Writing: A Novel Strategy to Bring Issues in Science and Engineering to Non-Majors

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Abstract

Writing has long been established to be an effective means of expressing one's ideas, thoughts, and understanding about nature and the world. This paper will report on an ongoing research study designed to address the role of writing in terms of the assessment of student learning. To this end, a new instructional technique for incorporating writing into the curriculum for non-majors will be described. This technique was developed to bring science and engineering topics to the forefront in a new introductory physics course *(Physics for a New Millennium)* designed exclusively for non-majors at American University in Washington, DC. Participants in this study were enrolled in *Physics for a New Millennium* during the fall 1999 semester. The technique employed required students to write and present a scientific paper for their peers. Students were exposed to all aspects of preparing a paper for publication including the submission of an abstract, the preparation of a draft of their paper for a formal review process, and the preparation of a revised, camera-ready copy for publication in the conference proceedings. Students were also required to present their final papers at the New Millennium Conference at the end of the fall 1999 semester. In this paper, a summary of the curriculum devised for this writing technique will be presented. Writing topics selected and presented by student participants will also be shared. In addition, links will be made to the importance of making science and engineering topics accessible to non-majors through the active process of writing.

I. Introduction

The primary purpose of teaching is to facilitate student learning. However, many traditional teaching methodologies have clearly been shown to put students in a role of passive rather than active learning [1]. In addition, traditional instructional methods have been shown to be clearly inadequate in terms of promoting deep learning and long-term retention of important concepts. Students in traditional classrooms acquire most of their "knowledge" through classroom lectures and textbook reading. Good teaching involves a great deal more than simply pouring information into the heads of students. Students do not enter the classroom with a tabula rasa. Instead, students bring with them their own world views which have been developed and formed over their lifetimes. Cobern [2] describes a world view as "… how one understands the world" (p. 15). Furthermore, students' world views often differ greatly from that of scientists and engineers. A troubling fact is, after instruction, students often 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 be an effective vehicle for allowing students to develop their critical thinking and problem-solving skills. In addition, writing can assist students with the identification and confrontation of personal misconceptions regarding a specific topic in physics [16].

Science classes in particular, are seen by many students to be threatening and intimidating places to be. Tobias [17] 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 mechanism through which students may be offered a non-threatening vehicle through which these barriers to learning could be reduced and possibly even removed. Tobias [18] also indicates that writing can serve as a means to help students relieve their anxiety and help them unlearn models and techniques that have been shown to be scientifically unsound.

This paper describes a novel technique for infusing writing into the introductory physics curriculum for non-majors. The technique to be described here required students to experience all aspects of preparing a professional paper for publication. The students' experiences culminated with a presentation of their papers at the *New Millennium Conference* held at American University in December, 1999. The *Physics for a New Millennium* course will first be described. The curriculum involved with the development of the writing activity will then be discussed. This discussion will be followed by a summary of the *New Millennium Conference* in which students participated. Feedback from student participants will also be shared. Finally, a summary of this technique will be presented in light of its relevance to science, mathematics, engineering, and technology (SMET) education.

II. The *Physics for a New Millennium* Course

Physics for a New Millennium (PNM) is a new second-tier course in the Natural Sciences portion of the General Education core at American University. Prior to enrolling in PNM, students had first taken the foundation course *Physics for the Modern World* (PMW). Students are required to take a 2-course sequence in the Natural Sciences as part of the General Education requirements towards graduation at American University. Approximately 120 students enroll in PMW each semester (60 in each lecture section). In terms of content, the PMW course is a fairly traditional one-semester, algebra-based introductory course for non-majors. Topics typically addressed in the PMW course include: Kinematics, Newton's Laws, Momentum and Energy, Rotational Motion, Fluid Mechanics, and Waves & Sound. The course includes strong conceptual and problem solving components. In addition, the course involves a writing component. Although traditional in its content, numerous teaching strategies have been developed with center around the accommodation of students' diverse learning styles [19 – 23]. This foundation course is of critical importance because the students enrolled are not science or engineering majors.

