AC 2009-2450: PAIRED-COURSE AND PEER-TUTORING IMPACT ON CRITICAL-THINKING AND WRITING SKILLS OF FIRST-YEAR ENGINEERING STUDENTS

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Paired Course and Peer Tutoring Impact on Critical Thinking and Writing Skills of First-year Engineering Students

Abstract

For the engineering educator, implementing and integrating the professional, institutional, and pedagogical goals and expectations into a course is complex and becomes much more so when developing and implementing curricula for first-year students. These students are not always comfortable with problem posing situations, and as the tasks increase in complexity, so does the difficulty in thinking and writing about those tasks. John Dewey’s claim still holds today, "much of present education fails because it neglects this fundamental principle of the school as a form of community life." The establishment of "learning communities," has been one of the most important educational reforms to come about based on Dewey’s challenges.

This study integrates the notion of a learning community with problem-posing by using a model of critical thinking (Foundation for Critical Thinking) to structure writing assignments requiring students to report about in-class, team-based activities and apply them to engineering concepts. This study was conducted to determine critical thinking and writing skills of freshman engineering students as measured by assessing assignments written in response to cooperative in-class activities, engineering and writing attitude surveys and critical thinking disposition surveys, and academic performance. Students in three sections of an Introduction to Engineering course participated in the study (n=68) in 2007. Two sections of the course were paired with two sections of English composition, and one section was not paired. The study also included several students in a female only composition class. Attitude surveys correlated with these scores showing that attitudes toward writing and engineering were a factor. Results of the 2007 study show that mean scores of paired students were generally higher in both writing and critical thinking. Paired course students also showed significant positive changes in viewing themselves as writers.

For the fall of 2008, the study has been expanded to look at the impact of writing fellows (WF). Four undergraduate engineering students and one undergraduate English student were chosen as WFs. The students in the class wrote reports based on design activities. For each report, the students were required to turn in a draft. The reports were distributed to the Writing Fellows who then read the reports; filled out a checklist (based on the requirements of the assignment); and wrote a cover letter, which addressed the strengths and weaknesses of the individual student’s report. The Writing Fellow and student then met for a 30 minutes face-to-face tutorial to discuss the Writing Fellow’s comments on the paper. The students then revised the reports and turned in the final draft to the Engineering 1111 instructor, who then graded the reports.

Background

The impetus for this research study came from the co-presenters’ 1) local interest in writing and critical thinking general education assessment work in progress on the Oklahoma State University Campus, and 2) larger concerns expressed in such studies as Rising Above the Gathering Storm\(^1\), The Engineer of 2020\(^2\), and ABET accreditation criteria that focus on ‘professional skills’. All of these documents indicate a need to study and incorporate such ‘process’ or ‘awareness’\(^3\) skills into engineering education in order to produce engineers who will be able to compete globally in the coming decades.
Research in engineering education in recent years shows that studying writing, thinking and learning communities in various combinations has become an important trend. Studies have been done on writing across the curriculum and writing in disciplines including the role of Writing Centers. Several universities are exploring ways of knowing that engineers engage in as well as ways of learning, which help us think about processing and its relationship to critical thinking. There have been studies done in writing and critical thinking and the close pairing of courses in learning communities. The work that has been done in the engineering context with writing has included current theories of writing to learn, as well as the importance of informal writing such as journal writing. In addition, studies of various forms of writing instruction have informed the research as well as grading and assessment practices of writing. In this paper, we are extending the research to include all four elements: writing, critical thinking, learning communities and engineering. The study presented here focuses on the skills of writing and critical thinking of first-year engineering students, and whether participating in a learning community with a writing course has any effect on these skills.

