LINKING PHYSICS WITH COLLEGE WRITING: AN INTERDISCIPLINARY APROACH

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Abstract *— During the fall 2000 semester, a joint study was undertaken between the Physics and Literature Departments at American University. The study involved the linking of an introductory physics class for non-majors with an introductory college writing class. One goal of the study was to provide more content-specific writing assignments within the college writing class by linking them to material being covered in the physics class. The writing assignments given in both classes formed the basis of the data collected during the study. The underlying questions involved the assessment of student learning in physics as well as in college writing. The primary research questions were: (1) could this course linkage serve to enhance student motivation to think more deeply and critically about the physics-specific content they were writing about in each class? (2) If so, could this enhanced motivation be linked to increased student understanding in physics? In this paper, highlights of the curricula developed for the linked classes will be provided along with a summary of the data collected. In addition, results related to the assessment of student learning in physics will be presented. This study should have broad-based applications for other educators within the domains of SMET education, particularly those interested in integrated curricula.*

Index Terms — Assessment, Curricular Innovations, General Education, Writing-to-Learn

INTRODUCTION

The primary purpose of teaching is to facilitate student learning. However, many traditional teaching methods have clearly been shown to encourage passive rather than active learning [1]. These methods (classroom lectures and textbook reading, for instance) have also proven inadequate in promoting deep learning and long-term retention of important concepts. Good teaching involves a great deal more than simply pouring information into the heads of students, because they do not enter the classroom with a tabula rasa. Instead, students bring with them their own worldviews which have been developed and formed over their lifetimes [2], and often differ greatly from those of scientists and engineers. Due in large part to these differences, students regularly emerge from our classes with serious misconceptions [3] - [7].

In recent years, a number of writing techniques have evolved that make use of various writing-to-learn strategies within the domains of engineering, mathematics, and the sciences [8] - [15]. The use of writing in introductory physics classes for non-majors may help students develop their critical thinking and problem-solving skills. Writing can also assist students with the identification and confrontation of their misconceptions about a specific topic in physics.

Science classes, in particular, may be viewed by many students as being threatening and intimidating places to learn. Tobias [16] has been critical of introductory college science courses and has argued that typical classrooms are "…competitive, selective, intimidating, and designed to winnow out all but the 'top tier' … there is little attempt to create a sense of 'community' among average students of science" (p. 9). Hence, a traditional science classroom may present potential barriers that could inhibit learning for some students. The active process of writing may provide one non-threatening mechanism through which students could reduce or even remove these barriers to learning. Tobias [17] also indicates that writing can serve as a means to help students relieve their anxiety and help them unlearn models and techniques that have proven scientifically unsound.

This paper describes a novel technique for infusing more writing into the introductory physics curriculum for non-majors by linking one section with an introductory college writing class. The course linkage was designed to provide more physics- and science-related writing assignments within the college writing class by linking them to material being covered in the physics class. In addition, some of the assignments given in the college writing class directly followed writing assignments given in the physics class, thus enhancing the course linkage.

In the sections that follow, a description of each of the courses involved in this study will be shared. This description will be followed with a discussion of the curriculum developed to link the two courses. Information regarding assessment techniques will also be provided. Finally, some general observations and preliminary conclusions based on the authors' experiences will be shared. These observations and experiences should provide

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useful information for other educators interested in weaving more writing into the introductory curriculum either for majors or non-majors.

DESCRIPTION OF THE "LINKED" COURSES

As part of the General Education requirements towards graduation at American University, students are required to take a 2-semester sequence of courses in Curricular Area 5, the Natural Sciences. Students first choose to take a foundation course in the Biology, Chemistry, Psychology, or Physics Departments. Students who elect to take their foundation course from the Physics Department will enroll in *Physics for the Modern World*. Upon completion of the foundation course, students choose from six second-tier courses designed to complement and build upon the topics learned in *Physics for the Modern World.*

The General Education requirements at American University also require a College Writing component designed to help develop students' skills in reading, summarizing and synthesizing information, and in writing correct, reasoned prose. The particular writing course linked with *Physics for the Modern World* during the Fall 2000 semester was entitled *College Writing: Composing the Physical World.* In the subsections that follow, each of these courses will be briefly described.