The PNM course was designed to build upon the foundation laid in PMW. The content of the new course included: Electricity & Magnetism, Light & Color, and Modern Physics. The PNM course was developed through the use of current research in Physics, Physics Education, and Engineering. As a result, the course was taught using an integrated lab-lecture approach. Students met once a week for a 75-minute lecture. Students also met once a week for a 150-minute activity-oriented session. During these activity-oriented sessions, students were able to perform a number of interactive, hands-on, investigative activities. For example, students explored the topics of Electricity & Magnetism by building electric circuits and motors. The students' motors actually worked once they had completed this activity! The topics of Light & Color and Modern Physics were explored through the use of award-winning interactive software entitled "Visual Quantum Mechanics" (VQM) developed by the Physics Education Research Group at Kansas State University [24]. Using the quantum model of the atom, students investigated various properties of gas lamps, incandescent bulbs, and light-emitting diodes (LEDs) using the VQM materials. In addition, students were also exposed to materials with luminescent properties. The VQM materials provided students an opportunity to explore light spectra through hands-on activities. In addition, students were exposed to various computer simulation tools such as the "Spectroscopy Lab Suite [25]."

Traditionally, topics in Modern Physics are highly mathematical in nature. However, the VQM materials are very unique in that they were designed specifically with the non-science student in mind, and hence, require only a minimum background in mathematics. Students taking one semester of college algebra, which is typical of the students enrolled in the PNM course, are well-prepared to handle the mathematics involved with the VQM materials. The underlying message to the students is that both the foundation course, PMW, and the second-tier course, PNM, have and will continue to play an extremely important role in shaping and developing the highly technology-based society in which we all live.

PNM was taught for the first time during the Fall 1999 semester. Because this was the first time the course was offered, enrollment in the course was intentionally kept low. A total of 16 students enrolled in this course during the pilot semester (10 sophomores, 4 juniors, 2 seniors). These students' major areas of study included: Broadcast Journalism, Business, Economics, Finance, Graphic Design, International Studies, Political and Computer Science Information Systems, and Public Communication. Clearly, this course was not made up of science and engineering majors!

The following section presents a description of a rather unique writing activity developed for use in the PNM course. This activity was designed to give students experience with all aspects of preparing a formal paper for publication and presentation.

III. Description of the Writing Activity

Early in the Fall 1999 semester students enrolled in PNM were informed that one of the key components of the course would be the preparation of a formal written paper for publication and presentation at a "conference" planned for the end of the semester. Students were allowed to choose a topic for their papers that interested them. The only stipulation given them was that the physics content involved with their topic must closely parallel one or more of the topics covered

on the course syllabus. The idea was to have students explore one or more topics in more depth than they would be covered in class, thus making students the "experts."

Throughout the semester, students were exposed to all aspects involved in the preparation of a formal paper for publication. These aspects included the following items which are further described and illustrated in the sub-sections below:

1) Responding to a call for papers through the submission of an abstract;
2) Receiving notification of the acceptance of their abstracts;
3) Conducting the necessary research;
4) Preparing and submitting a formal paper for review, following strict formatting guidelines;
5) Receiving feedback from reviewers regarding their written paper; and
6) Revising their papers for inclusion in the conference proceedings.

The Call for Papers

Figure 1 shows the official "Call for Papers" given to students in the PNM course:

The New Millennium Conference
December 3, 1999

CALL FOR PAPERS

Abstracts are now being accepted for *The New Millennium Conference* to be held on December 3, 1999 at American University in Washington, DC. A wide range of paper topics will be considered. Where possible, papers should involve some aspect of the topics listed on the Physics for the New Millennium course syllabus (electricity & magnetism, light & color, and quantum mechanics).

Possible presentation/paper topics include (but are not limited to):

- Historical, current, or futuristic views on a topic related to electricity, magnetism, light, color, or quantum mechanics;
- Physics as it relates to the design, development, and/or function of a commonly used device (e.g. What is the physics involved in a burglar alarm? How is sound created for a movie film? How does the detector in the light meter of a camera work?);
- Physics/Science and public policy issues;
- Physics/Science and society issues;
- Medical applications of physics;
- Physics as it relates to any major offered by American University;
- Other topics of broad interest.