Learning Communities

Learning communities have been defined variously, most notably by the pioneers in the field, Smith et al. as “a variety of curricular approaches that intentionally link or cluster two or more courses, often around a disciplinary theme or problem, and enroll a common cohort of students. They represent an intentional restructuring of students’ time, credit and learning experiences to build community, enhance learning and foster connections among students, faculty and disciplines.” Studies show that there are various benefits of learning communities. Stassen found that linked course learning communities were effective across campus to keep at-risk students in school and for the quality of social and academic integration. Rutar and Mason found that pairings of college engineering students with high school technology students both facilitated understanding and confidence in the technical aspects of design for the college students and increased interest in engineering design from the high school students. First year programs have been a very amenable place for development of learning communities as they are seen as “a promising strategy for creating knowable communities that make a new place, and especially a large place, more welcoming and more navigable.” Many institutions across the country have learning communities of various sorts for first year students. A common course for pairing in the first year curriculum is a disciplinary course with a first year writing course. More specific to the linking of writing and disciplinary courses, studies such as Collins’, which linked Composition/Religion courses, found that increase in knowledge, intertextuality and reasoning skills resulted, and Lengsfeld et al.’s Writing/Engineering pairings demonstrate that while linking courses with writing did not increase work load, they did contribute to retention in their program. Zawacki and Williams report on writing within interdisciplinary learning communities at George Mason University and report on the benefits of this endeavor: “WAC [Writing Across the Curriculum] may be most fully realized within the LC [Learning Community] movement, which shares its values of inclusiveness, conversation, and collaboration, and the belief that writing should be a central mode of learning in a learning-centered pedagogy.” This work needs to be extended to examining the assessment of the writing to see if there is evidence for writing improvement in these situations. This study looks at the elements of a writing and learning community through the use of assessment rubrics.

Critical Thinking

After considering several approaches to critical thinking, the researchers decided to test the Foundation of Critical Thinking Model created by Richard Paul. According to this model, “Critical thinking is the
intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief and action...It entails the examination of those structures or elements of thought implicit in all reasoning: purpose, problem, or question-at-issue; assumptions; concepts; empirical grounding; reasoning leading to conclusions; implications and consequences; objections from alternative viewpoints; and frame of reference. The Paul model includes three major components of critical thinking, which are in turn divided further: Intellectual standards that include clarity, accuracy, relevance, logic, breadth, precision, significance, completeness, fairness, depth; The elements of thought that include purposes, questions, points of view, information, inferences, concepts, implications, and assumptions; and Intellectual traits including humility, autonomy, integrity, courage, perseverance, confidence in reason, empathy and fairmindedness. The elements of thought are the focus for the purposes of this study.

Writing and Critical Thinking

Writing across the curriculum initiatives generally embrace the assumption of writing as a mode of learning; that is, thinking and writing go together. Bean proposes that the connection between writing and critical thinking is that “writing is both a process of doing critical thinking and a product communicating the results of critical thinking.” As such, critical thinking and writing go hand in hand. Students are not always comfortable with problem-posing situations, and as the tasks increase in complexity, so does the difficulty in thinking and writing about those tasks. Bean suggests that teaching the process, which involves engaging, developing, complicating and clarifying ideas through writing, is slow and developmental. In order to help students through this process, Bean also suggests that the teaching should create “cognitive dissonance” or using “decentering” exercises, exercises that challenge students to look at other perspectives. Thus, critical thinking, writing and pedagogy work together to develop both writing and critical thinking skills. There has been some question about the relationship between writing and critical thinking; for example, Condon and Kelly-Riley found an inverse relationship between writing and critical thinking—the higher the writing score, the lower the critical thinking and vice versa, they also recognize the complexity of the two phenomena, “Both constructs—writing and critical thinking—are abstract, complex, socially constructed, contextually situated terms, and this presents problems in analyzing our conflicting results.” This study seeks to add to the research on critical thinking and writing.

Research Questions

In order to test the effect of learning communities on writing and critical thinking skills for first year engineering students we asked the following questions:

- Will students’ critical writing and thinking skills be enhanced as measured by rubrics developed at Oklahoma State University?
- Will students’ perceptions of their writing abilities be improved as measured by attitude surveys such as the Pittsburgh Freshman Attitude Survey provide insight into whether engineering attitude affects these other measures?
- What effect do writing fellow have on the students writing and critical thinking skills?

