# AC 2009-1689: PEER REVIEW FROM A STUDENT PERSPECTIVE

# Teresa Larkin, American University

Teresa L. Larkin is an Associate Professor of Physics Education in the Department of Physics at American University. She also serves as Faculty Liaison to the Pre-engineering Program. Dr. Larkin received her B.S. and M.S. degrees in Engineering Physics from South Dakota State University in Brookings, SD in 1982 and 1985, respectively. She received her Ph.D. in Curriculum and Instruction with special emphasis in Physics and Science Education from Kansas State University in Manhattan, KS in 1997. Dr. Larkin's research interests primarily involve the assessment of student learning in introductory physics courses. She makes use of writing as a learning and assessment tool for understanding how non-majors learn physics. Embedded within this research is the study of how the formal assessment of student learning styles can enhance learning in physics. An additional focus of her research involves studying the role of technology as an assessment and learning tool. Dr. Larkin has been an active member of the American Association of Physics Teachers (AAPT) and the American Society for Engineering Education (ASEE) for over 20 years. She served on the AAPT Minorities in Physics Committee from 1997 - 2000, was Chair of the Physics and Engineering Physics Division from 1994 - 1996 and from 1998 – 2004, and was Chair of the Women in Engineering Division from 2000 - 2002. Dr. Larkin served on the Board of Directors for ASEE from 1997 - 1999 as Chair of Professional Interest Council III (PIC III) and as Vice President of Professional Interest Councils. In 1998 she received the Distinguished Educator and Service Award from the Physics and Engineering Physics Division of ASEE. She served as a National Science Foundation ASEE Visiting Scholar during the 2000 - 2001 academic year. In April 2000 Dr. Larkin was awarded the Outstanding Teaching in the General Education Program Award from American University. Dr. Larkin has received numerous international awards including the Excellence Award in Recognition of Meritorious Services and Outstanding Contributions in the Fields of Engineering, Computer Science, and Technology Education in the 21st Century at the World Congress on Computer Science, Engineering, and Technology Education (WCCSETE 2006) held in Itanhaém, Brazil as well as an Honoring Award in Recognition of Extraordinary Achievements and Contributions to the Fields of Engineering and Computer Education Worldwide at the International Conference on Engineering and Computer Education (ICECE2007) in Santos/Monguaguá, Brazil. In her free time, Dr. Larkin enjoys reading, traveling, and spending time with her family, including the family cat, Mikaela Rose. She also enjoys preparing (and especially eating) Indian, Ethiopian, Chinese, and Thai cuisines. Dr. Larkin can be reached at: American University, Department of Physics, 4400 Massachusetts Ave. NW, Washington, DC 20016-8058; 202-885-2766. [tlarkin@american.edu]

# Peer Review from a Student Perspective

#### ABSTRACT

Writing has been shown to serve as an effective tool to improve the quality of student engagement and learning. This paper will provide a strategy in which writing can be used to enhance student understanding within the introductory physics classroom. This strategy has been previously reported and involves having students research, write, and present a paper at a formal class "conference" held at the end of the term. Throughout this process, students are exposed to all aspects of preparing a professional conference paper including the submission of an abstract, preparation of a paper for review, participation in a rigorous peer review, and presentation of their final paper at the conference. A significant focus of this paper will be to expand upon the discussion of the peer review process. The rubrics developed and used during the peer review process will be shared. Following the completion of the spring 2008 semester, students in a second-level introductory physics course who had completed the writing tasks in their entirety were given a questionnaire. Highlights from the results of this questionnaire will be shared. Of particular interest is how the students made use of the peer review process as they were engaged in the writing task. Of additional interest is how the peer review experience has translated into other areas of their academic endeavors. It is anticipated that an understanding of peer review from a student perspective would be valuable for educators who are interested in, or who are currently engaged in, similar types of writing activities in their own classrooms.

