Writing as a Teaching and Learning Tool in SMET Education

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Abstract

This article reports on a research study designed to address the role of writing in terms of the assessment of student learning. The two-phase study involved an instructional technique for incorporating writing into the curriculum for non-majors. This technique was developed to bring science and engineering topics to the forefront in a new introductory physics course entitled *Physics for a New Millennium* designed exclusively for non-majors at American University in Washington, DC. Participants in the initial phase of this study were students enrolled in *Physics for a New Millennium* during the fall 1999 semester and those in the second phase were students enrolled during the spring 2001 semester. Throughout this course students were exposed to all aspects of preparing a formal research paper for publication. The process began with the submission of an abstract and was followed by the preparation of a draft paper for formal review, as well as the preparation of a revised, camera-ready copy for publication in the conference proceedings. Students then presented their final papers at an in-class conference held at the end of the semester. A summary of the curriculum devised for this writing technique will be presented. In addition, lessons learned from the initial phase of the study will be shared along with how those lessons were translated into effective changes for the second phase of the study. Connections will be made to the importance of making science and engineering topics accessible to non-majors through the active process of writing. Students' overall perceptions of this activity will also be shared.

Introduction

The primary purpose of teaching is to facilitate student learning. Traditional teaching methodologies have been shown to put students in a role of passive rather than active learning (Jones & Paolucci, 1998). In addition, traditional instructional methods have also been shown to be very inadequate in terms of the promotion of deep learning and long-term retention of important concepts. Students in traditional classrooms acquire most of their "knowledge" through classroom lectures and textbook reading. A troubling fact is, after instruction, students often emerge from our classes with serious misconceptions (Arons, 1990; Halloun & Hestenes, 1985; Hein, 1999a; Hein & Zollman, 2000; McCloskey, Caramazza, & Green, 1980: McDermott, 1984; McDermott, 1991).

A significant body of educational research supports the fact that students must be functionally active to learn (Laws, 1991; Chiappetta, 1997; McDermott; 2001). Furthermore, Koballa, Kemp, and Evans (1997) note that "ALL students must become scientifically literate if they are to function in tomorrow's society" (p. 27). Scientific literacy is of critical importance for all students, at all educational levels, but is especially important for students who are not science or engineering majors. In written remarks regarding the improvement of science and technology literacy of all undergraduate students, given to the National Science Foundation and contributed as part of the Education and Human Resources Advisory Committee Public Hearings on Undergraduate SME&T Education, it was suggested that

> *"In the information age we have already, no college educated person can expect to be fully equipped for a job or career without at least a working knowledge of modern scientific theory and a modicum of technical competence and know how. This will require our colleges and universities to revisit the general curriculum and revise the requirements to ensure that their students are prepared. This will not happen without the enlightened leadership of scientists and other academics. It will not work if all the scientific community is willing to offer is the usual array of introductory courses intended to introduce the student to the major. True literacy of all students will require science departments to become much more creative; to work collegially with other science departments and resource centers. Scientists must offer courses that the non-scientist likes and which are conceptually oriented, not just fact oriented. The 'sage on the stage' will have to be replaced by the talented storyteller and the multimedia expert who has not only mastery of the material but mastery of the method of conveying the exciting and dynamic world of science"* (Shaping the Future: Volume II, p. 34).

The active and creative process of writing about current topics in science and engineering can significantly foster, as well as contribute to the enhancement of, scientific literacy. Furthermore, writing activities in nontraditional courses such as is the focus of this article can lead to deeper learning and heightened scientific literacy.

The *National Science Education Standards* (NRC, 1996) further emphasize that inquiry-based techniques should form the core of what it means to learn and do science. Edwards (1997) suggests that the publication of the *National Science Education Standards* offer reason to be optimistic that inquiry-based learning will become a central part of science education. Inquiry-based learning strategies originate from the constructivist model and encourage an active, hands-on approach to learning (Brooks & Brooks, 1993; Cobb, 1999). The constructivist approach embraces the idea that knowledge cannot be acquired passively (Yager, 2000). In addition, the National Science Foundation currently has several programs that promote the integration of standards- and inquiry-based SMET educational materials and instructional strategies from elementary through graduate school (Fortenberry, 2000).