Physics for the Modern World

The introductory foundation course for non-science majors at American University in Washington, D.C. is a one-semester, algebra-based course entitled *Physics for the Modern World* (PMW). Topics covered in the PMW course typically include Kinematics, Newton's Laws, Conservation of Momentum and Energy, Rotational Motion, Fluid Mechanics, Waves, and Sound. Although traditional in its content, the course is not taught in a traditional lecture format. Numerous teaching strategies have been developed which correspond to the accommodation of students' needs and diverse learning styles [18] - [23]. One such strategy involves the use of writing [24] - [25]. A significant amount of research conducted in the sciences and in engineering suggests that the active process of writing can be an effective teaching and learning tool. In addition, the PMW course includes strong conceptual and problem solving components.

College Writing: Composing the Physical World

Composing the Physical World asks students to look beyond equations to investigate the relationship physics has to philosophy, history, literature, and Western culture. Students are asked to think about what physics could teach them about the world, about themselves, and about society as a whole. Although some assignments are meant to satisfy the general goals of the College Writing Program, others are specifically linked to physics and to science in general.

During the Fall, 2000 semester, 2 lecture and 8 laboratory sections of *Physics for the Modern World,* consisting of approximately 16 students in each, were offered. Typical enrollments average about 120 students each semester in *Physics for the Modern World*. One of the 8 laboratory sections was linked with one section of the college writing class. This particular section consisted of 7 students who were simultaneously enrolled in *Composing the Physical World*. Although *Physics for the Modern World* typically consists of freshman through seniors, all students enrolled in the linked courses were freshman – the College Writing class is a mandatory requirement for all American University students, and the logical plan is for students to complete College Writing during their freshman year. A description of the curricular tools developed to link *Physics for the Modern World* and *Composing the Physical World* follows.

CURRICULAR TOOLS DESIGNED TO LINK PHYSICS WITH COLLEGE WRITING

As part of their homework assignments in the physics class, students are given short writing activities in the form of "folder assignments" (one-to-two pages of writing submitted to the instructor in a two-pocket folder). Typically, students receive 5 - 10 folder assignments each semester. Upon collection of the folders, a block of time is set aside (approximately 6 - 8 hours) by the instructor to read them and provide each student with written feedback. This written feedback is absolutely essential. Numerous studies have pointed out the importance and value of prompt and thoughtful feedback to students [26] - [30]. When students take time to reflect on their writing and on the comments provided, the folder becomes a highly effective tool in helping them uncover and then wrestle with their misconceptions while the learning is actually taking place.

The content and structure of the writing assignments vary, depending on the goals and objectives for a particular topic or content area. For example, for some assignments students are asked to explain a problem or a concept that was discussed during a class session. Thus, students essentially have the answer to the problem in their hands when they write up this assignment. The rationale for this type of activity is that learning can be enhanced when students take on the role of teacher through their detailed responses and explanations. For other assignments students are sometimes asked to write (and actively think) about a question that pertains to content yet to be discussed during class. As a result, this helps students to better tune-in when the question resurfaces during a later class session. Typical folder activities range in length from 1 - 4 pages.

Through the folder activities, students are encouraged to share their understanding of a particular topic or concept in their own words – with no pressure to use scientific jargon. This gives a much clearer window into the students' thoughts and to their current levels of understanding.

During the Fall 2000 semester, 5 folder assignments were given to all students taking the physics course. Three of

these assignments were specifically designed to link to assignments in the college writing class. The assignments given in the college writing class were called "concept papers." The concept papers were designed to allow students to further their understanding of concepts presented in the physics class. The concept paper assignments were always given after a folder assignment had been completed. Furthermore, for each concept paper students were asked to have a specific audience in mind when they wrote (a different audience for each paper). Note that all students in the physics class completed all 5 of the folder assignments. However, students enrolled in the linked section then used these folder assignments as a baseline for writing assignments given them in the college writing class. A description of each of the linked assignments follows.