These issues are important for discovering the importance of writing, critical thinking and linked courses for the learning processes of engineering students.
Methods

To determine whether participation in learning communities affected first-year engineering students writing and critical thinking skills, three sections of Engineering 1111, Introduction to Engineering, a one-credit course, were identified. Each section contained a different subgroup of engineering students: women, entrepreneurs, chemical. Two sections, the women and entrepreneurs, were paired with English Composition I, and the chemical section was not paired (although there were students in the section who were taking disparate sections of composition). Students wrote assignments in their Introduction to Engineering course, which were evaluated for writing and critical thinking skills. In addition, students completed attitude surveys.

Participants

The study involved three sections of Engineering 1111, an Introduction to Engineering course—two sections paired with English composition classes and one non-paired and several students in a female only composition class (affecting a total of 68 students). The sections had specific cohorts: one paired section was all women, who were also part of a living community, and the other paired section consisted of students interested in the Entrepreneurial Engineering program. The students in the non-paired section were chemical engineering students. Various factors affected the enrollments in the sections resulting in a rather more complicated distribution of pairings. Table 1 shows the learning community cohort distribution.

| TABLE 1 COHORTS OF PAIRED AND NON-PAIRED SECTIONS |
|-----------------------------------|---------|--------|--------|
|                                  | Women   | Entrepreneur | Chemical |
| Paired                           | 12      | 15       | 0       |
| Non-paired English                | 7       | 0        | 0       |
| Non-paired Engineer               | 8       | 7        | 19      |
| Total                            | 27      | 22       | 19      |

These distributions resulted in six distinct cohorts. The results of the study will be reported in terms of cohort and paired and non-paired course affiliation.

Procedures

The composition instructors and researchers met and discussed that the content of the composition courses could be more engineering focused, but there were no formal constraints on the instructors. Instructors and students were provided with the pamphlet, *Engineering Reasoning*, published by the Foundation for Critical Thinking. The instructor of the engineering course discussed the pamphlet and had students do an exercise from the pamphlet, which required them to apply the critical thinking elements to a design before having them do the main writing assignment.

The writing assessed for this study was done in the Introduction to Engineering course. In week seven of the semester, the students were required to write reports resulting from an in-class group design activity—The Airplane Design Challenge, which required students to build airplanes from candy and other ordinary materials to help them understand the concepts of process and product design and the relationship between the two. The writing assignment was designed using an introduction, methods,
results, conclusions and implication organization with the eight elements of critical thinking from the Paul model in mind:

- **Purpose**—What is the overall purpose?
- **Problem**—What is the question at hand?
- **Point of view**—What perspective are you taking? Have you considered other point of view?
- **Assumptions**—What assumptions do you bring?
- **Implications**—What is your reasoning leading? What are the consequences of this line of thinking?
- **Information**—What data and evidence are you using?
- **Inferences**—What are the interpretations you use to make conclusions?
- **Concepts**—What concepts and theories are you using? Have you considered other theories?

Figure 1 contains the portions of the writing assignment that were written to specifically address the elements.

### The Writing Rubric uses the following four criteria:
1. **Content**
2. **Organization**
3. **Style and Mechanics**
4. **Documentation**

### The Critical Thinking Rubric uses the following seven characteristics:
1 – 4: **Essential Characteristics**
1. Identification and/or summary of the problem/question at issue
2. Presentation of the **STUDENT’S OWN perspective and position** as it is important to the analysis of the issue.
3. Assessment and appropriate use of supporting data/evidence.
4. Discussion of conclusions, implications and consequences.
5-7: **Optional Characteristics (evaluate where appropriate)**
5. Consideration of OTHER salient perspectives and positions that are important to the analysis of the issue.
6. Assessment of the key assumptions and the validity of the supporting/background information.
7. Consideration of the influence of the context on the issue (including where appropriate, cultural, social, economic, technological, ethical, political, or personal context)

*The papers are ranked on a 1 to 5 scale for each with 1=low and 5 = high on each of the criteria. Both rubrics have an Overall category.*

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**FIGURE 1** WRITING ASSIGNMENT FOR PROCESS/PRODUCT DESIGN

The purpose of this paper is for you to consider the differences between product and process design using information and evidence from your reading and your airplane design experience in order to understand the relationship of the two for engineering. (Your paper will consist of the following five sections.)