# I. INTRODUCTION

For educators, a primary goal in teaching is to facilitate student learning. However, traditional teaching methodologies, particularly in science classes have clearly been shown to put students in a role of passive rather than active learning [1]. Traditional instructional methods have also been shown to be very 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. A troubling fact is, after instruction, students often emerge from our classes with serious misconceptions [2 - 6]. Research on the constructivist approach to learning (i.e. the learner must *construct* their knowledge) reveals that when students are actively engaged with the material, learning is clearly enhanced [7]. The active process of writing within a science classroom has great potential for making the learning experience for students richer and more robust.

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 - 21]. The use of writing in introductory classes for non-majors (and majors alike) 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 [22].

Science classes are seen by many students to be threatening and intimidating places to be. Tobias [23] 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 these barriers to learning could be reduced and possibly even removed. Tobias [24] 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 strategy for infusing writing into the introductory physics curriculum for non-majors. This strategy is used in a second-level physics course at American University. Following a brief description of the course and the student population the writing strategy will be described. Of particular interest in this paper is to take an initial look at the peer review process from a student perspective. To this end, a questionnaire was given to students in the spring 2008 physics class after the end of the term. Selected questions are summarized and feedback from students presented. One objective is to look at students' conceptions of the review process and to compare their feedback on questions related to the peer-review versus instructor-review portions of the writing activity. In addition, a summary the effectiveness of incorporating a writing strategy(s) into science, technology, engineering, and mathematics (STEM) classrooms will be shared.

# II. THE PHYSICS FOR A NEW MILLENNIUM COURSE AT AMERICAN UNIVERSITY

The writing strategy to be described is used within an introductory level physics course for non-science majors at American University. The course is entitled *Physics for a New Millennium (PNM)* and is a second-tier course in the Natural Sciences portion of the General Education core. Prior to enrolling in PNM, students have typically taken the first-level foundation course in physics. In addition, American University offers a unique minor in Applied Physics (in addition to the traditional minor in Physics). Students are allowed to count their introductory General Education courses towards the Applied Physics minor, and approximately half of the students enrolled in the course choose that option.

The PNM course was designed to build upon the foundation laid in the first-level introductory physics course. The content of the PNM course includes:

- Waves & Sound,
- Electricity & Magnetism,
- Light, Color, & Optics, 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 lab-lecture approach. During these activity-oriented sessions, students are able to perform a number of interactive, hands-on, investigative activities. While this approach has been ongoing at American University for the past decade, many other universities are now seeing the benefits of an integrated, active-learning format for introductory physics instruction [25].

Numerous interactive projects have been developed for the PNM course. For example, students explore the topics of electricity & magnetism by constructing electric circuits and building their own individual battery-operated motors. Students also dissect an incandescent bulb and learn how a 3-way bulb is configured. Figure 1 shows a typical scene during the activity-oriented sessions and depicts students actively engaged in some electrical measurements.



FIGURE 1 M Students Actively Engaged with Electrical Measurements

Furthermore, throughout the course, numerous strategies, including the writing activity to be described, have been developed that center around the accommodation of students' diverse learning styles [26 - 31].

The following sections present a description of the writing activity developed for use in the PNM course. The activity involves the preparation of a formal conference paper based on research that they carry out over the entire semester. The conference paper activity was designed to give students experience with all aspects of preparing a formal professional research paper for publication and presentation at an actual conference.

# III. THE CONFERENCE PAPER ACTIVITY

At the beginning of the semester students enrolled in PNM are informed that one of the key components of the course would be the preparation of a formal written research paper for publication and presentation at a "conference" to be held at the end of the term. Students are allowed to choose a topic that interests them provided that the physics content involved closely parallels one or more of the topics covered on the course syllabus. The idea was to have students explore a topic(s) in more depth than would be covered in class, thus making students the "experts." Some of the topics students in the spring 2008 PNM class chose to write about are expressed in the following paper titles:

- Capturing the Stars: The Reflecting Telescope
- LASIK: Bringing "Good" Vision to "Great" Vision
- RFID: Radio Frequency Identification
- The Sound of Music: The Physics of a Violin
- Acoustics of the Mixing/Mastering Studio
- Professional Recording: Evolutions in Audio Technology
- The Deadliest Predators: Sharks and the Bioelectromagnetic Sense

In addition to writing about topics that relate to topics covered in class during the semester, students are also encouraged to choose topics that overlap in some way with their major area of study. For example, the student that wrote about bioelectromagnetism and sharks is an Environmental Science major with a minor in Applied Physics.