Linked Assignment #1

Near the beginning of the semester students in the physics class were studying motion concepts and the application of the constant acceleration equations to numerical (as well as conceptual) problem solving. During one class session, a one-dimensional motion problem was worked out in its entirety. Students were then given a folder assignment asking them to prepare an explanation of this problem for a classmate who happened to miss class that day. Students were asked to prepare a narrative that would clearly outline for their classmate the key ideas involved with the solution to the problem worked out in class. Thus, students had the "answer" to the problem in their hands when they wrote up their folder assignments.

The first concept paper assignment followed shortly and asked the students to write a 2-page paper that explained the concepts of motion, specifically acceleration, to an audience of the students' choice. Students were required to clearly articulate who their specific intended audience was. Students were also encouraged to make use of analogies, anecdotes and/or metaphors to illustrate their explanations.

Linked Assignment #2

The second linked assignment involved the physics concepts of momentum and impulse. In their folder assignments students were given a specific scenario from which they were to demonstrate their understanding of these concepts. The scenario involved a minor traffic accident between a Mazda Miatta and a Ford Explorer. The students were asked to imagine that they were a passenger in the Miatta that was being driven by a friend. Then, while stopped at a traffic light, the Miatta was hit from behind by the Ford Explorer. Students were then asked to answer the following questions: *1) Upon which vehicle was the force of the collision the greatest? 2) Which vehicle will have the greater acceleration during the collision? 3) Which vehicle will experience the greater change in momentum? 4) Which vehicle will experience the greater impulse?* Students were given the freedom to be creative with this assignment. Many were very creative, completing the scenario with a variety of endings.

The concept paper that followed this assignment asked students to write a 2-page paper that explained, from the point of view of the Miatta passenger, to the Miatta driver why his/her car took the brunt of the damage in the collision with the Ford Explorer. Students were instructed to use scientific concepts to back up their explanations, but were cautioned not to speak over the heads of their audience. They were also reminded that the Miatta driver was not a scientist. Again students were encouraged to use analogies, anecdotes, and evidence from the collision in their explanations.

Linked Assignment #3

The third linked assignment was given near the end of the semester when students were learning about fluid mechanics in the physics class. The folder assignment centered on students' understanding of Archimedes' Principle and buoyancy. In particular, students were told they were having a discussion over lunch with a friend when the following question came up: *A bucket partially filled with water rests on a scale. Does the scale reading change when a lead block is suspended from a thread and lowered into the water where it is held submerged without touching the bottom or sides of the bucket? (No water spills out of the bucket when the lead is lowered into it.)* The students were then told that their friend answered this question by saying that the scale reading doesn't change (incorrect response). Students were told they must disagree with their friend and use the physics concepts being discussed in class to explain the correct response to the question.

Students were also asked to explain a second related question that came up during their lunchtime discussion with the friend: *If the lead block in the previous question was suspended from a spring scale, what happens to the reading of that scale when the block is submerged in water?* The students were told that their friend said that the scale reading would increase (incorrect response). Students were again told that they must disagree with their friend and use the physics concepts being discussed in class to explain the correct response to the question. Finally, students were asked to rate their level of confidence in their responses using a scale from 1 - 10 (with 10 being the highest).

The concept paper that followed this folder assignment required students to play the role of a physics teacher and instruct the class about Archimedes' Principle, using the lead bucket example described above. Students were asked to keep in mind that their audience was made up of their physics classmates and that all were non-science majors. This concept paper was required to be 400 - 500 words long and was to be mechanically perfect.

Additional Linked Assignments

In addition to the linkage between the folder activities and the concept papers, students in the college writing class were given some additional reading and writing assignments that were in some way related to science. The reading assignments involved a book by Michael Guillen [31] entitled "Five Equations That Changed the World" and a play by David Frayn [32] entitled "Copenhagen." Guillen's book highlights the life's work of 5 well known scientists – their scientific contributions play a big part, but Guillen's approach is very humanistic, so it is a very accessible book for non-science majors. Frayn's play, a more challenging text for non-scientists, attempts to interpret the mysterious and controversial meetings between Niels Bohr and Werner Heisenberg in 1941.