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 (Connolly & Vilardi, 1989; Countryman, 1992; Hein, 1998; Hein, 1999b; Kirkland, 1997; Mullin, 1989; Rice, 1998; Sharp, Olds, Miller, & Dyrud, 1999; Walker, 2000). The use of writing in introductory classes for non-majors may be an effective vehicle for allowing students to enhance their critical thinking and problem-solving skills. Writing can also assist students with the identification and confrontation of personal misconceptions (Hein, 1999a; Hein, 2000).

Science classes are often seen by many students to be threatening and intimidating places to be. Tobias (1990) 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 can provide one mechanism through which these barriers to learning could be reduced and possibly even removed. Tobias (1989) 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 article describes a study involving a novel technique for infusing writing into the introductory physics curriculum. Student participants were non-majors enrolled in a General Education course entitled *Physics for a New Millennium* during two different semesters [fall 1999 (Phase I) & spring 2001 (Phase II)]. The techniques to be described here allowed students to experience all aspects of preparing a professional paper for publication. The students' experiences culminated with the presentation of their papers at *The New Millennium Conference*. Following a brief course description, the curriculum developed for 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 highlighted. In addition, lessons learned during Phase I of the study will be shared along with how the lessons translated into effective changes and improvements during Phase II. Finally, a summary of this technique will be presented in light of its relevance to science, mathematics, engineering, and technology (SMET) education.

The Physics for a New Millennium Course

Physics for a New Millennium (PNM) is a relatively new second-tier course in the Natural Sciences portion of the General Education core at American University. All students at American University are required to take two courses within the same curricular area in the Natural Sciences. Thus, students can choose to take two courses in either the biology, chemistry, physics, or psychology. Prior to enrolling in PNM, students will have first taken the foundation course *Physics for the Modern World* (PMW). Approximately 120 students enroll in PMW each semester (60 in each class session). In terms of content, the PMW course is a fairly traditional one-semester, algebra-based introductory course for non-majors. Students in PMW attend two 75-minute classes every week and a 2 1/2 hour laboratory every other week. 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 significant writing component (Hein & Joyner, 2001). Although traditional in its content and format, numerous teaching strategies have been developed for use in PMW that focus on the accommodation of students' diverse learning styles (Hein, 1995; Hein & Budny, 1999; Hein & Zollman, 2000). This type of course is of critical importance on college campuses often not because of the clientele, but rather because of the revenues associated with the large enrollments that are typical of such courses. In fact, this course deals with a population of students that is often overlooked, non-majors enrolled in General Education physics courses, yet they are so important as sci-

Figure 1. Students in the Fall 1999 class demonstrate an optics experiment

Figure 2. Members of the Fall 1999 class view the sky through a pinhole camera

entifically literate citizens. At American University significant attention is paid to the general education courses and to the students enrolled in them.

The PNM course was designed to build upon the foundation laid in PMW. The content of PNM includes: Electricity & Magnetism, Light & Color, and Modern Physics. The PNM course was developed through the use of current research in Physics and Engineering Education. As a result, the course is taught using an integrated, inquiry-based format. Students meet once a week for a 75-minute class session and once a week for a 150-minute activity-oriented session. During these activity-oriented sessions, students are able to perform a number of interactive engagement, hands-on, investigative activities thus enabling them to more deeply probe the topics being discussed during class. Typical inquiry-based activities are highlighted in Figures 1 and 2.

During some sessions students explored the topics of Electricity & Magnetism by building electric circuits and motors (Figure 3). Students also enjoyed exploring the physics involved with the operation of an incandescent bulb (Woolf, 2000). Students especially enjoyed dissecting a 3-way light bulb and switch to help them understand how each operated.

