Purdue University

Purdue e-Pubs

Libraries Faculty and Staff Scholarship and Research

Purdue Libraries and School of Information Studies

2-2021

# Improving Writing Quality of Capstone Reports

Fred Berry
*Purdue University*, berryf@purdue.edu

Margaret Phillips
*Purdue University*, phill201@purdue.edu

James Condron
*Purdue University*, jcondron@purdue.edu

Phillip Sanger
*Purdue University*, psanger@purdue.edu

Follow this and additional works at: https://docs.lib.purdue.edu/lib_fsdocs

 Part of the Engineering Education Commons

## Recommended Citation

Berry, Fred; Phillips, Margaret; Condron, James; and Sanger, Phillip, "Improving Writing Quality of Capstone Reports" (2021). *Libraries Faculty and Staff Scholarship and Research.* Paper 249.
http://dx.doi.org/10.1109/TE.2021.3059739

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact epubs@purdue.edu for additional information.

# Improving Writing Quality of Capstone Reports

Frederick C. Berry, *Senior, IEEE*, Margaret Phillips, James Condron, and Phillip A. Sanger

**Abstract-*Contributions:* The main contribution is to share a series of practical methods that improve the writing quality of capstone reports.**

***Background:* The ability to write well is critical to the success of an engineering technology graduate. However, the evidence points to the fact that industries are disappointed with the quality of writing skills graduates demonstrate.**

***Intended Outcomes:* A faculty review of capstone reports showed little improvement in writing quality from the first course to the second in a two-semester capstone sequence. Therefore, the instructors explored what actions were needed to improve the writing quality of the capstone reports.**

***Application Design:* Several changes in the capstone courses were developed and implemented. The changes included 1) using instructional technology as a scaffolding to help frame the writing required for the course and 2) engaging students in iterative writing with feedback.**

***Findings:* The assessment data showed a significant improvement, at the 5% level. The iterative process of writing and rewriting the report, coupled with frequent meetings with faculty mentors, proved to be a powerful combination for improving the writing prowess of the students.**

***Index: Capstone, engineering technology, writing quality, assessment.***

## I. Introduction

The School of Engineering Technology (SoET) is educating engineering technology students to think critically, communicate effectively, and employ lifelong learning skills to address important technical and social issues. Capstone education, in the SoET, uses a design thinking methodology [1]. Design thinking focuses on activities where students learn the intellectual constructs and practical methodologies needed to create a deliverable that meets or exceeds a client's expectations. One of these practical methodologies is the ability to communicate effectively in writing.

The ability to write well is critical to the success of engineering technology graduates in the knowledge economy [2]. Studies have shown the level of oral and written communication skills a graduate possesses impacts their level of success in the workplace [3], [4]. Therefore, ABET, the accrediting body for engineering technology programs, requires engineering technology programs to demonstrate that students are able to "apply written, oral, and graphical communication in both technical and non-technical environments" [5].

The act of writing is a different mode of learning [6] that helps the engineering technology worker develop a more complete understanding of a design, application, or process [7]. Writing is a major component of the linguistics bridge that enables teamwork and collaboration [8]. Being able to articulate the needs for goods, products, and services in writing is a critical skill needed by business and industry [9].

At the end of each academic year the SoET performs an internal ABET review. During the ABET review of 2016-17, it was noted the writing quality of the capstone reports seemed to show little improvement from the first course to the second in a two-semester capstone sequence. The question from the reviewers was, what changes can be made to the capstone courses to improve the writing quality of the team reports?

Writing quality for the capstone reports is defined by the rubrics presented in Table III. Each mentor uses the rubric criteria to assess their team reports. The mentors are assessing the coherence of each item found in Table III from report section to report section. The report coherence is defined, and all the report sections fit together to create a logical sequence from one section to another, presenting the current state of the capstone project.

## II. Research on Improving Writing

The overwhelming volume of evidence points to the fact that industries are disappointed with the quality of writing skills graduates demonstrate [10], [11]. The focus of this paper is on improving the writing quality of capstone reports by students in the SoET [12]. The improvement in writing quality is measured by faculty assessments of the capstone reports. The authors performed a literature search to find practices that demonstrated improvements in writing quality.

First Finding, the use of instructional technologies coupled with instruction has shown to be an effective combination for improving writing [13]. This combination provided the instructors with better insights into the level of knowledge gained by students [14]. The instructional technology was used as a scaffolding to help frame the writing requirements [15].

Second Finding, the development of writing templates, which included writing samples, helped students organize their project reports [16] by providing them with guidance on format, style, and report structure [17], [18]. In addition, writing templates provided a single approach for students to follow when writing their reports, reducing confusion [17].

Third Finding, students engage in iterative writing with feedback. The major issue found with student writing was not

All four authors listed below contributed equally to this work.

F.C. Berry is a Professor in the School of Engineering Technology at Purdue University, West Lafayette. Professor (e-mail: berryf@purdue.edu).

M.L. Phillips is an Assistant Professor in the Purdue University Libraries and School of Information Studies at Purdue University, West Lafayette (e-mail: phill201@purdue.edu).

