWAs were introduced to the students in the first class of the capstone project course.

The writing qulaity rubrics included these key attributes, namely: Comprehension, Organization, Gammar & Vocaublary, adherance to APA style and formatting, Citations and References. Each attribute was scored and graded as exceeding (Honors), meeting the expectations (Satisfactory) or not meeting the expectations (Unsatisfactory).

From an interaction perspective, TWAs met once a week with the student-teams in class for onsite students. For online students, blackboard was used astheLearning Management System (LMS), and the TWA met with the student-teams once a week in a separate online session. TWA proposed a project doucment template to suit the program specific capstone project. Student-teams were set to communicate directly with TWA on all document writing related matters. Student-teams submitted their draft documents to the TWA for review and feedback.

3.3   Execution – Phase 2

In the execution phase the focus was on the iterative document review and feedback by the TWA to the student-teams, leading up to the final version submission at the end of the course. For each draft submitted by the student-teams, the instructor reviewed for the content and the TWA reviewed for the writing quality on the categories laid out in the rubrics. Details on the execution process is shown in Figure 3.
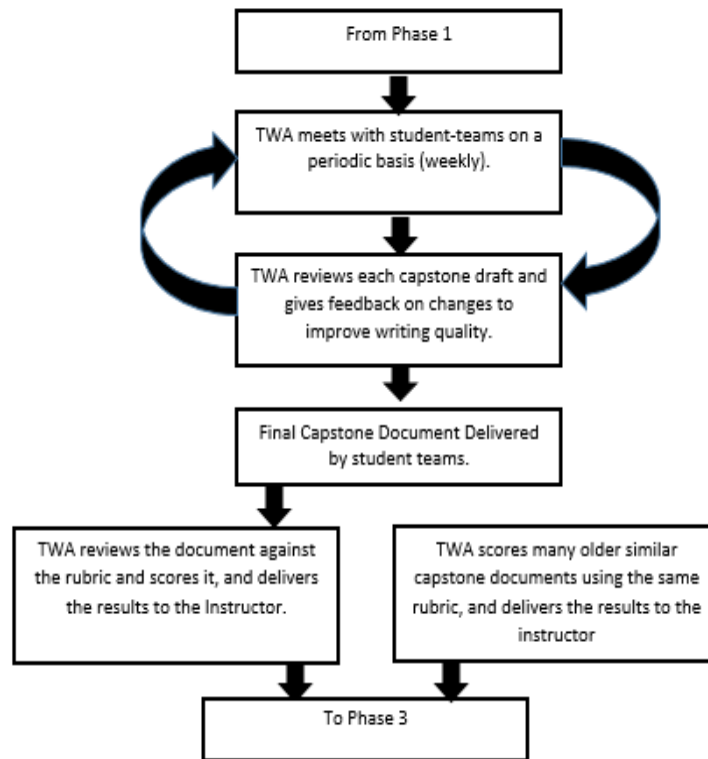
Figure 3 – Phase 2 Execution Process Diagram

The TWA completed two major tasks at the end of this execution phase. First one is the evaluation and scoring of each student-team's final document for writing quality per the rubrics. Points were assigned to each course grade for each of the writing quality attributes. Secondly, in order to have a reference, TWA also scored several similar previous capstone project documents using the same rubrics. Results were entered in a spreadsheet and delivered to the instructor.

3.4 Analysis – Phase 3

In the analysis phase, both qualitative and quantitative analysis of the processes and the outcome were evaluated. The process is shown in Figure 4.
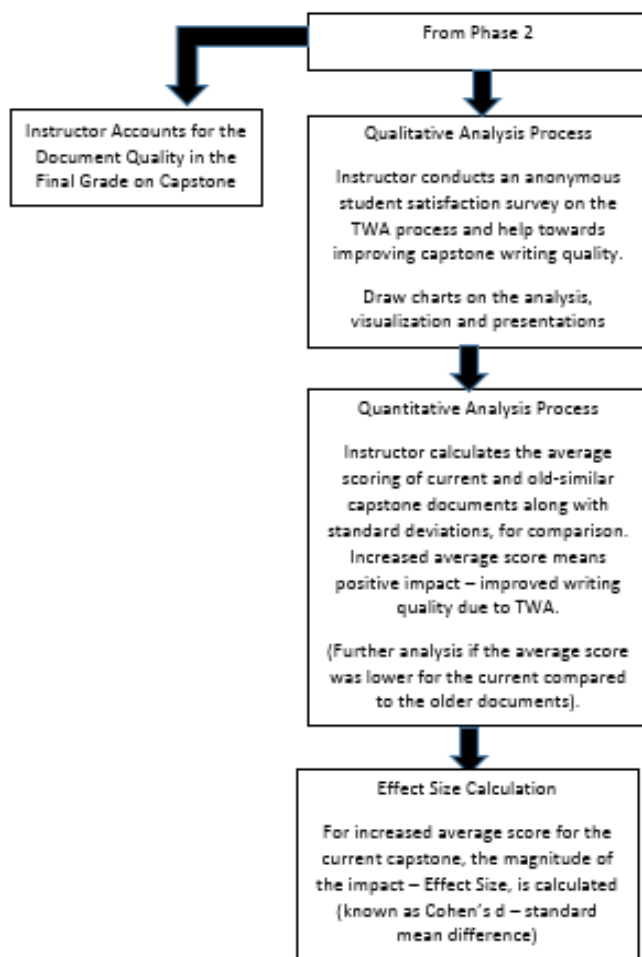
Figure 4 – Phase 3 Analysis Process Diagram

