The Effectiveness of Incorporating Conceptual Writing Assignments into Physics Instruction

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Abstract. This preliminary study examines the impact of conceptual writing assignments on student understanding of two physics concepts. Writing assignments covered the concepts of Newton's Third Law and the impulse-momentum relationship and were given to students in both high school and college level introductory physics classes. The students in these classes along with students in classes taught in an identical fashion by the same instructors without the addition of writing assignments were tested on their conceptual understanding of the two content areas. The results of this initial study indicate that the efficacy of this approach varied with topic. This study further indicates that students' benefit from the writing assignments was independent of their writing ability.

Keywords: Writing, Conceptual Learning, High School, College

INTRODUCTION

In this paper we report on a small, preliminary study of the effectiveness of conceptual writing assignments in regard to conceptual learning for introductory physics students at the high school and college level. In addition, we probe whether students of greater writing ability benefit more from such assignments than students of lesser writing ability as some researchers would predict.[1]

Although there is a common belief among teachers that writing helps students learn, there is limited evidence that this is true in regard to physics concepts.[2-4] Thus, this study is designed to confirm earlier results and provide a basis for further studies of similar design and refined scope. This study is important because without proof of effectiveness it is difficult to convince physics instructors to incorporate conceptual writing into their classes. These types of assignments take significant time to grade carefully and accurately. The reluctance of instructors to incorporate this type of assignment into their class structure is reflected in the small sample sizes noted in the study discussed here.

POPULATION AND METHODOLOGY

The sample group consisted of high school physics students from two Connecticut public high schools as well as students from Southern Connecticut State University's conceptual physics course.

Two conceptual writing assignments were designed based on accepted models [5-11] for each of the two topics discussed in this paper: Newton's Third Law (N3) and the impulse-momentum relationship. As an example, one of the assignments addressing the relationship between impulse and momentum follows.

After coming home from a long physics class, you decide to dive on your nice fluffy couch and relax. Explain why jumping on the couch is a better, and less painful idea than diving onto the hardwood floor. Be sure to think in terms of momentum, impulse, and force when describing the situation.

All of the writing assignments describe a specific real-world situation and ask students to demonstrate, in a one or two paragraph written response, their understanding of the physics concepts that apply.

Evaluation of students' conceptual understanding was measured using a subset of questions from the *Force and Motion Conceptual Evaluation* by Sokoloff and Thornton[12], and the *Energy and Momentum Conceptual Survey* by Chandraleka Singh[13]. Five questions on the evaluation dealt with Newton's Third Law and three questions covered impulse and momentum. These questions were given to students post-instruction as a measure of conceptual understanding of these two topics. At both the high school and college level, students in classes taught in an identical fashion by the same instructors but without the addition of writing assignments were also tested and serve as a control group. Since the sample size for this study is quite small, we employ t-tests to evaluate the statistical significance of any differences in the mean scores for the groups.

Research in other domains indicates that students with greater writing ability might preferentially benefit from assignments such as these.[1] In order to probe this issue, students' writing ability was evaluated using a five point rubric, designed by Robin Lee Harris Freedman in her book Open-ended Questioning.[7] The mean score for each student was calculated from the grades on all of their writing assignments. Students who completed the writing assignments were then divided into two groups based on the quality of their writing. Students who scored an average of '3' or better on a rubric used to determine writing ability were considered to have "high" writing ability while students who averaged less than '3' on the rubric were categorized as having "low" writing ability. Note that these scores do not indicate correctness or incorrectness of the writing in any way. They are purely a measure of writing ability.

RESULTS

Scores for the impulse and momentum part of the study range from zero to three points (there were three J-p questions). Scores for the Newton's third law part of the study range from zero to five points (there were five N3 questions). These results are shown in tables 1-5 below.

Tables 1 and 2. These tables summarize the test scores for one high school and the college group on the impulse-momentum portion of the assessment. P values from t-tests are shown at the bottom of the tables.

Table 1. High School A : Impulse and Momentum

Without Writing Assignments		**With** Writing Assignments	
Score	Frequency	Score	Frequency
0	0	0	0
1	5	1	2
2	9	2	8
3	1	3	5
N =	15	N =	15
Mean	1.73	Mean	2.20
S.D.	0.59	S.D.	0.68
P = 0.03			

Table 2. College: Impulse and Momentum

Without Writing Assignments		**With** Writing Assignments	
Score	Frequency	Score	Frequency
0	26	0	0
1	33	1	3
2	14	2	3
3	2	3	0
N =	75	N =	6
Mean	0.893	Mean	1.50
S.D.	0.798	S.D.	0.548
P = 0.04			

Tables 3-5. These tables summarize the test scores for two high schools and the college group on the Newton's Third Law portion of the assessment. P values from t-tests are shown at the bottom of the tables.