J. Condron is an Assistant Professor of Practice in the School of Engineering Technology at Purdue University, West Lafayette (e-mail: jcondron@purdue.edu)

P.A. Sanger is a Professor Emeritus in the School of Engineering Technology at Purdue University, West Lafayette (e-mail: psanger@purdue.edu).

grammar, spelling, or punctuation, but coherence of the writing [19]. The issue with coherence included incomplete report sections, insufficient literature reviews, and lack of data to support conclusions, resulting in poor report structure. Therefore, the clarity and message of the reports are lost [19]. However, students demonstrated significant improvement in coherence when feedback and rewriting were integrated into the writing assignments [14], [19].

## III. Course Design

Each year, the SoET launches a two semester Multidisciplinary Senior Capstone Project Course for the soon-to-be graduating engineering technology students. The first course, ECET43000 is 3 credit hours, with two 1-hour lecture periods and one 2-hour laboratory period. The second course, ECET46000 is 3 credit hours, with one 1-hour lecture period and two 2-hour laboratory periods. In addition to the required lecture and laboratory periods each team has required weekly meetings with their academic and industry mentors. A stage/gate process is used to guide the capstone students through team formation, project proposal, conceptual design, preliminary design, critical design review, fabrication and test, and ultimately to completion of their final deliverables [20], [21]. Gates 1-3 are completed in ECET43000 and Gates 4-6 are completed in ECET46000.

In addition to the course instructors, each capstone team is assigned an academic mentor who is a faculty member in the SoET. The faculty mentors are responsible for meeting with their teams weekly and grading/assessing their teams' capstone reports for each gate. Table I shows the enrollment of undergraduate students by majors in the capstone course sequence for ECET43000 and ECET46000, and the number of SoET faculty that served as academic mentors.

TABLE I
ENROLLMENT BY MAJOR AND MENTORS

| | 2016-17 Fall - Spring | 2017-18 Fall - Spring | 2018-19 Fall - Spring | 2019-20 Fall - Spring |
|---|---|---|---|---|
| EETs Students* | 79 | 79 | 67 | 50 |
| METs Students* | 68 | 33 | 20 | 49 |
| MFETs Students* | | 5 | 22 | 39 |
| IETs Students* | | | 7 | 39 |
| Total | 147 | 117 | 116 | 177 |
| Mentors** | 21 | 15 | 15 | 23 |

*Electrical Engineering Technology (EET)
*Industrial Engineering Technology (IET)
*Manufacturing Engineering Technology (MFET)
*Mechanical Engineering Technology (MET)
**Mentors are SoET Faculty Grading/Assessing Their Team's Reports

## IV. Research Questions

The following three hypotheses will be tested to assess the impact of changes made to ECET43000 and ECET46000 to improve the quality of capstone report writing:

1) There is a difference in mean ratings between the end of ECET43000 and ECET46000.
2) There is a difference in mean ratings between the end of ECET43000 across years.
3) There is a difference in mean ratings between the end of ECET46000 across years.

## V. Interventions to Improve Writing Quality

During an internal ABET review, a faculty committee in the SoET noted the writing quality of the team reports showed little improvement from the first course to the second in a two-semester capstone sequence. Therefore, the instructors explored what actions were needed to improve the writing quality of the capstone reports. Based on a literature review on how to improve student writing, the instructors made the following changes to the capstone courses. Table II details a timeline of the events and interventions.

First Change, over the summer of 2018 the faculty reviewed two years of capstone reports and found exemplary reports for each gate that could serve as writing samples for the students [22]. Next, report templates/outlines for each gate were created using the sample reports as guides [16], [23]. Fig. 1 is a screen capture of the course welcome page for ECET43000, the first capstone course. Under the gate information columns in Fig. 1 there are sample reports, report outlines, and rubrics for each gate. In addition, Gates 2 and 3 have sample oral presentations, oral presentations outlines, and rubrics. Also, for ECET46000, the second capstone course, report and presentation outlines for each gate were created using the sample reports and presentations as guides.

TABLE II
TIMELINE OF EVENTS AND INTERVENTIONS

| 16-17 | 17-18 | 18-19 | 19-20 |
|---|---|---|---|
| ABET review identified an issue | ABET review showed same issue | First Change | Fourth Change |
| | | Second Change | Fifth Change |
| Collect another year of data | Developed improvement plan | Third Change | Sixth Change |

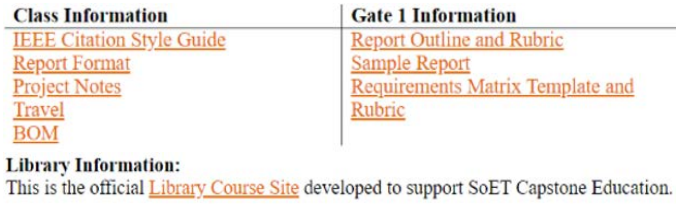


Fig. 1 Partial Screen Capture of ECET43000 Welcome Page [14]

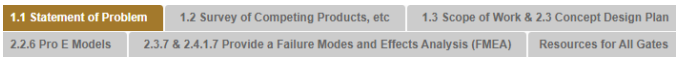


Fig. 2. Partial Screen Capture of the Library Course Site [24]

Second Change, over the summer of 2018 the instructors designed lectures, team assignments, and individual assignments to support student teams in building their gate reports collectively. Shown in Fig. 1 there is a Library Information section [14] which has a link to the Library Course Site [24]. The Library Course Site, shown in Fig. 2., was designed and built to support the SoET capstone courses [15].