The topics of Light & Color were studied using various hands-on optics activities and experiments. Using the quantum model of the atom, students investigated various properties of gas lamps, incandescent bulbs, and light-emitting diodes (LEDs) and were then able to link them to practical, everyday applications within the domains of science and engineering. This approach to bringing topics in Modern Physics to non-majors involved the use of award-winning interactive software and hands-on activities entitled "Visual Quantum Mechanics" (VQM) developed by the Physics Education Research Group at Kansas State University (Donnelly, 1997; Rebello, Cumaranatunge, Escalada, & Zollman, 1998). 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-major in mind, and hence, require only a minimum background in mathematics.

Phase I of the current study was conducted in fall 1999, the semester that PNM was first piloted. Because of the interactive and investigative nature of the PNM course, enrollment was limited to 16 students per semester (which is the standard size for a typical laboratory section). Students in the fall 1999 class were majoring in areas of study that included: Broadcast Journalism, Business, Economics, Finance, Graphic Design, International Studies, Political and Computer Science Information Systems, and Public Communication. Phase II was conducted during the spring 2001 semester with enrollment again limited to 16 students. Typical student majors included: Audio Technology, Broadcast Communications, Business, International Relations, Political Science, and Studio Art. In addition, the spring 2001 class was very diverse with students hailing from 10 states and 5 countries.

The following section presents a description of the writing activity developed for use in Phase I of this study. This activity was designed to give students ex-

Figure 3. Students in the Spring 2001 class enjoy success after building a motor

posure to all aspects of preparing a formal research paper for publication and presentation. Based on lessons learned during Phase I, some modifications and enhancements were made to the writing activity during Phase II. The specific lessons and modifications will be discussed in a subsequent section.

Description of the Writing Activity: Phase I

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 research paper for publication and presentation at a "conference" to be held at the end of the term. Students were allowed to choose a research topic that interested them provided that the physics content involved closely paralleled one or more of the topics covered on the course syllabus. In addition, topics selected were required to be congruous with the new millennium conference theme. The key idea was to have students explore a topic(s) in more depth than would be covered in class, thus making them the "experts."

Throughout the semester, students were exposed to all aspects involved in the preparation of a formal research paper for publication. These aspects included: responding to a call for papers, being notified of the acceptance of their abstracts, conducting the necessary research, preparing and submitting a draft for formal review, and receiving and utilizing the feedback to prepare a final paper. The importance of prompt and effective feedback has been widely documented in the research literature (Brown & Knight, 1994; Cross, 1988; Gastel, 1991; Harmelink, 1998; Hein, 1998; Hein, 1999a; Wiggins, 1997). Each of these items are further described and illustrated in the sub-sections that follow.

The Call for Papers

The conference call for papers was distributed at the beginning of the semester. Students received a paper copy as well as an electronic copy of the call via the class listserv. Figure 4 shows the actual "Call for Papers" that was distributed to students:

The purpose of having students prepare an abstract was twofold. First, the preparation of an abstract gave students a sense for how the abstract submission process is handled for a professional conference. Second, it provided students the incentive to choose a topic for their papers early and to begin to focus on the research aspects of the project.

The call for papers marked the beginning of a semester-long research and 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 definitely be accepted! All submitted abstracts were reviewed by the course instructor. Approximately one week after the submission of their abstracts, students were informed (electronically) that their abstracts had been accepted. Figure 5 illustrates a typical abstract acceptance notification sent to a student following the submission of their abstract.

Conducting the Necessary Research

Upon receipt of the formal acceptance of their abstracts, students were instructed to set up an appointment to discuss the comments and suggestions provided by their instructor. Students were asked to bring all of the research materials that they had collected thus far with them to their appointment. Viewing the research materials allowed the instructor to help students narrow and refine their topics. After this meeting, students began the process of collecting additional resources as well as preparing a first draft of their written papers for formal review.

