Writing in an Introductory Physics Lab: Correlating English Quality with Physics Content

Dedra Demaree*, Cat Gubernatis†, Jessica Hanzlik*, Scott Franklin**, Lisa Hermsen‡ and Gordon Aubrecht*

*Department of Physics, The Ohio State University, Columbus, Ohio 43210
†Department of English, The Ohio State University, Columbus, Ohio 43210
**Department of Physics, Rochester Institute of Technology, Rochester, New York 14623
‡Department of English, Rochester Institute of Technology, Rochester, New York 14623

Abstract. Members of the Physics and English departments at The Ohio State University and Rochester Institute of Technology are involved in an ongoing study addressing issues related to writing activities in the physics classroom. In summer quarter, 2005, the introductory calculus-based physics lab students wrote essays, some sections with and some without explicit writing instruction. We found a student's essay grade for English correlated strongly with that assigned for physics. In addition, we have studied the location and type of comments made by both physics and English instructors on individual student essays, and the statements students made within their essays. The results from the analysis of our data will be presented.

Keywords: writing to learn, laboratory
PACS: 01.40.Fk

INTRODUCTION

The project discussed in this paper is part of a collaboration between the Physics and English departments at the Ohio State University (OSU) and Rochester Institute of Technology (RIT). We focus here on the first project of our collaboration, which took place summer quarter, 2005, at OSU. We address the questions: is there a correlation between the types of English comments and the types of physics comments made in grading? What type of comments are more frequent? Does harder content engender more comments? Do any of these factors change with instruction and/or practice?

MOTIVATION

At OSU, the College of Engineering surveyed alumni and their employers and found both groups overwhelmingly wished they had been better prepared for writing and communication. The students in this study are predominantly engineering majors, and at this level have been observed to have difficulty with written explanations of physics concepts. In addition to the need for increased writing practice, the need for strong studies to establish the benefits of writing and writing instruction within disciplines has been shown in the literature [1, 2, 3]. Establishing an understanding of how students write in the context of physics, and the relationship between the physics content and the quality of their writing is a step toward approaching these larger issues. Writing activities in physics have been shown qualitatively to improve student writing [4, 5, 6], and the precedent for having an English instructor in the physics classroom has been established [7]. Our method of simultaneously giving a paper to a content and writing expert was first reported by the RIT collaborators [8].

IMPLEMENTATION DETAILS

This project was implemented in OSU's electricity and magnetism segment of introductory calculus-based physics. Two laboratory sections did writing activities during lab. One with 11 students had explicit writing instruction (WI) and the other with 17 students had no writing instruction (NI). The details are in Table 1.

TABLE 1. Division of time on lab activities

Group	Lab	Writing	Extra Instruction
NI	Reg., 1 h	1/2 h, at end of lab	5 min general instruction plus physics help during writing
WI	Reg., 1 h	1/2 h, at end of lab	As above, plus 15 min English instruction

The writing activity consisted of creating a paragraph missing from a pre-written essay. Students were given an explicit prompt including cues for what information was missing. The topics included why a car is safe during lightning, how electrostatic precipitators work, how holiday lights are wired, and how solar particles are trapped in Earth's magnetic field. The missing paragraphs re-

quired explanations of some aspect of the phenomena based on content from that day's lab. The students had six labs throughout the quarter, but because slightly different assignments were given the first and last weeks, those essays were omitted from this study.

The weekly writing instruction consisted of lesson plans beginning with higher order concerns and moving to progressively lower order concerns. Higher order concerns are universal issues such as organization, or logical flow, while lower order concerns are sentence or word level issues (e.g., word choice). In one lab, students outlined the information needed to respond to the prompt from the previous essay, then compared their outlines to the essays they wrote. They then discussed what information was missing, and how the order of information could be improved to strengthen their argument. In another lab, students were given a handout with sample sentences from the previous week's essays illustrating problems such as using transitions and equations. After discussion, students corrected the sentences.