**Introduction**
Your introduction should give background to the activity (including your definitions of product and process-from your sources) and your point of view about process and product design (the importance of process and product design in Engineering). Your research question is “What is the difference between product and process design?” and your thesis should answer this question.

**Methods**
This part of your paper should describe your group (group name and members), the materials you used, and the steps you went through to design your airplane prototype and the manufacturing method.

**Results**
Describe the results of the product ranking and process evaluation. (What ranking in the two parts of the contest did your plane receive?)

**Conclusions**
This section should discuss the strengths and weaknesses of your product and process, tying that in with your group process. (Did group issues facilitate or hinder your product/process?)

**Implications**
How do the results of your Airplane Design Challenge experiment “What is the difference between product and process design?” help you understand the importance of these concepts for Engineering? (How does one affect the other and vice versa? Why is understanding these two concepts important for engineers?)

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**FIGURE 2** WRITING AND CRITICAL THINKING RUBRIC ITEMS

The reports were evaluated by trained raters using _SU-generated critical thinking and writing rubrics. Figure 2 shows the criteria and characteristics evaluated by the rubrics. In addition to the characteristics, each rubric has an “Overall” score.

The results of these evaluations were analyzed in conjunction with results obtained from surveys: the Pittsburgh Freshman Engineering Attitude Survey (PFEAS-Pittsburgh), and the self-generated Writing Attitudes Survey. The PFEAS is a validated instrument consisting of 50 items designed to determine attitudes toward engineering. The Writing Attitudes survey consisted of two sections: Section A
contains open-ended questions and scaled items. Section B contains scaled items. Figure 3 shows the questions administered on the Writing Attitude Survey. Numbered questions are open-ended and the bulleted items required students to respond to a 1-6 scale with 1 being “poor” and 6 being “excellent.” Paired course students were asked to complete both sections. Non-paired course students were asked to complete only section B.

Writing assignments were rated by trained raters: one chemical engineering graduate assistant, one English graduate assistant and one of the authors. Scores were compiled and compared among cohorts and between paired and non-paired course students. PFEAS and Writing Attitude responses were collated and statistics were performed to determine differences between paired and non-paired course students.

SECTION A

1. Do you feel the writing assignments in Engineering 1111 helped you with your course assignments in English 1113? Why/How?
2. Given the opportunity to do this again, would you enroll in an English composition course that required you to study with students in engineering? Why?
3. By enrolling in Engineering 1111 and English 1113 that allowed you to write about engineering topics, do you feel you have a better understanding of the subject matter? Why/why not?
4. Do you feel you would have learned more in English 1113 if you had not been grouped with other engineering students? Why/why not?
5. How could the course be changed to increase your writing ability?
   - To what extent has participating in the paired courses helped your writing?
   - To what extent has participating in the paired courses helped you understand your engineering course better?

SECTION B

- How would you have rated yourself as a writer before the semester started?
- How would you rate yourself as a writer now?
- How enthusiastic were you toward writing before the semester began?
- How enthusiastic are you toward writing now?
- How comfortable were you with writing before the semester began?
- How comfortable are you with writing now?

FIGURE 3 WRITING ATTITUDE SURVEY QUESTIONS

Results

Written reports of the Airplane Design Activity were assessed using the _SU writing and critical thinking rubrics (interrater reliability was 92% for overall scores and 79% for subscores). Subscore-7 “Consideration of the influence of context on the issue” was the only optional Critical Thinking subscore used. Table 2 shows the means of the rubric scoring results.
TABLE 2 MEANS OF RUBRIC SCORES FOR WRITING AND CRITICAL THINKING NON-PAIRED VS. PAIRED