For qualitative analysis, a student survey was conducted about the process, student-TWA interactions and students' recommendations on the future introduction of TWAs to improve document writing quality in capstone project courses. The survey questionsare in Figure 5.

The capstone project document score averages for the classes with TWA intervention were calculated and compared against the scores of similar previous documents (without TWA intervention) to quantitatively assess the improvement in writing quality. Further, the concept of Effect Size, also known as Cohen's d (Standard Mean Difference) – which statistically measures the impact size due to the intervention was calculated using standard deviations [13-14]. These details are further discussed with charts in the next Data Analysis section.

4. DATA ANALYSIS

Data Analysis phase is perhaps the most significant part of thisresearch for evaluating the benefits of introducing TWAs with the specific goal of improving the writing quality of capstone project documents. The qualitative approach was getting feedback from students through an anonymous student satisfaction survey and evaluating their ratings and comments. Quantitative analysis was done with standard statistical tools including calculating 'Effect Size' of the TWA intervention per *Cohen's d* (Standard Mean Deviation) [13].

4.1 Qualitative Analysis

The student satisfaction anonymous survey was conducted on both the graduate courses and in one undergraduate. There were eight questions that were asked with a rating scale of 1 (low) to 5 (highest-best). The questions, as included in Figure 5, cover the introduction, interaction with and help from TWA, the process, and students' thoughts/recommendations for future capstone projects. Students also could write comments for every question.

Figure 5 shows the results of all students' responses (undergraduate and graduate) for the survey questions – a full sample of 50 student responses. The chart also shows the standard deviations for each of the questions.
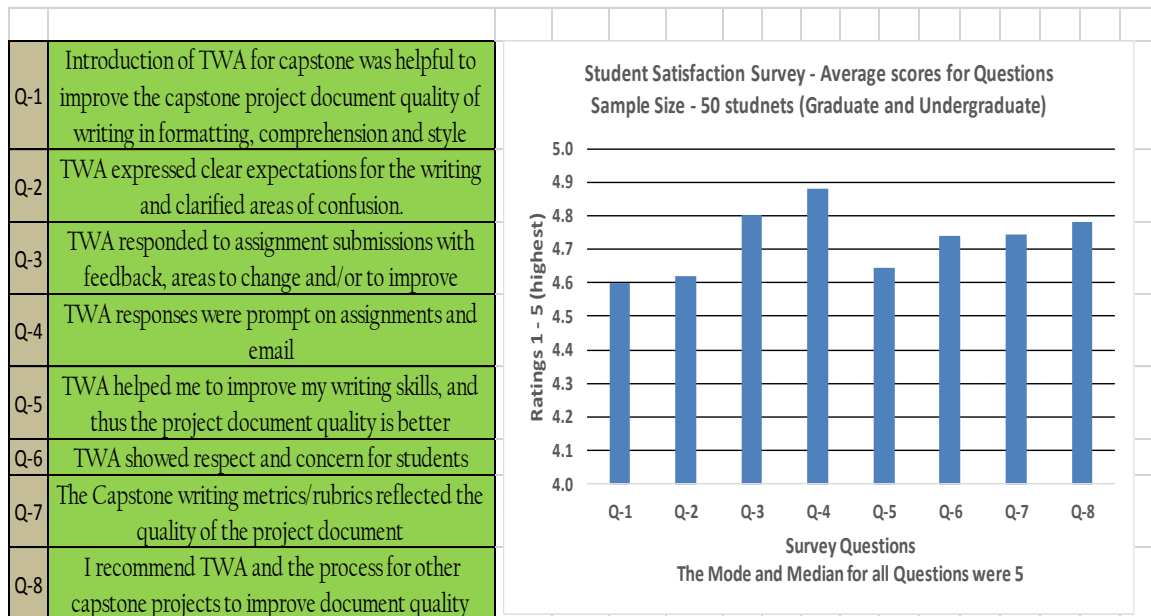