The Library Course Site [24] was structured to provide additional guidance to the students throughout all of the gate stages, culminating in the final deliverable of their projects and capstone reports. At the top of Fig. 2 there are tabs titled 1.1 Statement of Problem, 1.2 Survey of Competing Products, etc. These tab names align with the subsection titles of the gate reports [15].

A series of assignments and lectures was created to support student teams in collectively writing their gate reports. Fig. 3

is a screen capture of one lecture for subsection 1.1 Statement of Problem and 1.2 Survey of Competing Products [13].

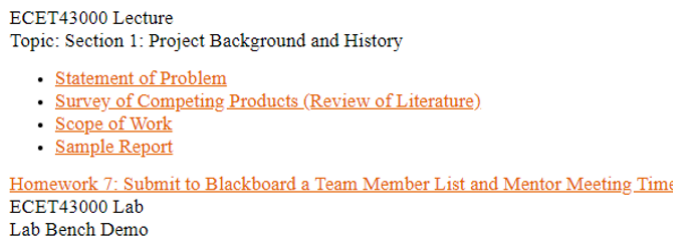


Fig. 3. Screen Capture of a Lecture Set

Third Change, the instructors started each lecture with the Library Course Site tab (see Fig. 2). They presented and demonstrated the resources available to the students. The students were encouraged to use their digital devices and explore these resources during the lectures. Next, the instructors gave the students a required assignment. The student teams would then incorporate the relevant information generated during the assignments into their gate reports.

For example, literature review methods were presented in one of the lectures and the students were given an individual assignment to complete a brief annotated bibliography. The team would then evaluate the information gathered by each individual and synthesize and utilize the relevant sources in their gate reports.

Fourth Change, lectures and assignments were introduced to teach students how to use tools like Zotero [25] and Mendeley [26] to collect, organize, cite and share their research.

Fifth Change, rationale statements were included as part of the project requirements document. Rationale statements were a great tool for reducing ambiguity in a team's requirements document by requiring students to provide a rationale and cite evidence for each requirement. Rationale statements allow teams to simplify their requirements statement and provide instructors, mentors, and clients with additional information about the team's decision-making processes.

Sixth Change, in the week before a gate report was due the teams would start integrating the content from their different assignments [22]. The faculty would assist the teams in synthesizing the content and preparing the gate reports during the lectures, labs and outside of the course [19]. Since the gate reports are cumulative the existing sections are always updated and refined, and new sections are added with each gate. This has turned into a very useful iterative process that has greatly improved the coherence of the reports [14], [19].

More on coherence, the writing of the first gate reports generally does not flow smoothly, which is evident in the assessment of the document organization. There seem to be two major reasons for the lack of coherence. First, the teams have superficial knowledge about their projects and their initial writing reflects the collective lack of project understanding. Second, different students are writing the various report sections and pasting their content together at the last minute. They are not doing a final review and edit to make sure the report is consistent and coherent before they submit their Gate 1 reports. However, continual working with the students enhances the writing coherence and improvements in spelling and grammar follow.

## VI. Results

The capstone reports written by the student teams are submitted once every five weeks and assessed by their academic mentors. Again, the academic mentors are faculty members in the SoET who are responsible for meeting with their teams weekly and grading/assessing their teams' capstone reports for each gate. The number of academic mentors varies between 15-23 per year, depending on the number of capstone projects. Table III presents the rubric criteria the academic mentors use to assess their team reports for each gate. Table III shows the rubric criteria that are the same for all gates and the rubric criteria that tailored to specific gates. These rubric criteria were agreed upon by the SoET Department and are used to assess learning outcomes and for ABET.

TABLE III
GATES 1-6 CAPSTONE REPORT RUBRIC CRITERIA

| | | | | |
|---|---|---|---|---|
| **Same Rubric Criteria** | | | | |
| Gate 1 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | |
| Gate 2 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | All sections updated & corrected from Gate 1 |
| Gate 3 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | All sections updated & corrected from Gate 2 |
| Gate 4 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | All sections updated & corrected from Gate 3 |
| Gate 5 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | All sections updated & corrected from Gate 4 |
| Gate 6 | Document organized well, no misspelling, clear sentence structure, etc. | Font size & correct format | Sources are properly identified & cited | All sections updated & corrected from Gate 5 |
| **Tailored Rubric Criteria** | | | | |
| Gate 1 | Design requirements understood by team | Work breakdown structure & milestones | Problem stated & theory understood by team | |
| Gate 2 | Down selection process presented to justify decisions | Work breakdown structure & milestones | Conceptual design steps well thought out | Budget for project with bill of materials |
| Gate 3 | Failure Modes & Effect Analysis | Work breakdown structure & milestones | Conceptual approaches supported by research, etc. | Testing started, data presented, plans developed |
| Gate 4 | Design challenges of selected design understood | Work breakdown structure & milestones | System configuration & interconnects defined | Testing critical performance parameters is complete |
| Gate | Failure Modes & | Work | Data | Testing is |

| | | | | |
|---|---|---|---|---|
| 5 | Effect Analysis | breakdown structure & milestones | collected & organized to assess quality of design | complete & verifies requirements |
| Gate 6 | Experiments on the final prototype verify final design | Work breakdown structure & milestones | | Data evaluation is clear & understood by the team |