<table>
<thead>
<tr>
<th>Rubric Category</th>
<th>Non-Paired</th>
<th>Paired</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Writing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>3.11</td>
<td>3.17</td>
</tr>
<tr>
<td>Organization</td>
<td>3.17</td>
<td>3.37</td>
</tr>
<tr>
<td>Style and Mech</td>
<td>3.11</td>
<td>2.98</td>
</tr>
<tr>
<td>Documentation</td>
<td>2.46</td>
<td>2.48</td>
</tr>
<tr>
<td><strong>Critical Thinking</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT1</td>
<td>3.06</td>
<td>3.46</td>
</tr>
<tr>
<td>CT2</td>
<td>2.89</td>
<td>2.85</td>
</tr>
<tr>
<td>CT3</td>
<td>2.96</td>
<td>2.91</td>
</tr>
<tr>
<td>CT4</td>
<td>2.98</td>
<td>3.04</td>
</tr>
<tr>
<td>CT7</td>
<td>2.85</td>
<td>2.70</td>
</tr>
<tr>
<td><strong>CT Overall</strong></td>
<td>3.06</td>
<td>3.02</td>
</tr>
</tbody>
</table>

T-tests showed that there was no significant difference between the groups’ scores. Table 3 shows the mean scores of the rubric ratings by cohort.

TABLE 3 MEANS OF RUBRIC SCORES FOR WRITING AND CRITICAL THINKING BY COHORT

<table>
<thead>
<tr>
<th>Rubric Category</th>
<th>Paired</th>
<th>Non-Paired</th>
<th>Cohort</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W</td>
<td>E</td>
<td>W</td>
</tr>
<tr>
<td><strong>Writing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Content</td>
<td>3.45</td>
<td>2.96</td>
<td>3.14</td>
</tr>
<tr>
<td>Organization</td>
<td>3.40</td>
<td>3.35</td>
<td>3.07</td>
</tr>
<tr>
<td>Style and Mech</td>
<td>3.05</td>
<td>2.92</td>
<td>3.00</td>
</tr>
<tr>
<td>Documentation</td>
<td>2.70</td>
<td>2.31</td>
<td>2.21</td>
</tr>
<tr>
<td>Overall</td>
<td>3.20</td>
<td>2.96</td>
<td>2.93</td>
</tr>
<tr>
<td><strong>Critical Thinking</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-ID of problem</td>
<td>3.65</td>
<td>3.31</td>
<td>3.00</td>
</tr>
<tr>
<td>2-Perspective</td>
<td>3.15</td>
<td>2.62</td>
<td>3.14</td>
</tr>
<tr>
<td>3-Data/evidence</td>
<td>3.05</td>
<td>2.81</td>
<td>2.93</td>
</tr>
<tr>
<td>4-Conclusions</td>
<td>3.10</td>
<td>3.00</td>
<td>3.21</td>
</tr>
<tr>
<td>7-Context</td>
<td>2.80</td>
<td>2.62</td>
<td>2.79</td>
</tr>
<tr>
<td>Overall</td>
<td>3.20</td>
<td>2.88</td>
<td>3.07</td>
</tr>
</tbody>
</table>

*W=Women, E=Engineers, C=Chemical

When compared by cohort, there were no significant differences. However, the non-paired entrepreneur group means were highest in seven of the 11 categories. The paired female students were highest in 4 of the 11 categories.

Results from the Writing Attitude Survey indicated that the paired course students were significantly different in their ratings of themselves as writers vs. non-paired students: the paired students’ view of their writing improved significantly from beginning to end of semester. Table 4 shows the means of the paired and non-paired responses to two items that showed the significance (p<.05).
TABLE 4 MEANS OF PAIRED AND NON-PAIRED RESPONSES ON WRITING ATTITUDE ITEMS

<table>
<thead>
<tr>
<th></th>
<th>P</th>
<th>NP</th>
</tr>
</thead>
<tbody>
<tr>
<td>How would you have rated yourself as a writer before the semester started?</td>
<td>3.38</td>
<td>4.34</td>
</tr>
<tr>
<td>How would you rate yourself as a writer now?</td>
<td>4.42</td>
<td>4.69</td>
</tr>
</tbody>
</table>

The paired course students rated themselves significantly lower at the beginning of the semester than the non-paired (based on a paired t-test p<.05). At the end of the semester, there was no significant difference between the paired and the non-paired in their perceptions. However, the paired students showed a significant change in perception from beginning of semester to end and the non-paired students did not.

The results of the PFEAS showed few significant differences between the paired and the non-paired groups. Items with significant difference between the paired and non-paired students were

- The advantages of studying engineering outweigh the disadvantages (paired was lower).
- My parent(s) are making me study engineering (paired was lower).
- How confident you are of your abilities in the subject or skill: Physics (paired was higher).