Throughout a given semester, students are exposed to all aspects involved in the preparation of a formal paper for publication. These aspects include:

- responding to a call for papers by electronic submission of an abstract to the conference web site,
- receiving formal confirmation of the acceptance of their abstract,
- conducting the necessary research,
- preparing and submitting a first draft for formal instructor review,
- receiving instructor feedback,
- preparing and submitting a second draft for formal peer review,
- receiving peer review feedback,
- preparing a final "camera ready" version of their paper, and,
- presenting their paper at a formal conference held on the last day of class.

All aspects of the paper production and submission process are handled electronically.

Two days prior to the actual conference, students meet with the instructor to go through a practice-run of their presentations. The students prepare and make use of PowerPoint slides as well as demonstrations during their presentations.

Students are given 10 minutes for their presentations and then allowed two minutes for questions. Because the students had practiced their presentations extensively prior to the conference, each presentation fit nicely into the time allotted. Overall, the presentations made by students are impressive and professionally done.

Students are asked to wear appropriate attire for the conference. When students arrive to class on the day of the conference they were given a nametag and a bound copy of the conference proceedings which included a copy of each of their papers. Figure 2 shows one of the students from the spring 2008 PNM class presenting her paper.



FIGURE 2 Student Presentation on "LASIK: Bringing 'Good' Vision to 'Great' Vision

The conference is always well-attended. Numerous department faculty members, former students who have taken the course and parents of the presenting students often attend. For the spring 2008 conference, several parents drove considerable distances and one mother even flew

in from the Midwest on the morning of the conference to see her daughter present her paper. It is not uncommon for the Director of the General Education program and the Dean of the College of Arts and Sciences to attend the conference as well. Typically, the audience size is approximately 30 - 50 individuals for any given presentation. The conference has evolved into a "showcase" activity for the students as well as for the course.

Many students from previous classes have noted that they have used their papers as a writing sample when applying for internships or professional jobs. Because of the nature of their papers (i.e. physics), their writing has served as a wonderful example of their ability to communicate in written form. In addition, due to the fact that their papers were also presented at a formal conference, students have been able to demonstrate their oral communication skills to potential employers. The use of their papers as an example of written and oral communication skills to a potential employer was not a primary goal when the activity was originally crafted and implemented in PNM approximately 10 years ago. Over the past decade, there have been so many success stories highlighted by students that it has now become one of the selling features of the course.

A brief overview of the assessment process used for the conference paper activity is provided in the following section. Of particular interest are the students' perceptions in regard to the peer review process. Typically, none of the students have had any type of experience performing a peer review in any of their other classes, so the experience they have in PNM is quite unique.

## IV. ASSESSMENT OF CONFERENCE PAPER ACTIVITY

The conference paper activity accounts for about 35% of a students overall course grade. In fact, given the significance of this activity, the course conference replaces a more traditional paperand-pencil final exam. The activity is presented to the students on the first day of class and continues throughout the entire semester. Each milestone in the paper writing process (submission of abstract, preparation of paper drafts, etc.) is given a certain number of points. Students begin accumulating points as they move from one milestone to the next. The individual milestones are given a certain amount of weight depending upon their level of sophistication and the estimated amount of time required to complete each one.

Students are given formal written guidelines (which were originally adapted from the Frontiers in Education (FIE) conference) that they have to follow. Papers that strictly adhere to the guidelines are given higher marks than those that do not. In addition, for the peer review, students are given an outline and a set of questions that they must respond to as they complete their reviews. This outline is presented in Figure 3 on the following page. The outline serves as a framework for the grading rubric used to assess the peer reviews.