The New Millennium Conference **CALL FOR PAPERS** **December 3, 1999**

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 a New Millennium course syllabus. 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; and 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 Larkin-Hein, Conference Coordinator.

Figure 4. The Call for Papers

Congratulations! I am pleased to inform you that your abstract “The Creation and Detection of Tsunamis” 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) In your first statement that the tsunamis can “... be explained very simply by the application of physics.” Could you expand briefly on this statement by highlighting the specific physics you intend to focus on in your paper? Further more, can you make some links between the tsunamis and any of the physics topics that we have or will discuss in class this semester?
3) What I read from your abstract is that the tsunamis can be easily explained using some physics - but they are not as easy to detect. Is this a correct interpretation? If so, I suggest that you expand (briefly) your discussion of why they are so difficult to detect.
4) You begin your third sentence with the word “this.” I suggest that you don’t start a sentence with “this.” Instead you should indicate specifically what it is that “this” refers to.
5) Your last sentence is important. It is here that you are telling the readers what it is you intend to focus on in your paper. I suggest that instead of starting the sentence with “This study...” you start with something like “This paper will focus on....” I think it would be better to refer to the paper rather than a “study” since you really aren’t doing a study in the sense of a scientific study.
6) You might also consider splitting your last sentence into two or three sentences. You’ve packed quite a bit of infor mation into that one sentence and it might read a little better if you break it up just a bit.
7) I also suggest that you conclude your abstract with some type of a summary statement. If you conclude the abstract with a summary statement this will aid your readers in knowing exactly where you are intending to go (and not go) with the body of your paper.
8) 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 Larkin-Hein

Figure 5. Typical Abstract Acceptance Notification

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 as they prepared their papers. The guidelines that were given to the students were essentially the same guidelines given to authors submitting a paper to the ASEE/IEEE Frontiers in Education (FIE) Conference held in San Juan, Puerto Rico in November 1999. Students were also given a copy of a paper written by the author for the 1999 FIE conference that had utilized the same guidelines. Students submitted their paper drafts to the instructor in hard copy format.

Receiving Reviewers’ Feedback

All paper drafts were subjected to a formal review 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.

Revising Papers for the Conference Proceedings

Near the end of October 1999 students were ready to begin the preparation of the final copies of their papers. Students submitted final copies of their papers in electronic form near the latter part of November 1999. Typical papers ranged in length from 5 – 8 formatted pages. The submitted papers were then arranged according to “common themes.” A brochure highlighting each paper and a spiral-bound conference proceedings were produced and distributed to each student on the day of the conference.

The New Millennium Conference: Phase I

On December 3, 1999 *The New Millennium Conference* was held. The conference was 4 hours in duration. A typical the class period was 150 minutes in length, however, students were informed that this class period was "special" and that they would need to arrange their schedules accordingly. Fortunately the class met on Friday afternoons, so conflicts were minimal. In addition, students were released from one day of class earlier in the semester to give them time to work on their papers and to compensate them for the longer class period for 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. Figure 6 gives an overview of the sessions and topics presented during the conference:

Two days prior to the actual conference, students met with the instructor to go through a practice-run of their presentations. The students prepared and made use of overhead transparencies, PowerPoint slides, and demonstrations during their presentations. The practice-run proved to be very important, as many students had prepared substantially more material than could be presented in the time allotted. At the practice-run students were also reminded to wear appropriate attire for the conference.

Inspection of the schedule given below shows that a time limit was allotted for presentation of papers at the conference, just as there would be at a professional conference. Students were given 10 minutes for their presentations and then allowed two minutes for questions. When the time came for the two absent students to present their papers at the conference, a break was taken in order to keep the sessions on track (again as is typically done at a professional conference). Overall, the presentations made by students were of a very high quality.

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 student impressions regarding their overall experiences in the PNM course during Phase I. In addition, feedback received from students via a written questionnaire is summarized.