Q-1	Introduction of TWA for capstone was helpful to improve the capstone project document quality of writing in formatting, comprehension and style
Q-2	TWA expressed clear expectations for the writing and clarified areas of confusion.
Q-3	TWA responded to assignment submissions with feedback, areas to change and/or to improve
Q-4	TWA responses were prompt on assignments and email
Q-5	TWA helped me to improve my writing skills, and thus the project document quality is better
Q-6	TWA showed respect and concern for students
Q-7	The Capstone writing metrics/rubrics reflected the quality of the project document
Q-8	I recommend TWA and the process for other capstone projects to improve document quality

Figure 5 - TWA Student Satisfaction Survey Responses

It is clear from the response ratings that the students were very satisfied with the introduction of TWA to help improve the writing quality – all averages were above 4.5 in a rating scale of 1 to 5 (highest rating). Overwhelming positive responses to note on the two items: TWA's prompt responses (Q-4) and their recommendation of TWA and the process for other capstone projects (Q-8). The response averages were about the same for graduate and the undergraduate students.

The survey also collected open comments from the students.These were very positive and some areas to improve as well were noted in the written comments.

4.2 Quantitative Analysis of the Project Document Writing Quality

The objective of this statistical quantitative analysis was to have a measure that demonstrates the improvement in the writing quality and to understand the impact on thestudents. Instructor and TWA jointly agreed on points to be assigned to the various writing quality assessment categories in the rubrics (added up to 100 points).

4.3 Project Document Scoring

TWAs evaluated and scored each team's final capstone project document output. For comparison and to help quantify the improvement in writing, TWAs also evaluated and scored several previous documents that were written without help (or intervention) from a TWA. Average scores and standard deviations were calculated – as shown in Table 1 below.

	Writing Quality Score	Std Deviation	Number of Capstone Project Documents
Assessment with TWA	83.4	7.5	Total of 17 Project Documents
Assessment without TWA	77.8	7.7	Total of 22 Project Documents
Increase in Score	5.7		Reflects higher writing quality

Table 1 Project Documents Assessment with and without TWA

Table 1 also shows the number of project document samples involved in each assessment (with and without TWA). Overall there was a writing quality score increase of 5.7 among all the three courses under study, a 7.32% increase in the final scores.

4.4 Effect Size and Its Interpretation

The magnitude or size of impact quantification, referred to Effect Size Cohen's d (also sometimes referred to as Standard Mean deviation or Standard Mean Effect) - is calculated as follows [13-15]:

d = (A1 – A2)/s,

Where   A1 = Average of assessment score with TWA (referred to as the Intervened)

A2 = Average of assessment score without TWA (referred to as the Control group)

s = pooled standard deviation of assessments of both groups.

In other words, the Effect Size is expressed in standard deviation units.

Calculating the Effect Size for the current analysis:

Effect Size = 0.75.

The meaning of Effect Size number - the standard interpretation offered by Cohen [13] as it relates to its real impact on the team members:

0.8 = large (8/10 of a standard deviation unit)

0.5 = moderate (1/2 of a standard deviation)

0.2 = small (1/5 of a standard deviation)

With the calculated Effect Size shown above being at 0.75, the effect size is closer to being large - the intervened group's mean score increased closer to 8/10 of a standard unit.

Another statistical interpretation by Coe [15] for the Effect Size being between 0.7 and 0.8 (see Table 2) – giving percentage probabilities of higher (or lower) individual project document scoring between the two groups:

Effect Size	Percentage of control group who would be below average person in experimental group	Probability that a document score from experimental group will be higher than document score from control
0.7	76%	0.69
0.8	79%	0.71

Table 2 – Statistical Interpretation of the Effect Size for Impact [15]

It is clear from Table 2 that the probability of a document score from the experimental group will be higher than document score from the control by about 70% at an Effect Size of 0.75.

Unlike the qualitative survey, there were differences in the project document score averages in the three courses in the study. The capstone courses had teams ranging from 2 to 9. Class with smaller number of teams had a higher average score than those with higher number of teams. A simple explanation could be that the TWA was able to spend more time with the

student-teams with smaller number of teams. This was also confirmed with the TWAs – which leads to an interesting decision to make for the future courses as to the optimum number of teams to be in a capstone class.