Each week, the students' essays were copied, and one copy was given to Cat Gubernatis and graded for the quality of the writing (but not grammar or spelling mistakes). This grade was not biased by the physics content, since she does not have any background knowledge of physics. The other copy was given to Dedra Demaree and graded for physics content. Each grader made comments on the papers as they were graded. The final grade students received for each essay was the average of the English and physics grade. Essay grades were out of 15 points, with 9/15 considered the threshold for passing; most essays obtained between 9 and 15 points.

DATA OBTAINED

The English and physics grading comments were coded by Jessica Hanzlik. Although the graders discussed the importance of students producing a strong argument in their writing, each grader separately came up with their own grading rubrics. Despite this, Jessica found that the English and physics comments were often similar. Most statements could be grouped into five or six subcategories belonging to three main categories. English comments included external and internal language issues (e.g., "need transition," "awkward wording"). Others focused on content issues (e.g., "be more specific," "put this in context"). Both graders used "good" as a common positive comment. Physics comments centered around clarity issues (e.g., "physics not clear"), while others focused on the correctness of the physics.

The location of each physics and English comment was coded for each essay for lab weeks two through five. The basic content of each sentence was also coded. In addition, the students also took the Conceptual Survey of Electricity and Magnetism (CSEM) [9] diagnostic test. The lecture instructor also put a question on the final exam requiring a written explanation of the motion of a charged particle in a magnetic field. This question was graded by Dedra for physics content for the sake of their final exam grade, and later also graded for comparison by Cat for English.

RESULTS

Our results consist of qualitative and quantitative data, based on essay grades, exam grades, surveys, observations, and written comments made by the essay graders. A Mann-Whitney U test showed the CSEM pretest scores for the NI and WI groups were not significantly different ($\rho = 0.846$); therefore they are directly comparable to each other.

The main problems observed in the student writing included clarity, organization, and language. Cat noted that she could not always gain an understanding of the ideas from reading their work. She also noted that students had problems showing the relationships between ideas, equations and diagrams, and physics terminology. It seemed students were often not thinking about these assignments as constructing arguments, but instead thinking of them as just describing facts.

However, student writing became easier to read and was expressed more clearly as the quarter progressed. Students also showed improvement in integrating diagrams and equations in their writing. Only a few students improved greatly, with most obtaining a grade on their final essay within two points of the grade they got on their first essay. We observed that the quality of writing was heavily dependent on students' understanding of the content. Students struggled with the content of the final essay topic: their writing was not as clear, understandable, or well organized.

We consider if explicit writing instruction had an impact on the physics quality in the student writing. The essay grades based solely on physics are graphed in Fig. 1. This shows that although the NI group started with higher physics grades, by the end of the quarter the WI group had higher grades. In weeks one through three, a Mann-Whitney U test showed a 2-tailed significance of no lower than $\rho = 0.4$. However, in week four $\rho = 0.1$, and in week five significance is reached with $\rho = 0.05$. Each week, the physics and English grades correlated well, with a correlation coefficient ranging between 0.51 and 0.79. In addition, 68% of all essays had physics and English grades within 1 point of each other. Due to this, similar results from those shown in Fig. 1 can be shown for the total essay grades (with $\rho = 0.4$ in week 5).

A question on the final exam required explaining particle motion, similar to the week five essay. This specific

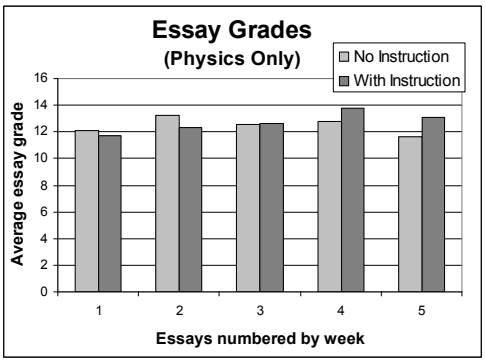

FIGURE 1. Weekly Physics essay grades.