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 6. The Conference Program

Feedback from Students: Phase I

Near the beginning of the semester, students were quite apprehensive about the prospect of preparing a formal written paper. None of the students had ever been given a writing assignment of this magnitude before. Although the students had done a significant amount of writing while 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. Initial comments from several 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, however, successfully able to present their papers within the given time period. Figure 7 presents a photograph of the student authors taken on the day of the conference.

On a questionnaire given students near the end of Phase I, students were asked to describe their overall impressions regarding the conference paper assignment. Typical student responses included:

- *I've never written a technical paper like that before. The topic was much more involved - and required you to really understand what you were writing about.*
- *I thought this was a difficult assignment that taught me a lot and was worth doing. It was a lot of work, but after doing it, I felt like I learned a lot. I never had to write a technical paper before and I'm happy that I can now say that I wrote a conference paper.*
- *I learned a lot about a subject that I would not otherwise have learned about. I had never written one of this magnitude, or that required so much in-depth research. We were allowed to pick the topic - which was nice.*
- *I have never written any form of technical paper at all. At first, I was not very excited about the idea of writing such a paper, but I did feel that I had a very valuable experience. I feel that I have learned so much - beyond physics principles. I also appreciated you forcing us to do rough drafts, so I was able to pace myself and put more effort into it than I otherwise would have.*

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.

Figure 7. Members of the Fall 1999 PNM Class on conference day

In the next section, lessons learned during Phase I of this study are presented. In addition, changes and improvements made during Phase II are highlighted.

Additions and Improvements: Phase II

Upon completion of Phase I of this study, several interesting items emerged. One item of critical importance during all aspects of Phase I was the need to continuously provide feedback to the student authors. One improvement made during Phase II was the addition of even more frequent meetings with the students. Thus, students were able to better pace their research and writing over the course of the semester. These meetings were established at the request of either the instructor or the students. With a writing project of this magnitude, students appreciated the many opportunities to give a progress report and to receive oral and written feedback on their work.

New to Phase II was the creation of an author and paper topic list that was distributed to all students electronically. Several students were researching topics that were related in that they involved similar physics principles and ideas. The author and topic list allowed students to work collegially in the sense that they could easily share important resources with each other.

During Phase II, the topics students were researching were brought up and discussed frequently during the class sessions. These discussions served to encourage students as well as to call their attention to the research being conducted by various members of the class. These discussions also helped students to realize the importance of collaboration amongst peers. This type of collaboration also served to foster a more genuine community of learners than might be found in a more traditional, lecture-type course.

Class discussions regarding the ongoing research projects also encouraged students to view their classmates, and, more importantly, their instructor as "co-searchers." Kutz (1993) described this type of co-searcher collaboration as one in which an instructor helps students frame questions and design projects, suggests ways to analyze data and readings that might answer specific questions generated by the research, and engages them in discussions about these questions. For many students in the class, this format required a significant paradigm shift in terms of how they were most comfortable in viewing the role of their instructor.

During many of the class discussions

students were reminded of the fact that they were the authors and their instructor was simply offering suggestions to them. Many students were initially uncomfortable with not being told exactly what they needed to do with their research projects. Instead they were given suggestions and advice and were thus required to make significant choices on their own. For many students, this was the first time they had ever experienced this level of independence in a college classroom.

During Phase I the only aspect of the submission process that was handled electronically was the call for papers. Once students had submitted their abstracts, the remainder of the process was carried out through hard copy paper submissions. To provide students with a more authentic experience, all aspects of the submission process was converted to a web-based format during Phase II. A web site was created which allowed students to submit their abstracts, paper drafts, and final papers electronically. This process was very efficient and substantially reduced the number of late submissions. The electronic submission process also served to enhance the activity by providing a more professional overall format. Figure 8 shows a view of the electronic submission site created for Phase II of this study.