The capstone report rating scales is as follows:
5 report is exceeding expectations
4 report is meeting expectations
3 report is lacking in some sections
2 report is lacking in most sections
1 report is lacking in all sections

### A. Data Sources

The data for this study are the academic mentors' assessments of their team's gate reports. Overall, there are six gates of data. The authors only include data from the end of the first and second semesters, Gates 3 and 6 respectively, for the academic years of 2016-17 through 2019-20.

### B. Descriptive Statistics

Fig. 4 and Table IV show the results of a descriptive statistics analysis of the assessment data. This analysis was performed to determine the basic features of the data and to begin the process of understanding and describing the structure of the data.

Fig. 4 and Table IV show a change in the interquartile range between Gates 3 and 6 for each year except the 18-19 academic year. In addition, Fig. 4 and Table IV show a noticeable change in the interquartile range of Gates 3 and 6 in the 19-20 academic year when compared to the three previous years.

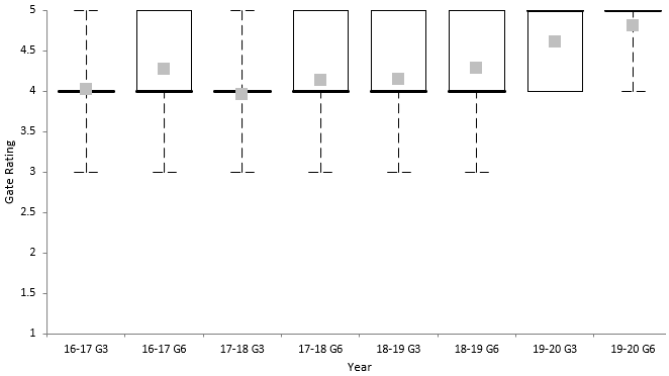


Fig. 4. Report Ratings for Gates 3 and 6 from years 16-17 to 19-20. Median Values are Black Lines, 1st to 3rd Quartiles are Boxes, and Mean Values are Gray Squares

TABLE IV
DESCRIPTIVE STATISTICS GATES 3 AND 6, 2016-17 - 19-20

| Year | N | Mean | 95% CI | | SE | SD |
|---|---|---|---|---|---|---|
| 16-17 G3 | 768 | 4.0 | 4.0 | to 4.1 | 0.02 | 0.6 |
| 16-17 G6 | 757 | 4.3 | 4.2 | to 4.3 | 0.03 | 0.7 |
| 17-18 G3 | 768 | 4.0 | 3.9 | to 4.0 | 0.03 | 0.7 |
| 17-18 G6 | 768 | 4.1 | 4.1 | to 4.2 | 0.02 | 0.6 |
| 18-19 G3 | 672 | 4.1 | 4.1 | to 4.2 | 0.03 | 0.7 |
| 18-19 G6 | 768 | 4.3 | 4.2 | to 4.3 | 0.03 | 0.7 |
| 19-20 G3 | 672 | 4.6 | 4.6 | to 4.7 | 0.02 | 0.6 |
| 19-20 G6 | 704 | 4.8 | 4.8 | to 4.8 | 0.02 | 0.4 |

| Year | Min | 1st | Median | 95% CI | | 3rd | Max |
|---|---|---|---|---|---|---|---|
| 16-17 G3 | 2 | 4.0 | 4.0 | 4.0 | to 4.0 | 4.0 | 5 |
| 16-17 G6 | 1 | 4.0 | 4.0 | 4.0 | to 4.0 | 5.0 | 5 |
| 17-18 G3 | 1 | 4.0 | 4.0 | 4.0 | to 4.0 | 4.0 | 5 |
| 17-18 G6 | 2 | 4.0 | 4.0 | 4.0 | to 4.0 | 5.0 | 5 |
| 18-19 G3 | 3 | 4.0 | 4.0 | 4.0 | to 4.0 | 5.0 | 5 |
| 18-19 G6 | 2 | 4.0 | 4.0 | 4.0 | to 4.0 | 5.0 | 5 |
| 19-20 G3 | 3 | 4.0 | 5.0 | 5.0 | to 5.0 | 5.0 | 5 |
| 19-20 G6 | 3 | 5.0 | 5.0 | 5.0 | to 5.0 | 5.0 | 5 |

### C. Inferential Statistics

Table V is an ANOVA analysis of the difference in mean ratings between Gates 3 and 6 for the four years of assessment data. This analysis shows that there were statistically significant differences, at the 5% level, between the mean ratings among the four years.