Table 3. High School A : Newton's Third Law

Without Writing Assignments		**With** Writing Assignments	
Score	Frequency	Score	Frequency
0	5	0	3
1	4	1	5
2	3	2	3
3	0	3	1
4	2	4	0
5	1	5	3
N =	15	N =	15
Mean	1.53	Mean	2.07
S.D.	1.64	S.D.	1.79
P = 0.26			

Table 4. High School B: Newton's Third Law

Without Writing Assignments		**With** Writing Assignments	
Score	Frequency	Score	Frequency
0	0	0	1
1	0	1	1
2	1	2	1
3	2	3	0
4	1	4	2
5	1	5	4
N =	5	N =	9
Mean	3.40	Mean	3.44
S.D.	1.14	S.D.	1.94
P = 0.48			

Table 5. College: Newton's Third Law			
Without Writing Assignments		**With** Writing Assignments	
Score	Frequency	Score	Frequency
0	9	0	1
1	16	1	2
2	21	2	2
3	11	3	1
4	10	4	1
5	6	5	1
N =	73	N =	8
Mean	2.21	Mean	2.25
S.D.	1.46	S.D.	1.46
P = 0.47			

The tables shown below articulate the frequency of scores for only those students who were taught using the writing assignments. If students with "high" writing ability benefited more from the writing assignments the mean score should be higher for these students than those with "low" writing ability. However, these tables provide no such indication.

Table 6 High School A: Newton's Third Law			
		Writing Ability	
		High	Low
Newton's Third Law Score	0	2	1
	1	3	2
	2	1	2
	3	1	0
	4	0	0
	5	2	1
N =		9	6
Mean Score		1.83	2
Std. Dev.		1.72	1.94
P = 0.43			

Table 7 High School A: Impulse & Momentum			
		Writing Ability	
		High	Low
Impulse & Momentum Score	1	1	1
	2	5	3
	3	3	2
N =		9	6
Mean Score		2.17	2.22
Std. Dev.		0.753	0.667
P = 0.44			

Table 8 High School B: Newton's Third Law			
		Writing Ability	
		High	Low
Newton's Third Law Score	0	1	0
	1	0	1
	2	1	0
	3	0	0
	4	1	1
	5	1	2
N =		5	4
Mean Score		2.75	4.00
Std. Dev.		2.22	1.73
P = 0.19			

Table 9 College: Newton's Third Law			
		Writing Ability	
		High	Low
Newton's Third Law Score	0	1	0
	1	0	2
	2	1	1
	3	1	0
	4	1	0
	5	0	1
N =		4	4
Mean Score		2.25	2.25
Std. Dev.		1.89	1.71
P = 0.50			

Table 10 College: Impulse & Momentum			
		Writing Ability	
		High	Low
Impulse & Momentum Score	1	3	0
	2	3	0
	3	0	0
N =		6	0
Mean Score		1.50	n/a
Std. Dev.		0.548	n/a

Tables 6-10. These tables summarize the test scores for students of "high" and "low" writing abilities. Tables 6-8 are for students at the high school level. Tables 9 and 10 are for students at the college level. P values from t-tests are shown at the bottom of the tables were applicable.

DISCUSSION AND CONCLUSIONS

Based upon the data shown in tables 1-5, several preliminary conclusions can be drawn. The incorporation of writing assignments related to Newton's Third Law seemed to have no statistically significant effect on students' conceptual understanding. However, the use of writing assignments related to impulse and momentum did impact students' conceptual understanding of this topic. Both of these results were consistent across the three different instructors involved in this study and at both the high school and college level.

These results lead to an unpredicted (preliminary) conclusion. Namely, that writing assignments may be more beneficial in certain content areas than others. This may be an "artificial" result due to writing assignments with a context more closely linked to the context of the associated test questions. However, it could be that some materials is truly more easily learned via writing. Perhaps the closer a student is to correctly understanding an idea the better a conceptual writing assignment works. All of these possibilities offer interesting opportunities for further research.

In addition, tables 6-10 show that scores on the conceptual questions are fairly evenly distributed amongst all students who completed the writing assignments. Again, this result is true for all three instructors and at both instructional levels. Students with high writing ability did not score better than those with lower ability. In fact the mean test score was slightly higher for those of "low" writing ability than those of "high" writing ability in both content areas. However, the very high P-values indicate that the difference in these means are not statistically significant. It will be interesting to repeat this study with a larger sample size to determine if this result becomes significant.

The idea that students of various writing ability benefit equally (or that weaker students benefit more) from conceptual writing assignments is especially interesting because it conflicts with the educational theory known as "multiple intelligences". This theory , originally purported by Howard Gardner, presents the idea that "each individual possesses at least seven different intelligences, each with varied abilities."[7] One of these seven intelligences is 'logical-mathematical,' which is appropriate for much of the traditional instruction of physics; another is 'linguistic.' According to the theory, students who have initial strengths in one of the intelligences will learn better from activities that relate to their individual intellectual strengths. As applied to this study, this means students who excel in linguistic intelligence (those of higher writing ability) should be better able to develop their understanding of physics concepts through the process of writing. Our data do not seem to confirm this hypothesis. This is another result rich in interesting research topics for future studies.

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