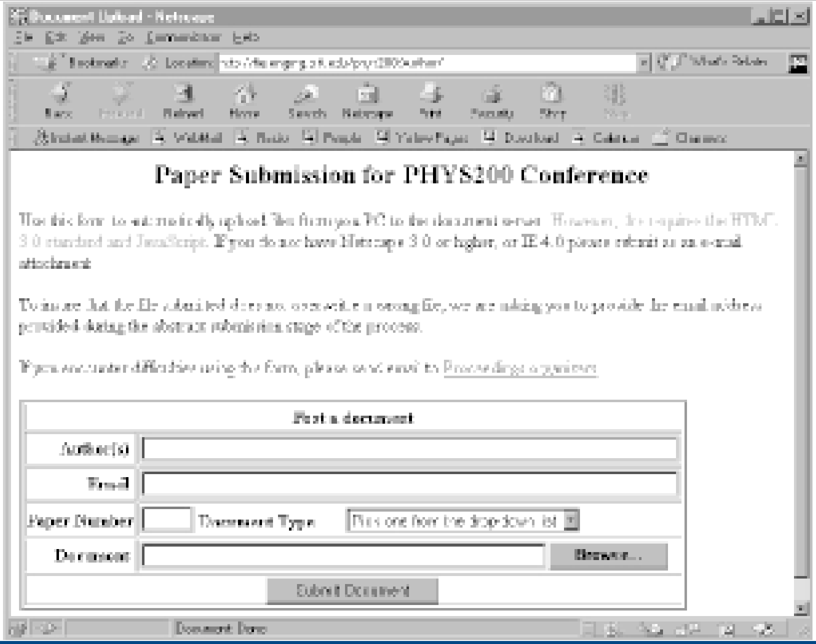

Figure 8. The electronic submission site for 2001 New Millennium Conference Papers

During Phase I, the paper review pro-

2001 New Millennium Conference Review Form

Please review this paper critically. Your professional judgement will help maintain the quality and credibility of the papers that appear in the Conference Proceedings. One of the main goals of this review is to assist the authors in improving their work. Thus, be sure to consider the demeanor of your comments and their intent.

A. Reviewer's Recommendation (please recommend as you feel appropriate).

- ■ ACCEPT paper as is for publication in the conference proceedings.
- ■ ACCEPT paper for publication with minor revisions, as indicated.
- ■ ACCEPT paper for publication with major revisions, as indicated.
- ■ REJECT paper - do not publish (please give a brief summary of your reasons for rejection in the "Additional Comments" Section given below).

B. Specifics

Respond in writing to each of the items listed below. Your responses must be typed and in a format suitable for use by the author. Your responses must be completed by Friday, March 30, 2001.

1. Does the paper present new and/or innovative ideas or materials?
2. Is the paper written at a level appropriate for the intended audience?
3. Is the information in the paper sound, factual, and accurate? If no, please explain why.
4. On a scale from 1 - 5, rate the paper on its contribution to the "body of knowledge" in science, engineering or technology education particularly as it relates to the general population. (none = 1, very important = 5) What is the major contribution(s) of the paper?
5. On a scale from 1 - 5, rate how well the overall ideas in the paper are presented. (very difficult to understand = 1, very easy to understand = 5)
6. Rate the overall quality of the writing. (very poor = 1, excellent = 5)
7. Is the formatting of the paper done correctly following the conference guidelines?
8. Does the paper cite and use appropriate references?
9. Does the paper make appropriate use of tables, figures, and/or other illustrations? Would the inclusion of additional tables, figures, and/or illustrations enhance the paper in any way? If so, how?
10. Does the paper use gender neutral language?
11. Should anything be deleted or condensed in the paper? Please be specific.
12. Is the treatment of the subject complete (i.e. no important ideas, analysis, or information)? If no, please explain.
13. Additional comments. This is the place to comment on other items you feel are important to the quality of the paper but weren't specifically addressed in the questions listed above.