5. CONCLUSIONS

In order to assess the impact of TWAs, this paper analyses and compares capstone project reports done with and without TWAs using a developed metrics/rubrics. The objectives were 1) to implement a process that ensures TWA's role to help student teams to enhance the written quality of the capstone project documents, 2) The process be flexible so it can be applied to both online and onsite (live class) capstone courses, and 3) apply both qualitative and quantitative analysis to measure the final writing quality. The measurement rubrics were developed and the process, as explained in an earlier section, was implemented. It was ensured that this process was flexible enough to be applied to both onsite (in-person) and online classes. For the qualitative analysis, a student satisfaction survey in both the graduate courses and in one undergraduate classes showed the results from the responses were positive with the introduction of TWA to help improve the writing quality – all averages were above 4.5 in a rating scale of 1 to 5 (highest rating). The two maximum ratings were for the TWA's prompt responses, and recommendation of TWA and the process for other capstone projects. The survey also collected comments from the students. These were positive and some potential areas for improvement were suggested.For the quantitative analysis, each document was scored against a predeveloped rubric. For comparison and to quantify the improvement in writing, TWAs also evaluated and scored several previous documents that were written without a TWA. Average scores and standard deviations showed an overall writing quality score increase of 7.32% for these three classes. In addition, this quantitative analysis showed that the probability of a document score from the experimental group to be higher than document score from the control group by about 70% at an Effect Size of 0.75.

Findings of this evaluation and analysis can lay the foundation for changes, recommendations, and deployment of TWAs in engineering curriculums.This research also opened up an interesting decision to make for the future courses as to the optimum number of teams to be in an engineering capstone class.

6. CONTINUING RESEARCH

This research was performed with a relatively small number of students, in two programs, and all in the USA. This needs to be studied further and it is suggested that additional research be undertaken with international English-Second-Language (ESL) students from different parts of the world. Additionally, other technical programs and curriculums need to be analyzed to understand the variations, if any, due to the topics covered. A research may be designed that incorporates possible quantitative and qualitative impact with available teaching and learning approaches. This can be taken further to analyze the correlation between different teaching and learning paradigms (flipped classes, problem-based learning, accelerated courses, etc.) and the impact of TWAs on the report quality.

7. ACKNOWLEDGEMENTS

8. REFERENCES

[1]   Gassman, S.L., Maher, M.A. and Timmerman, B.E. (2013). Supporting Students' Disciplinary Writing in Engineering Education. International Journal of Engineering Education. 29(5), pp. 1270-1280.

[2]   The National Commission on Writing. The Neglected "R". The need for a Writing Revolution. http://www.collegeboard.com/prod_downloads/writingcom/neglectedr.pdf . Accessed May 01, 2016.

[3]   Accreditation criteria and Supporting docs. http://www.abet.org/accreditation/accreditation-criteria/. Accessed August 30, 2016.

[4]   LEA, M. (1998).Student Writing in Higher Education" An Academic Literacies approach. Studies in Higher Education, Jun 98, Vol. 23 Issue 2, p157, 16p

[5]   LEA, M. (1994). 'I thought I could write till I came here': student writing in higher education, in: G. GIBBS (Ed.) Improving Student Learning: theory and practice, pp. 216- 226 (Oxford, Oxford Centre for Staff Development).

[6]   Sperber, M. (2011).We must Overhaul College Writing. Here's a not so modest proposal that will turn American students from poor writers in to good ones. http://www.popecenter.org/commentaries/article.html?id=2539 Accessed May 01, 2016.

[7]   The Challenges of Academic Writing. http://www.uefap.com/articles/furneaux.pdf . Accessed May 01, 2016.

[8]   Leveling UP: How to Win in the Skills Economy. Pay Scale Human Capital 2016 Workforce-Skills Preparedness Report). http://www.payscale.com/data-packages/job-skills.

[9]   American Society of Mechanical Engineers. 'How Engineers Can Improve Technical Writing'. https://www.asme.org/career-education/articles/business-writing/how-engineers-can-improve-technical-writing   . Accessed May 01, 2016.

[10]   Walker, K. (2000, July). Integrating Writing Instruction into Engineering Courses: A Writing Center Model. *Journal of Engineering Education, 89*(3), 369-375.

[11]   Mathes, J. C.; Stevenson, Dwight W.; 1976. *Designing Technical Reports for Audiences and Organizations*.

[12]   Queesland Government Statistician's office, 'Presenting Survey Results – Report Writing. Accessed October 9, 2016. http://www.qgso.qld.gov.au/about-statistics/presentation/presenting-survey-results.pdf

[13]   Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd Ed.). Lawrence Erlbaum Associates.

[14]   Cohen, J (1992). Quantitative Methods in Psychology. Psychological Bulletin, July 1992; 112, 1; PsycArticles. Pg155

[15]   Coe, R. (2002). *It's the Effect Size, Stupid. What effect size is and why it is important*. British Educational Research Association Conference, 2002. http://www.cem.org/attachments/ebe/ESguide.pdf Accessed May 7, 2016