The deadline for submission of abstracts is 5 pm on Tuesday, September 21, 1999. Authors will be notified as to the acceptance of their abstracts on or before Tuesday, September 28, 1999. Along with formal notification authors will receive instructions for formatting their written papers. Please note that first drafts of papers will be due on October 19, 1999. Electronic submissions of abstracts are welcome. Hard copies are also acceptable.

Please direct all questions/correspondence to: Dr. Teresa L. Hein, Conference Coordinator

Figure 1. The Call for Papers

With the call for papers came the beginning of a semester-long writing project for the students. Students were informed that the only difference between submitting an abstract for *The New Millennium Conference* and an actual conference was that their abstracts WOULD be accepted!

Notification of Acceptance of Abstracts

Approximately one week after the submission of their abstracts, students were informed (electronically) that their abstracts had been accepted. Figure 2 illustrates a typical notification sent to a student regarding their abstract submission:

Congratulations! I am pleased to inform you that your abstract "Fluorescence Polarization as a Means for Drug Testing" has been accepted for presentation at The New Millennium Conference to be held at American University on December 3, 1999. You are now invited to submit a full paper for review. If accepted (and it WILL be accepted) your paper will be published in The New Millennium Conference Proceedings at the end of the fall semester. Attached you will find the guidelines you are to use when formatting your paper.

Specific reviewer feedback pertaining to your abstract is as follows:

1) Overall this is an interesting topic.
2) I suggest a minor revision to the second sentence. Consider something like: "All people are equally susceptible to substance abuse - from professional sports players to the homeless." You might come up with a better way of making it read a little more smoothly.
3) You have indicated in sentence 4 that the paper will address the recent advances made in drug testing procedures through the use of FPIA. If this is indeed going to be the focus of your paper, do you think you could you tie this in with the remainder of your abstract? Further, could you briefly highlight what some of these advances are? How are they an improvement over what was done - say 10 or 20 years ago? Once highlighted in the abstract these things can be expanded upon and discussed in your full paper.
4) You have a number of technical elements to your abstract - which is fine. However, keep in mind that your readers are your peers and not folks in the medical profession. Thus, I suggest that you consider briefly defining some of the key things. For example, when I read your abstract I was unsure of what things like "pretreatment solution" and "unbinding force" and "T4 antibodies and T4 tracers" were. Could you give the reader a little more insight on some of these things? I might suggest revising the second half of your abstract to eliminate some of the technical material. You could then save the detailed discussion for the body of your paper.
5) The end of your abstract leaves the reader "dangling." Could you try summarizing briefly how you intend to conclude your paper at the end of your abstract?
6) I will keep the copy of the abstract you have submitted for my file. I trust that you have saved a copy. If not, please see me to make a copy of it.

Overall, good job! It is clear to me that you've begun your library search for materials to support your paper.
I look forward to receiving the draft of your full paper. Just a reminder, your draft is due on **Tuesday, October 19.** Electronic as well as paper submissions are acceptable. Please don't hesitate to contact me if you have any questions as you are putting your paper together. I would also like for you to schedule a short meeting with me to discuss the overall outline of your paper. Please contact me sometime this week so that we may set up such an appointment. Thanks so much.

Once again, congratulations on the acceptance of your abstract!
Professor Hein

Figure 2. Typical Notification Sent to a Student Regarding Their Abstract Submission

Conducting the Necessary Research

Once students received the formal acceptance of their abstracts, they were instructed to set up an appointment to discuss the comments and suggestions provided by their instructor (the author). Students were asked to bring all of the research materials that they had collected thus far during the semester with them to this appointment. Seeing the research materials allowed the instructor

to help students who had chosen topics that involved a fair amount of mathematics in addition to the physics. After this meeting, students then began the process of collecting additional resources as well as the preparation of a first draft of their written papers. Each student submitted his/her written drafts for formal review near the mid-point of the semester.

Preparing and Submitting a Formal Paper for Review

When students initially received notification that their abstracts had been accepted, they were given a copy of the formatting guidelines to be followed when they prepared their papers. In addition, the students were given a copy of a paper written by the author that utilized the same guideline. The guidelines that were given to the students were essentially the same guidelines given to authors submitting a paper to the 1999 Frontiers in Education Conference held in San Juan, Puerto Rico in November 1999. (See: **http://fairway.ecn.purdue.edu/~fie/fie99/)**.