Table VI shows a Fisher's LSD analysis of the difference in mean ratings between Gates 3 and 6 for the four years of assessment data. This analysis was performed on all gate pairs and most of the Gate 3 and Gate 6 pairs were statistically different at the 5% level. The only exceptions were gate pairs (18-19G3, 17-18G6) and (18-19G6, 16-17G6), which were not statistically different at the 5% level.

TABLE V
ANOVA BETWEEN GATE 3 AND GATE 6

| Source | SS | DF | MS | F | p-value |
|---|---|---|---|---|---|
| Between Groups | 427.8 | 7 | 61.1 | 148.12 | <0.0001* |
| Within Groups | 2421.4 | 5869 | 0.4 | | |
| Total | 2849.2 | 5876 | 0.5 | | |

*Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.
**Do not reject the null hypothesis at the 5% significance level.

TABLE VI
FISHER'S LSD BETWEEN GATE 3 AND GATE 6

| Contrast | Diff. | 95% CI | | SE | p-value |
|---|---|---|---|---|---|
| 16-17G3 - 17-18G3 | 0.1 | 0.0 | to 0.1 | 0.03 | 0.0471* |
| 16-17G6 - 16-17G3 | 0.2 | 0.2 | to 0.3 | 0.03 | <0.0001* |
| 16-17G6 - 17-18G3 | 0.3 | 0.2 | to 0.4 | 0.03 | <0.0001* |
| 16-17G6 - 17-18G6 | 0.1 | 0.1 | to 0.2 | 0.03 | <0.0001* |
| 16-17G6 - 18-19G3 | 0.1 | 0.0 | to 0.2 | 0.03 | 0.0008* |
| 17-18G6 - 16-17G3 | 0.1 | 0.0 | to 0.2 | 0.03 | <0.0001* |
| 17-18G6 - 17-18G3 | 0.2 | 0.1 | to 0.2 | 0.03 | <0.0001* |
| 18-19G3 - 16-17G3 | 0.1 | 0.1 | to 0.2 | 0.03 | 0.0001* |
| 18-19G3 - 17-18G3 | 0.2 | 0.1 | to 0.3 | 0.03 | <0.0001* |
| *18-19G3 - 17-18G6* | *0.0* | *0.0* | *to 0.1* | *0.03* | *0.5575*** |
| 18-19G6 - 16-17G3 | 0.3 | 0.2 | to 0.3 | 0.03 | <0.0001* |
| *18-19G6 - 16-17G6* | *0.0* | *0.0* | *to 0.1* | *0.03* | *0.5499*** |
| 18-19G6 - 17-18G3 | 0.3 | 0.3 | to 0.4 | 0.03 | <0.0001* |
| 18-19G6 - 17-18G6 | 0.2 | 0.1 | to 0.2 | 0.03 | <0.0001* |
| 18-19G6 - 18-19G3 | 0.1 | 0.1 | to 0.2 | 0.03 | <0.0001* |
| 19-20G3 - 16-17G3 | 0.6 | 0.5 | to 0.7 | 0.03 | <0.0001* |
| 19-20G3 - 16-17G6 | 0.3 | 0.3 | to 0.4 | 0.03 | <0.0001* |
| 19-20G3 - 17-18G3 | 0.7 | 0.6 | to 0.7 | 0.03 | <0.0001* |
| 19-20G3 - 17-18G6 | 0.5 | 0.4 | to 0.5 | 0.03 | <0.0001* |
| 19-20G3 - 18-19G3 | 0.5 | 0.4 | to 0.5 | 0.04 | <0.0001* |
| 19-20G3 - 18-19G6 | 0.3 | 0.3 | to 0.4 | 0.03 | <0.0001* |
| 19-20G6 - 16-17G3 | 0.8 | 0.7 | to 0.9 | 0.03 | <0.0001* |
| 19-20G6 - 16-17G6 | 0.5 | 0.5 | to 0.6 | 0.03 | <0.0001* |
| 19-20G6 - 17-18G3 | 0.8 | 0.8 | to 0.9 | 0.03 | <0.0001* |
| 19-20G6 - 17-18G6 | 0.7 | 0.6 | to 0.7 | 0.03 | <0.0001* |
| 19-20G6 - 18-19G3 | 0.7 | 0.6 | to 0.7 | 0.03 | <0.0001* |
| 19-20G6 - 18-19G6 | 0.5 | 0.5 | to 0.6 | 0.03 | <0.0001* |
| 19-20G6 - 19-20G3 | 0.2 | 0.1 | to 0.3 | 0.03 | <0.0001* |

*Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.
**Do not reject the null hypothesis at the 5% significance level.

Table VII details the ANOVA analysis of the difference in mean ratings for Gates 3 and 6 across four years of assessment data. This analysis shows that there were statistically significant differences, at the 5% level, between the mean ratings across all four years.