Four additional writing assignments were given students in the college writing class. These assignments included an *Editorial*, an *Interview*, an *Advertising Analysis*, and a *Creative Assignment*. Each of these assignments is briefly outlined below.

Editorial Assignment

For the Editorial assignment, students were asked to compile appropriate resources (articles, books, web sites, etc.) that would assist them in taking a stand on one of two current controversial issues: 1) requiring science classes for non-majors, or 2) the effectiveness of single-sex math and science education. Students were to explore the nuances of their chosen issue and recommend a course of action in a 4 - 5 page paper, making use of at least 4 resources to support their analyses and opinions.

Interview Assignment

The Interview assignment provided students an opportunity to profile a practicing scientist and his or her work. Many students contacted their physics professor for assistance in selecting a scientist for their interviews. The students' written profiles were required to be approximately 5 - 7 pages in length.

Advertising Assignment

For this assignment, students were asked to analyze product ads to expose their misuse of science to manipulate the consumer. Students could choose any products they wanted to (from cereal to cellular phones, mouthwash to mayonnaise, beauty cream to batteries). The task of the students was to delineate the advertisements' implicit and explicit "scientific" claims, exploring the tactics they use to convince their audiences to buy. Students were required to have a minimum of 2 sources to support their analyses. In addition, students were required to attach the ads they analyzed to their final written papers. The required length was 4 - 6 pages.

Creative Assignment

The Creative assignment provided students some flexibility. Students were given 3 options to satisfy this assignment. The first option involved the writing of a 3 - 4 page children's story that would explain a physical concept to young children between the ages of 5 and 9. Students were allowed to choose which physical concept they wanted to explain and they could also decide in what context they wanted to present it. Students were also required to make use of illustrations when writing their stories; however, the type of illustration to be used was left to the discretion of the students.

The second option for the assignment was linked to the model represented in Guillen's book. Students were asked to write a profile of either Niels Bohr or Werner Heisenberg. In his book, Guillen builds each chapter around the life story of the scientist, culminating either in one important scientific discovery, or in a series of discoveries. For this assignments students were to make use of at least 3 outside resources to prepare a 4 - 6 page paper appropriate for an audience of non-scientists.

The third option for the Creative assignment was to write a short story (5 - 9 pages in length) or a poem cycle (at least 4 poems) with science as an element. Students were given the flexibility to decide how to include that element. Students were instructed that the story/poems must be polished and should confront complex ideas or emotions (in other words, no unearned happy endings).

The section that follows gives a brief summary of the techniques used to assess students' work. Note that work done in the physics class did not affect the grade a student received in the college writing class and vice versa.

ASSESSMENT OF STUDENT LEARNING

Assessment of Folder Activities

In terms of assessing the quality of the folder activities in the physics class, students were provided with a checklist outlining what would be expected on the course syllabus. The key element of the checklist involved the thoroughness with which they presented their responses. For example, a simple opinion statement that is unsupported by a physics principle or relationship would be considered a weak entry. A strong entry would be complete, well documented, and illustrated in terms of the physics involved. The folder activities constitute approximately 10% of a student's overall grade in the physics course. Other assessment measures included homework assignments, quizzes, exams, and written laboratory reports.

The assessment strategy used for the folders is rather unique. Students were not penalized for incorrect use of physics. This helps to make the folder assignments non-threatening. In fact, no numerical grade is put on their folder assignments at all until the end of the semester. The students have indicated that they aren't bothered by the lack

of a grade; in fact, they value the feedback they receive and genuinely look forward to reading the comments on their papers. Thus, students are encouraged to look at and digest the written feedback, rather than a numerical score when their folders are returned to them. Students are encouraged to think about the feedback they've received and then do whatever they need to do to correct existing flaws in their thinking. This unique assessment technique attempts to get students away from just looking at their numerical scores and then filing the activity away where it may never be looked at again.