Receiving Reviewers' Feedback

All students' papers were subjected to a formal review process in late October, 1999. All reviews were conducted by the instructor. Once the reviews were completed, each student met individually with the instructor to discuss the feedback and comments they had received. At this point in the semester, some students turned in papers that needed very little additional work, while others turned in papers that still needed a substantial amount of revision. As a result, some students were told that they could begin working on their final copies of their papers, while others were asked to submit a second draft within a week or two. Papers that were submitted in second draft form were re-reviewed by the instructor.

Revision of Papers for Inclusion in the Conference Proceedings

By approximately the end of October, 1999 the students had experienced most aspects of submitting a paper for publication, and were ready to begin the preparation of the final copies of their papers. Final copies of their papers were collected on November 30, 1999. Typical papers ranged in length from 5 – 8 formatted pages. The submitted papers were then arranged according to "common themes." As a result, four themes emerged which allowed the instructor to form the following four sessions for *The New Millennium Conference*. These themes were:

1) Transportation
2) Photography and Film
3) Communication
4) Applied Issues in Technology (A potpourri session)

IV. *The New Millennium Conference*

On December 3, 1999 *The New Millennium Conference* was held at American University from 1 – 5 pm. Typically the class period was 150 minutes in length, but the students were informed that this class period was "special" and that they would be given one day of course release in exchange for a longer class session during the conference. The conference consisted of presentations by 14 of the 16 students enrolled in the course. For various reasons, two students

did not participate in the conference. When it came time for the two absent students to present their papers at the conference, a break was taken in order to keep the sessions on track (as is done with a professional conference). Figure 3 gives an overview of the sessions and topics presented by the student authors at the conference:

SESSION I:

TRANSPORTATION

Presentation 1:	1:00 – 1:12 PM	*"The Maglev Train: Transportation for the New Millennium"*
Presentation 2:	1:12 – 1:24 PM	*"Physics of Maglev"*
Presentation 3:	1:24 – 1:36 PM	*"The Art of Entertainment: Exploring Technology Use in Amusement Park Rides"*
Presentation 4:	1:36 – 1:48 PM	*"Electric Cars: Past, Present, and Future"*
Presentation 5:	1:48 – 2:00 PM	*"The Complexities of the Airbreathing Engine"*

SESSION II:

PHOTOGRAPHY AND FILM

Presentation 1:	2:10 – 2:22 PM	*"The Camera: A Physical Component of Photography"*
Presentation 2:	2:22 – 2:34 PM	*"The Physics of the Lens: From Image to Reality"*
Presentation 3:	2:34 – 2:46 PM	*"The Photoelectric Effect and Its Application to Sound in Movies"*

SESSION III:

COMMUNICATION

Presentation 1:	3:00 – 3:12 PM	*"Applications of Physics in the Telephone Network"*
Presentation 2:	3:12 – 3:24 PM	*"The Computer"*
Presentation 3:	3:24 – 3:36 PM	*"Advanced Internetworking: Creating the Next Internet for the New Millennium"*

SESSION IV:

APPLIED ISSUES IN TECHNOLOGY

Presentation 1:	3:46 – 3:58 PM	*"The Creation and Detection of Tsunamis"*
Presentation 2:	3:58 – 4:10 PM	*"United States Nuclear Waste Policy: Do the Advantages Outweigh the Risks?"*
Presentation 3:	4:10 – 4:22 PM	*"Microwaves: The Physics Behind the Food"*
Presentation 4:	4:22 – 4:34 PM	*"Fluorescence Polarization as a Means for Drug Testing"*
Presentation 5:	4:34 – 4:46 PM	*"The Relativistic Heavy Ion Collider: Examining the Beginning Moments of the Universe"*

Figure 3. The Conference Program

Inspection of the schedule given above shows that a strict time schedule was developed for presentation of papers at the conference. Students were given 10 minutes for their presentations and then allowed two minutes for questions. Two days prior to the actual conference, students met with the instructor to go through a practice-run of their presentations. Many students found that they had to cut a substantial amount of material from their presentations in order to conform to the time restrictions. The students prepared and made use of overhead transparencies, PowerPoint slides, as well as demonstrations during their presentations.