TABLE VII
ANOVA GATE 3 ACROSS FOUR YEARS AND GATE 6 ACROSS FOUR YEARS

GATE 3

| Source | SS | DF | MS | F | p-value |
|---|---|---|---|---|---|
| Between Groups | 183.4 | 3 | 61.1 | 142.11 | <0.0001* |
| Within Groups | 1237.2 | 2876 | 0.4 | | |
| Total | 1420.6 | 2879 | 0.5 | | |

GATE 6

| Source | SS | DF | MS | F | p-value |
|---|---|---|---|---|---|
| Between Groups | 190.6 | 3 | 63.5 | 160.62 | <0.0001* |
| Within Groups | 1184.2 | 2993 | 0.4 | | |
| Total | 1374.8 | 2996 | 0.5 | | |

*Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.

Table VII also details the ANOVA analysis of the difference in mean ratings between Gates 3 for the four years of assessment data. This analysis shows that there were statistically significant differences, at the 5% level, between the mean ratings across all four years.

Table VIII shows a Fisher's LSD analysis of the difference in mean ratings between Gates 3 for the four years of assessment data. This analysis showed all Gate 3 pairs were statistically different at the 5% level, except for one Gate 3 pair (16-17, 17-18).

For Gate 6, Table VII shares the ANOVA analysis of the difference in mean ratings between Gates 6 for the four years of assessment data. This analysis shows that there were statistically significant differences, at the 5% level, between the mean ratings across the four years.

Table VIII includes a Fisher's LSD analysis of the difference in mean ratings between Gates 6 for the four years of assessment data. This analysis shows all Gate 6 pairs were statistically different at the 5% level, except for one Gate 6 pair (18-19, 16-17).

TABLE VIII
FISHER'S LSD ANALYSIS BETWEEN GATE 3 ACROSS FOUR YEARS AND BETWEEN GATE 6 ACROSS FOUR YEARS

GATE 3

| Contrast | Mean difference | Individual 95% CI | | SE | p-value |
|---|---|---|---|---|---|
| 19-20 - 17-18 | 0.7 | 0.6 | to 0.7 | 0.03 | <0.0001* |
| 19-20 - 16-17 | 0.6 | 0.5 | to 0.7 | 0.03 | <0.0001* |
| 19-20 - 18-19 | 0.5 | 0.4 | to 0.5 | 0.04 | <0.0001* |
| 18-19 - 17-18 | 0.2 | 0.1 | to 0.3 | 0.03 | <0.0001* |
| 18-19 - 16-17 | 0.1 | 0.1 | to 0.2 | 0.03 | 0.0002* |
| 16-17 - 17-18 | 0.1 | 0.0 | to 0.1 | 0.03 | 0.0519** |

GATE 6

| Contrast | Mean difference | Individual 95% CI | | SE | p-value |
|---|---|---|---|---|---|
| 19-20 - 17-18 | 0.7 | 0.6 | to 0.7 | 0.03 | <0.0001* |
| 19-20 - 16-17 | 0.5 | 0.5 | to 0.6 | 0.03 | <0.0001* |
| 19-20 - 18-19 | 0.5 | 0.5 | to 0.6 | 0.03 | <0.0001* |
| 18-19 - 17-18 | 0.2 | 0.1 | to 0.2 | 0.03 | <0.0001* |
| 18-19 - 16-17 | 0.0 | 0.0 | to 0.1 | 0.03 | 0.5415** |
| 16-17 - 17-18 | 0.1 | 0.1 | to 0.2 | 0.03 | <0.0001* |

*Reject the null hypothesis in favor of the alternative hypothesis at the 5% significance level.
**Do not reject the null hypothesis at the 5% significance level.

## VII. DISCUSSION

During an internal ABET review in 2016-17, an SoET faculty committee noted the writing quality of the capstone reports seemed to show little improvement from the first course to the second course. The committee recommended that the instructors collect data for one additional year, see Table II. The next year, the faculty committee reviewed the descriptive statistics (see Fig. 4 and Table IV) and observed there was no change in the mean values from 2016-17 G3 to 2017-18 G3 for Gate 3 and a decrease in the mean from 2016-17 G6 to 2017-18 G6 for Gate 6. Due to this issue, the committee decided changes in the capstone courses were necessary to improve writing quality.

Some authors had experience using Calibrated Peer Review (CPR) and learned engaging students in multi-staged-structured writing activities did improve writing and understanding of the topic being presented [22], [27]. In addition, other researchers using CPR indicated students improved their recognition of rhetorical features when the students reviewed writing samples during a calibration phase [28].

Building off experiences with CPR, additional methods for improving writing quality were researched in the summer of 2017-18. Six different interventions where developed and implemented in academic years 2018-19 and 2019-20, see Table II.

In 2018-19 the first group of interventions, changes 1-3, were implemented. Table IV shows the mean values for Gates 3 and 6 in 2018-19 exceeded or equaled the best mean values when compared to the past two years. In addition, Table IV shows the interquartile range for Gate 3 improved.

In 2019-20 the second group of interventions, changes 4-6, were implemented. Table IV shows the mean values for Gates 3 and 6 in 2019-20 exceeded the best mean values when compared to the past three years. In addition, Table IV shows the interquartile range for Gate 6 improved.