These results are puzzling since they were isolated items that seemed to contradict each other. Having said this, the entrepreneurs, both paired and non-paired, were more positive in their PFEAS scores overall. Further analysis will be done to determine importance of the individual items and to determine whether the entrepreneurs continue to score higher.

Writing Fellows

Four undergraduate engineering students and one undergraduate English student were chosen as WFs. There were 74 students enrolled in Engineering 1111, a one-credit introduction to engineering course. The FY students in the class wrote two reports based on design activities: one was written at the beginning of the semester and the other at the end in order to compare scores and the effectiveness of the interventions. For each report, the students were required to turn in a draft. The reports were distributed to the Writing Fellows who then read the reports; filled out a checklist; and wrote a cover letter, which addressed the strengths and weaknesses of the individual student’s report. The Writing Fellow and FY student then met for a 30 minute face-to-face tutorial to discuss the Writing Fellow’s comments on the paper. The FY students revised the reports and turned in the final draft to the Engineering 1111 instructor, who graded the reports.

Preliminary results show that WF experience has an effect on student performance. On the first report of the semester, 69 students (out of 74) turned in the design project report. The overall average grade for the project was 81.8%. For those that met with the WF (N=44), the average was 85.8%, and for those that didn’t (N=25) the average was 74.4%. For the second report of the semester, for those that met with the writing fellow (N=56) the average was 87.2% and for those that didn’t (N=11) the project average was 78.0%. For the students that met twice over the semester (once for each project) with their WF (N=37) the second project score average was 89.4%. For those that only met once (either for the first project or the second project) with their WF (N=26) the second project score was 80.8% average. Interestingly, for the 4 that never met with their WF, their second project score was 81.6%, but still below those that met twice!

First report subsections showed differences as well as shown in Table 5 below.
<table>
<thead>
<tr>
<th>Report Subsection</th>
<th>All</th>
<th>WF</th>
<th>No WF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>69.0</td>
<td>74.1</td>
<td>60</td>
</tr>
<tr>
<td>Methods</td>
<td>87.8</td>
<td>90.5</td>
<td>83.2</td>
</tr>
<tr>
<td>Results</td>
<td>82.2</td>
<td>88.6</td>
<td>70.8</td>
</tr>
<tr>
<td>Conclusions</td>
<td>81.7</td>
<td>82.7</td>
<td>80</td>
</tr>
<tr>
<td>Implications</td>
<td>78.7</td>
<td>83.0</td>
<td>71.2</td>
</tr>
<tr>
<td>Formatting</td>
<td>87.2</td>
<td>90.0</td>
<td>82.4</td>
</tr>
</tbody>
</table>

The evaluations of the WF experience showed that the FY students perceived the experience positively with averages of 4.8 or higher on a 5-point scale.

These initial results confirm early work done with Writing Fellows across the curriculum: WFs do enhance the writing skills of students in the disciplines, the students perceive them to be helpful and they do help content-based writing scores.

**DISCUSSION**

Based on the initial findings of this study, further examination of the impact of paired courses on student’s critical thinking and writing is needed. The 2007 pairings were constrained by the number of courses sections taught by the investigators. Future research plans include the examination of additional pairings with other subjects such as mathematics and engineering design, chemical engineering discipline sections and in sections of the engineering course not taught by the investigators to increase the generalizability of the work. Work planned for the future includes enhanced intervention for critical thinking and writing improvement and increased content and critical thinking model-sharing between the freshman composition course and the Introduction to Engineering course.

Questions for future exploration:

1) How do the critical thinking and writing skills of freshman engineering students compare to
   • Freshman in other disciplines?
   • K-12 students who will or will not eventually pursue engineering?
   • Upperclassmen and graduate students in engineering?
   • Professional engineers?

2) Is it possible to develop methods and interventions that teachers and faculty can employ to increase these skills?

These questions will be addressed using various measures and assessments: linguistic analysis, detailed statistical analysis of the 6 cohorts, correlation of college prep, GPA and ACT to Critical Thinking and Writing Rubric Scores.

**Acknowledgments**

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