Figure 9. Template for the peer review process

cess was conducted entirely by the course instructor. Thus all papers had only one reviewer. Many students did have a friend who was not taking the course read over their papers, primarily checking for errors in grammar and spelling. This process was revised during Phase II to incorporate a formal peer review. Students were paired up for the peer review based on the topics they were researching. For example, one student was researching the topic of how the concept of color is taught at the elementary level while another student was researching the topic of rainbows. Both students were researching topics related to color and light and hence were paired together to exchange papers for the review. The pairing of students with similar research topics allowed students to feel that they could provide not only a review of grammar and style, but also a more technical review of the key physics content. Figure 9 shows the review template students were given which provided needed structure and which framed the backbone of the review process.

Several researchers have documented the importance of having students participate in a peer review process (Trautman, Carlsen, Krasny, & Cunningham, 2000; Towns, et al., 2000/2001). The implementation of a peer review during Phase II was an important addition to the writing activity. An unanticipated, yet positive result of the peer review process was that students became better equipped to make revisions to their own papers. This occurred because students were forced to become more familiar with the paper submission guidelines in order to provide their peers with constructive feedback.

In terms of assessment, students were continuously reminded that their grades for the writing activity were going to be based on a more authentic assessment process and not simply a final product. From the time abstracts were initially accepted to the time final papers were submitted, students accumulated points that would be included in their final paper grade. The conference paper and presentation were worth approximately one-third of a student's grade in the course and essentially replaced the traditional final examination. The review template given in Figure 9 formed the backbone of the rubric that was used to assess the written conference paper.

Assessment of the overall paper preparation process, rather than just a final product, provided a more effective vehicle for authentic assessment of student learning. During the frequent progress report meetings, the instructor was able to better gauge students' understanding of the key physics content that was linked to topics within students' papers. By listening to the students discuss the progress they were making the instructor could clearly see that students were becoming more fluent in their understanding of key physics content. In addition, the instructor was able to ascertain a deeper level of student understanding than more traditional forms of assessment would provide. Thus, this assessment strategy provided a richer and more robust way for students to demonstrate their understanding of physics.

The improvements made during Phase II of the study served to provide more structure and a greater level of professionalism to the activity. Furthermore, as a result of the additions and improvements made during Phase II, students appeared to take a deeper level of ownership in their projects much earlier in the semester.

Feedback From Students: Phase II

The enhancements made to Phase II of the study led to an even greater sense of accomplishment for the students. Many students have added their conference paper to their personal portfolios. Others have used their papers when applying for internships and the like to demonstrate their communication abilities to prospective employers. Many students in Phase II of the study indicated that they felt the entire paper preparation process was very practical and worthwhile. The following is an excerpt from a letter received by the instructor which typifies the sentiments expressed by many Phase II students:

> *"I was pleased by how all of the presentations went, it was a fun day. This research paper, although demanding, was a great experience. It allowed me to learn how to write a good looking professional paper, and, in turn, taught me many interesting facts about digital audio and CD players. After completing 2 semesters of physics, I can truly say that these courses have changed the way I look at life. Although I am glad to have this new outlook on life, it drives my friends crazy when I disprove their theories on why things happen! Thanks for your genuine teaching."*

Summary and Conclusions

All aspects of *The New Millennium Conference*, from submission of an abstract to the formal submission of a camera-ready copy 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 a deeper understanding of a topic or a set of topics using their individual learning styles. This activity also provided the instructor with an additional and more authentic assessment tool, outside the limits 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" (Shaping the Future, p. 28).

Writing has proven to be an effective way to assist students in articulating their thoughts and their understandings about a topic or set of topics. The opportunity to write about a topic of personal interest gives students a chance to demonstrate their understanding in a way that traditional assessment measures do not permit. Furthermore, the research involved in a semester-long writing project, such as that described within this paper, provides students an opportunity to probe more deeply into the content being researched. This added depth may potentially lead to greater student understanding of important concepts and ideas. Hence, the application of a writing component into a course for non-majors (as well as majors) has significant potential within science and engineering communities.

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