ANOVA and Fisher's LSD analyses provided additional support that both sets of interventions caused a positive and significant improvement in the writing quality of the capstone courses. However, based on personal experience the fourth change was probably the keystone which locked all six changes together. The iterative writing process of writing and rewriting the report coupled with meeting frequently with academic mentors, proved to be a powerful combination for improving the writing prowess of the students [27], [29].

## VIII. CONCLUSION

The SoET faculty committee asked the capstone instructors to research and implement instructional interventions which could improve the quality of the student reports. This study found the instructional interventions, summarized in Table IX, were effective in significantly improving the ratings of capstone reports. However, what the data does not show is how the student-faculty interactions evolved.

The changes shown in Table IX enabled the faculty to expand their role from grading and scoring to include knowledge curation [30]. Faculty used the changes as a new set of tools to add value to their teams' projects, which increased student productivity. There are no direct measures of

the increase in student productivity other than peer-to-peer and self-rating received from CATME [31]. The CATME peer-to-peer and self-rating, over the same time-period, do show the same pattern of improvement for team performance as this study is reporting for improvements in writing performance.

TABLE IX
SUMMARY OF INSTRUCTIONAL INTERVENTIONS

| | |
|---|---|
| First Change | sample reports, report outlines, and rubrics for each gate were created |
| Second Change | lectures, team assignments, and individual assignments were designed to build the gate reports collectively |
| Third Change | lectures started with the Library Course Site to demonstrate and review the resources available to the students |
| Fourth Change | lectures and assignments were introduced to teach students how to use tools like Zotero, Mendeley, etc. |
| Fifth Change | rationale statements were included as part of the project requirements document |
| Sixth Change | in the week before a gate report was due the faculty would work with the teams to curate their reports |

Finally, there are some limitations to this study. First, the absence of a control group could limit the impact of the instructional interventions since the instructors could not control other experiences the students had during the capstone courses. Second, there could be differences in the way each faculty mentor rated the reports. However, there were meetings before the start of the academic year with the faculty mentors to present the schedule, rubrics, sample reports, and other instructional materials. Also, follow-up meetings occurred with the academic mentors before each Gate to reinforce the schedule, rubrics, sample reports, and other instructional materials.

## REFERENCES


[1] E. De S. Zancul *et al.*, "An Empirical Study on Design-Based vs. Traditional Approaches in Capstone Courses in Engineering Education," *Int. J. Eng. Educ.*, vol. 33, no. 5, pp. 1543–1560, 2017.

[2] W. W. Powell and K. Snellman, "The Knowledge Economy," *Annu. Rev. Sociol.*, vol. 30, no. 1, pp. 199–220, 2004.

[3] P. A. Koen and K. Pankaj, "ABET 2000: What are the Most Important Criteria to the Supervisors of New Engineering Undergraduates?," *ASEE Annu. Conf.*, 1999.

[4] J. D. Lang, S. Cruse, F. D. McVey, and J. McMasters, "Industry Expectations of New Engineers: A Survey to Assist Curriculum Designers," *J. Eng. Educ.*, 1999.

[5] ABET, "Criteria for Accrediting Engineering Technology Programs, 2018 – 2019, "Criteria for Accrediting Engineering Programs: General Criterion 3. Student Outcomes: Outcome (d)," [Online]. Accessed Feb. 08, 2021. Available: https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2018-2019/.

[6] J. Emig, S. C. Composition, N. May, and J. Emig, "Writing as a Mode of Learning," *Coll. Compos. Commun.*, vol. 28, no. 2, pp. 122–128, 1977.

[7] P. A. Carlson and F. C. Berry, "Calibrated Peer Review™ and assessing learning outcomes," *Proc. - Front. Educ. Conf. FIE*, 2003.

[8] W. T. Selmier and C. H. Oh, "International business complexity and the internationalization of languages," *Bus. Horiz.*, vol. 55, no. 2, pp. 189–200, 2012.

[9] A. L. Whiteside, "The skills that technical communicators need: An investigation of technical communication graduates, managers, and curricula," *J. Tech. Writ. Commun.*, vol. 33, no. 4, pp. 303–318, 2003.

[10] E. Ramadi, S. Ramadi, and K. Nasr, "Engineering graduates' skill sets in the MENA region: a gap analysis of industry expectations and satisfaction," *Eur. J. Eng. Educ.*, vol. 41, no. 1, pp. 34–52, 2016.

[11] B. Kotzee and R. Johnston, "'Can't String a Sentence Together'? UK Employers' Views of Graduates' Writing Skills," *Ind. High. Educ.*, vol. 25, no. 1, pp. 45–52, 2011.

[12] P. M. Berthouex, "Honing the Writing Skills of Engineers," *J. Prof. Issues Eng. Educ. Pract.*, vol. 122, no. 3, pp. 107–110, 1996.

[13] P. A. Carlson, F. C. Berry, and D. Voltmer, "Using calibrated peer review™ to mediate writing and to assess instructional outcomes," *ASEE Annu. Conf.*, 2003.

[14] P. A. Carlson and F. C. Berry, "Calibrated Peer Review: A tool for assessing the process as well as the product in learning outcomes," *ASEE Annu. Conf.*, 2005.