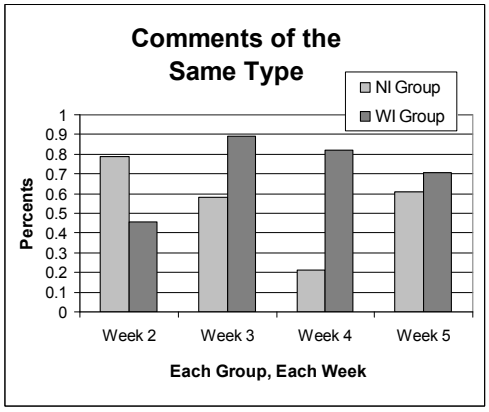

FIGURE 2. Percent of times physics and English comments at same location were of the same type.

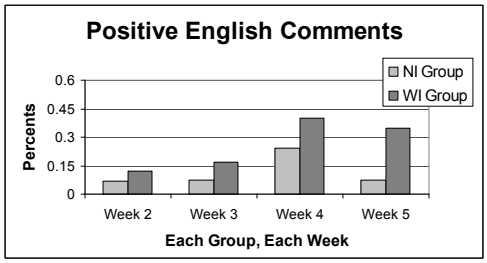

FIGURE 3. Percent of English positive-based comments.

question was covered in detail in lecture. The WI students had much higher physics grades on this problem than the NI students (average for WI = 7.1 out of 15, while the average for NI was 4.9). However, the English grades were nearly identical (10.6 for WI and 10.2 for NI). It should be noted the physics grade was based on points for the inclusion of various details of the problem, while the English grade (which did not count toward their final exam grade) was graded as we had graded in lab.

It seemed the students did not focus on English during the final exam; almost no responses appeared in full sentence form. It is not surprising that students did not transfer the idea of writing from lab to the final exam as the lab and lecture are fairly separate. There was no significant difference between physics grades for the NI and WI students on this problem, but there was a significant difference when the English and physics grades were averaged (the Mann-Whitney U test found $\rho = 0.11$ for the physics grades and $\rho = 0.027$ for the averaged grade). There was no significant difference between the two groups overall on the final exam ($\rho = 0.89$).

First we address the question: is there a correlation between the types of English comments and the types of physics comments made in grading? For every sentence that received either an English or physics comment during grading, 37% of the time there was a comment from both the English grader and the physics grader. For each group, and each week, the percent where both graders commented ranged from 29% to 47%; this agreement was fairly consistent across the two groups and throughout the quarter.

Both graders made comments based on language and clarity, content and correctness, or made positive comments. Grouping comments in that fashion, we found that 63% of the time when both graders commented at the same location, the comments were of the same type. This agreement ranged from 21% to 89% for the two groups each week. It is interesting that except for week 2, the WI group had a higher agreement between the English and physics comments than the NI group. The average agreement in the NI group was 55%, while in the WI group it was 72% (see Fig. 2). It is possible that the writing instruction impacted this agreement, though it is not obvious why it would.

Second we address: what type of comments are more frequent? We looked at the coded comments to see what types of comments occurred for each group throughout the quarter. The percent of positive English comments gradually increased through the quarter, with 9.5% in week 2 and 32% in week 4. This is consistent with both the improvements in student writing, and that the graders wanted to make sure we gave suggestions to correct student work early on, which artificially inflated the increase in positive comments.

Week five is interesting since the WI group received almost three times as high a percentage of positive comments as the NI group. These percents are shown in Fig. 3. Although this essay was difficult for both groups, as is seen by the lower grades in week five and the reduced number of positive comments, the difference between the two groups is striking. This is the week that the difference in essay grades between the two groups achieved statistical significance. The difference in the number of positive comments for each group supports that result.