In addition to not penalizing students for incorrect use of physics, the folder assignments are not graded for grammar and spelling. If a word is misspelled or some other grammatical error is found, it will be pointed out to the student, but they will not be marked down for it. However, the papers that students turn in are remarkably well written and grammatically "clean." Students have commented that because their papers are read so thoroughly and because they receive quality feedback, this provides additional incentive for them to do a good job. Consequently the feedback provided to the students has an added benefit, as it seems to encourage them to put even more thought and energy into what they turn in.

The folder activities also provide an additional assessment tool beyond such things as traditional paper and pencil tests. However, there is one shortcoming to the folder activities, and that is that they do take time to read and respond to, especially for instructors dealing with large numbers of students. One strategy that works well for handling and working with such large groups is to sometimes stagger the assignments. For example, it can be particularly enlightening to ask students in one section to respond to a question on a particular topic *before* it has been discussed in class and the other section to respond to the same question *after* it has been discussed in class.

Assessment of Concept Papers (and other College Writing assignments)

All college writing classes are built around the idea of *process* in writing a paper – in other words, students are encouraged to work on a written assignment in drafts, starting with ideas and written outlines and moving steadily towards a finished, polished paper. The instructor meets at least twice with each student one-on-one (usually 3 - 5 times) to discuss individual assignments, and a significant amount of class time is given to peer-reviewing. So, assessment of student writing is done gradually, and in a way that encourages the student to take and maintain control over her or his writing. At the outset, students are provided with some basic formatting guidelines for their papers. Students are reminded that they should take pride in their work and that their papers should be organized and mechanically perfect.

In addition to these requirements, students are required to make a substantial revision of one of their writing assignments. The revision is graded both on how good it is on its own, and on how much it improves upon the previous draft. Changes in style or voice, drastic reorganization, and risky, new thinking are strongly encouraged and rewarded. Students are told that revisions submitted with only copy editing (i.e. grammatical, sentence-level) changes would receive an automatic "F." Students are allowed to turn in their revisions at any point during the semester, and are encouraged to seek feedback from the instructor (again, supporting the idea that papers should be written in drafts, with time for contemplation between each draft). Students may also revise more than one paper during the semester (though this isn't a requirement). Revisions that meet the above standards and are improvements will receive grade adjustments.

OBSERVATIONS AND PRELIMINARY CONCLUSIONS

In order to capitalize on the successes of this collaboration, and to enhance the experience of our future students in these linked courses, we've proposed some ways to expand the link. First, there will be more linked assignments. We envision, for instance, an assignment that would be an extension of the existing Concept Paper assignment: a student-led presentation project (with both instructors present in the "audience"). Each student would either lead the class in a discussion of a physical concept, or demonstrate the concept to the class. To aid in these presentations, audio-visual and/or computer presentation equipment could be made available. The goal of such an assignment would be to extend the stated goals of the folder assignments and concept papers: to challenge students to think about these physical concepts in different ways, and to increase the opportunities for retaining the information learned in both classes. In addition, students would benefit simply from the challenges of preparing and delivering an oral and visual presentation — a discussion about how each student prepared for their presentation could be steered into a discussion about the organization of ideas, research, and ultimately about written expression.

Second, to build upon the inherent sense of community in the linked courses, we plan to occasionally gather the students together for events (on-campus or off) that have relevance to our courses. Such events might include speeches, plays, films, and exhibits. Other possibilities for outside-of-class activities include study sessions and informal discussions of relevant news or cultural events. The instructors also hope to be a more visible presence in each others' classes — this reinforces the sense of community.

Third, we want to create a semester-long program of assessment whereby we can gauge the effectiveness of the link in the learning progress of each student. Such a program would enable us to build upon our research in this area.

In conclusion, writing has proven to be an effective way to assist students in articulating their thoughts and their

understanding about a topic or set of topics. The opportunity to write about a topic of personal interest can allow students a chance to demonstrate their understanding in a way traditional assessment measures do not permit. Hence, the application of a writing component into a course for non-majors as well as majors, has enormous potential within both science and engineering communities.

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