[15] P. Carlson and F. Berry, "Using writing to assess learning in engineering design: Quantitative approaches," *ASEE Annu. Conf.*, 2008.

[16] J. H. Wandersee, R. M. Clary, and S. M. Guzman, "A Writing Template, for Probing Students' Botanical Sense of Place," *Am. Biol. Teach.*, vol. 68, no. 7, pp. 419–422, 2006.

[17] E. I. Eger, "A template for writing a scientific paper," *Anesth. Analg.*, vol. 70, no. 1, pp. 91–96, 1990.

[18] L. Ahmed, N. Quddus, P. Kannan, S. C. Peres, and M. S. Mannan, "Development of a procedure writers' guide framework: Integrating the procedure life cycle and reflecting on current industry practices," *Int. J. Ind. Ergon.*, vol. 76, no. Oct 2018, 2020.

[19] I. Vardi, "The impact of iterative writing and feedback on the characteristics of tertiary students' written texts," *Teach. High. Educ.*, vol. 17, no. 2, pp. 167–179, 2012.

[20] C. W. Ferguson and P. A. Sanger, "Facilitating student professional readiness through industry sponsored senior capstone projects," *ASEE Annu. Conf.*, 2011.

[21] B. Yang, P. A. Sanger, and P. Gardner, "Teaching and Learning of Project Management for Engineering and Technology Capstone Research Projects," *ASEE Annu. Conf.*, 2010.

[22] P. A. Carlson and F. C. Berry, "Using computer-mediated peer review in an engineering design course," *IEEE Trans. Prof. Commun.*, vol. 51, no. 3, pp. 264–279, 2008.

[23] S. Pella, "A Situative Perspective on Developing Writing Pedagogy in a Teacher Professional Learning Community," *Teach. Educ. Q.*, vol. 38, no. 1, pp. 107–125, 2011.

[24] M. L. Phillips and S. E. Huber, "Capstone Research Guide," *Libraries and School of Information Studies, Purdue University*, [Online]. Accessed Jun. 01, 2020. Available:

https://guides.lib.purdue.edu/metecetcapstone.
[25] "Your Personal Research Assistant," *Zotero*, [Online]. Accessed Jun. 01, 2020. Available: https://www.zotero.org/.
[26] "Getting started with Mendelay Desktop," *Mendeley*, [Online]. Accessed Feb. 08, 2021. Available: https://www.mendeley.com/guides/desktop.
[27] F. C. Berry and P. A. Carlson, "Assessing engineering design experiences using calibrated peer review™," *Int. J. Eng. Educ.*, vol. 26, no. 6, 2010.
[28] F. B. Enders, S. Jenkins, and V. Hoverman, "Calibrated peer review for interpreting linear regression parameters: Results from a graduate course," *J. Stat. Educ.*, vol. 18, no. 2, pp. 1–27, 2010.
[29] J. Craig, N. Lerner, and M. Poe, "Innovation Across the Curriculum: Three Case Studies in Teaching Science and Engineering Communication," *IEEE Trans. Prof. Commun.*, vol. 51, no. 3, pp. 280–301, 2008.
[30] L. Kathrein, K. Meixner, D. Winkler, A. Lüder, and S. Biffl, "Efficient Production System Resource Exploration Considering Product/ion Requirements," *IEEE Int. Conf. Emerg. Technol. Fact. Autom. ETFA*, vol. 2019-Sep., pp. 665–672, 2019.
[31] D. M. Ferguson, M. W. Ohland, C. Lally, H. I. Somnooma, and Y. Cao, "Evaluating the effect of different teamwork training interventions on the quality of peer evaluations," *Proc. - Front. Educ. Conf. FIE*, vol. 2018-Oct., pp. 19–23, 2019.

**Frederick C. Berry** is a Professor in the School of Engineering Technology at Purdue University, West Lafayette. Professor Berry received the B.S.E.E., M.S.E.E. and D.Eng. degrees from Louisiana Tech University in 1981, 1983, and 1988 respectfully. He works on the capstone education for the SoET.

**Margaret L. Phillips** is an Assistant Professor in the Purdue University Libraries and School of Information Studies at Purdue University, West Lafayette. Professor Phillips received a B.S. in Economics and a B.S. in Psychology from Purdue University, West Lafayette, 1999; and a Masters in Library and Information Science (MLIS) from Indiana University, Indianapolis, 2010.

**James Condron** is an Assistant Professor or Practice in the School of Engineering Technology at Purdue University, West Lafayette. Professor Condron received his B.Sc. (engineering), and Ph.D. degrees from Dublin Institute of Technology in 1997 and 2004. He works on the capstone education for the SoET.

**Phillip A. Sanger** is a Professor Emeritus in the School of Engineering Technology at Purdue University, West Lafayette. Professor Sanger received his B.A. Physics Saint Louis University 1970; D.E.A. Physique des Réacteurs, Institut National des Sciences et Techniques Nucléaires, Saclay, France 1971; M.S. Nuclear Engineering, University of Wisconsin, Madison, 1973; Ph.D. Nuclear Engineering, University of Wisconsin, Madison, 1977.