The percent of language-based English comments decreased steadily throughout the quarter, with a steeper decrease for the WI group, though not as striking as the increase in positive comments. A similar trend is seen in the content-based English comments, with the exception of week five, when students had a lot of difficulty with the content, and the proportion of content-based comments almost doubled. Similar analysis can be done with the physics comments, though no strong trends appear from this data.

Third we address: does harder content engender more comments? One of the authors looked at the sentence content categories that were coded, and rated them as easy, medium, or hard. Easy content would be something like the statement of a physical law when the prompt told students to use that law to show something. One hard sentence content-type was chosen for each essay, and was based mainly on memory of what students struggled with understanding when writing the essays. Considering only the non-positive comments, we calculated the percent of each sentence difficulty type that was commented.

Our prediction was that harder sentences would have a higher percent of negative comments than easier sentences. However, this prediction failed for both groups. In week five's essay, the hardest one, none of the NI students included the content which was coded as hard. However they had a greater percentage of sentences commented on for week five than for the previous weeks. Because they struggled with this content, this suggests that more negative comments were made when students struggled, but not necessarily within any given sentence type within the essay.

Another coding recorded what type of sentence was written in each essay: motivation, observation, speculation, inference, or fact. Speculation was defined as having no basis of support for the statement, so were not conducive to good arguments. Between the WI and NI group the results were fairly similar with observation and inference sentences most common, and the percent of each sentence type fairly steady throughout the quarter. The most notable difference was the amount of speculation: the NI students had considerably more speculative sentences than the WI group. It is also interesting that both groups had more speculative sentences in week five when they struggled with content.

DISCUSSIONS AND CONCLUSIONS

The main implementation problem we encountered was resistance to student writing, and resistance to having a non-physicist aid in instructing their course. Students seemed unwilling to believe that writing was an important skill for their future. If writing were a common part of science pedagogy this resistance would probably be decreased. We also found students seldom took advantage of Cat's presence in the room for help while writing, and they were sometimes resistant to her direct help. Our recommendation is that collaborators from the English Department can be used for designing lesson plans, but the lessons can be taught directly by the physics instructor in the classroom.

We see convincing evidence that writing instruction had a positive impact despite negative student attitudes. The strongest evidence is that the quality of physics by the end of the quarter was significantly better for the WI group than the NI group. In addition, the WI students did better than the NI students on the written final exam problem. It is difficult to conclude if students actually gained more physics knowledge, or if the WI students gained a better ability to explain their knowledge - hence producing better quality physics. The latter is supported by our observations, and is worthwhile even without the former, as improved writing skills are needed.

We also provide evidence for the correlation between English quality and the physics mistakes. This helps establish a connection between the ability to express content knowledge and writing, which provides support for the idea that writing is pedagogically beneficial. The data support the idea that students need explicit instruction in order to take full advantage of writing activities. We suspect that given more practice writing the results from our project would be stronger, and plan to implement writing over a longer time period in the future.

ACKNOWLEDGMENTS

The authors would like to thank Kathy Harper for putting a research question on the final exam.

REFERENCES

1. Ackerman, J., *Written Communication*, **July** (1993).
2. Russell, D. R., *Writing in the Academic Disciplines: A Curricular History*, Southern Illinois University Press, Carbondale and Edwardsville, 2002.
3. Franklin, S. V., and Hermsen, L., *Educational Researcher*, **In Preparation**.
4. Larkin-Hein, T., and Budny, D. D., *ASEE/IEEE Frontiers in Education Converence, Reno, NV*, **October** (2001).
5. Mullin, W. J., *The Physics Teacher*, **May** (1989).
6. John W. Jewett, J., *Journal of College Science Teaching*, **Sept/Oct** (1991).
7. Larry D. Kirkpatrick, A. S. P., *The Physics Teacher*, **March** (1984).
8. Franklin, S. V., and Hermsen, L., *129th AAPT National Meeting: Sacramento, CA* (2004).
9. Maloney, D., O'Kuma, T., Hieggelke, C., and VanHeuvelen, A., *Am. J. Phys.*, **69** (2001).