Overall, the presentations made by students were very professionally done. In addition, students were asked to wear appropriate attire for the conference. When students arrived to class on the day of the conference they were given a name tag and a bound copy of the conference proceedings which included a copy of each of their papers.

The conference itself attracted a modest amount of attention at American University. During the conference, the students enjoyed visits from the Dean as well as the Associate Dean of the College of Arts and Sciences. Both deans indicated that they were thoroughly impressed with the high quality of the papers presented by the students as well as the professional way in which they conducted themselves.

The following section highlights the students' impressions regarding their experiences over the course of the semester in preparing their written papers for publication and presentation at *The New Millennium Conference*. Feedback received from students via a written questionnaire is also shared.

V. Feedback from Students

Near the beginning of the semester, the students were quite apprehensive about the prospect of preparing a formal written paper. None of the students had ever been handed such an assignment before. Although the students had done some writing when they were enrolled in the foundation course, PMW, the task facing them in PNM seemed quite daunting. In addition, many students expressed anxiety regarding the fact that they were also being asked to present their papers orally at *The New Millennium Conference*. Comments from students suggested that they felt they would never be able to fill the 10-minute time period allotted them for their presentations. In reality, once students had completed their written papers and had prepared their materials for presentation, most found that they had too much material to fill the 10-minute time slot! Thus, the real challenge faced by most of the students was the condensation of their papers into a 10-minute presentation. Each and every student author was successfully able to present their papers within the given time period.

On a questionnaire given students near the mid-point of the semester, students were asked whether or not their overall expectations regarding the new course were being met. Typical student responses included:

- Yes, I always wanted to learn more about light and color and it seems that not only did we cover these topics, but I felt that in this setting we were able to discuss and explore these topics in further depth than if we were in a set structured class.
- I feel I am directly involved with the learning process and not just watching a teacher from afar.
- I have never had an instructor so interested and involved in a project (i.e. our presentation paper), and I find it very refreshing and helpful.

During a brief wrap-up session after the conference, students were asked whether or not they felt they had worked hard on their papers and presentations. Their overwhelming response was YES! After hearing all the student presentations, one student remarked "I never realized just

how much more there is to learn!" In addition, one student commented (via email): "Thank you again for a wonderful conference and thank you for, what I deem to this point in my college career as, the greatest set of classes (both Modern World and New Millennium) that a student could ask for."

At the conclusion of the conference, it was clear that the students felt that all of the time, energy, and hard work they had devoted to the preparation for the conference had paid off. Many expressed that they had experienced a fairly steep learning curve on both the content covered as well as the rules and regulations they were required to follow as they prepared their formal papers. In addition, many students expressed gratitude for the opportunity they were provided to participate in such a formal and professional activity.

VI. Summary and Conclusions

All aspects of *The New Millennium Conference*, from submission of an abstract to the formal submission of a camera-ready copy of their paper for publication and presentation, allowed students the opportunity to link the active process of writing to sound, scientific content. In addition, these activities allowed students to demonstrate their understanding of a topic or set of topics using their individual learning styles. In addition, this activity provided the instructor with an additional assessment tool, outside the confounds of traditional assessment measures.

Important to note is the fact that the PNM course was designed with non-majors in mind. However, the writing activity outlined in this paper could easily be applied to other courses in science and engineering, both for majors as well as non-majors. The underlying premise is that <u>all students</u>, no matter what their gender, cultural, or demographic backgrounds, can learn physics (and can even like physics!). In a recent report on its review of undergraduate education the Advisory Committee to the National Science Foundation Directorate for Education and Human Resources concluded that "… while K – 12 programming can expand the pool of those interested in pursing careers in SME&T [Science, Mathematics, Engineering, & Technology], it is at the undergraduate level where attrition and burnout can be most effectively prevented. What we in SME&T education must do is to concern ourselves with *all* students, not just those who historically have been represented in science, mathematics, engineering, and technology. Such a breadth of concern has important educational benefits as well, as it will force us to think more about how individuals learn and recognize what research has made clear: that there are differences in learning style which profoundly effect achievement. And let us not forget that increasing student achievement in SME&T education is exactly what is needed [26]" (p. 28).

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 the science and engineering communities.

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