The paper writing process is similar to making timely deposits in one's savings account. As more deposits are made, the savings account grows in value. Likewise, the students' scores continue to increase as they work towards the overall total points possible for the paper writing and conference activities. The paper and presentation are graded separately. Students also complete evaluations of each of their student colleagues' presentation. These evaluations do not affect the students' grades, but do provide them with collegial and constructive feedback.



Please review your assigned 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 <u>each</u> of the items listed below. Your responses must be thorough and typed in a format suitable for use by the author. In addition, hand-written comments, corrections, and suggestions should be placed directly on the document. It is recommended that your hand-written comments be recorded in pencil. Your hand-written comments on the paper draft itself should be substantive and in a form legible and useful for the author. Your responses must be completed by Tuesday, April 1, 2008.

- 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?
- Is the information in the paper sound, factual, and accurate? If no, please explain why.
   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
- 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? Are tables and figures properly referenced? 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, condensed, or expanded upon in the paper? Please be specific.
- Is the treatment of the subject complete (i.e. important ideas, analysis, or information)? If no, please explain.
   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 3 PEER REVIEW OUTLINE

During the fall 2008 semester, a questionnaire was sent via email to all students that had taken PNM in spring 2008. The questionnaire was designed to assess students' perceptions regarding the conference paper activity, and in particular, their thoughts about the peer review process. The following section provides an overview of that questionnaire followed by a summary of the feedback received from the respondents.

V. ASSESSMENT OF THE PEER REVIEW PROCESS FROM THE STUDENTS' PERSPECTIVE

The spring 2008 class was taken by 18 students. The class is usually limited to 16 students, but in order to accommodate students who are pursuing the Applied Physics minor, the enrollment grew to 18. While not a large class in a traditional sense, 18 is really the maximum

for a course that focuses on an integrated and activity-oriented approach to teaching and learning physics.

The questionnaire sent to the students consisted of 12 questions that focused specifically on the peer review portion of the conference paper activity. A 50% response rate was achieved with 9 of the 18 students completed and returned the questionnaire. For purposes of this paper, student responses from 2 key questions will be summarized. The questions to be probed are summarized in Table 1.

 TABLE 1

 Summary of Questions asked Students

QUESTIONNAIRE ON WRITING ACTIVITY/PEER REVIEW	
QUESTION	Focus
1	On a scale of $1 - 7$ (with 1 being the lowest and 7 being the highest) please rate how helpful the overall peer review process was to you. Please expand upon your rating by providing your thoughts about the overall peer review process.
2	On a scale of $1 - 7$ (with 1 being "no comparison to" and 7 being "very similar to") please rate how helpful the feedback you received on your second draft (which involved the peer review) was to you in comparison to the instructor-given feedback you received on the first draft.

The following section provides a summary of the students' responses to the questions highlighted above. Of particular interest is a comparison of the students' perceptions of the feedback they received from their student colleagues and the feedback they received from the instructor. As the students' responses are summarized, a key question emerges: Do students perceive the quality of the feedback they received from their peers as being as valuable as the feedback they received from the instructor?

# VI. FEEDBACK FROM STUDENTS

One of the goals of the paper writing activity was that students needed to write at a level suitable for an audience of their peers. In essence, the students were not asked to write at a level suitable for an audience of persons with physics degrees. Rather, they were to present their papers at a level that could be understood by students taking a second-level introductory physics course. The first review of the students' papers was conducted by the instructor when their first drafts were initially submitted. The peer review took place after students submitted the second draft of their papers.

Table 2 (on the following page) provides a summary of students' responses to question 1. Inspection of these responses reveals that students appreciated having a "colleague" review their papers. In addition, students appreciated having a "non-physicist" critically review their papers. Several students indicated that this was extremely helpful. In addition, the act of reviewing another classmate's paper provided them with critical insight into making improvements on their own paper. This was an added bonus for the students. Not only did they receive constructive criticism from a classmate, but the active process of reviewing a classmate's paper provided them with additional ideas for enhancing their own papers.

TABLE 2

SUMMARY OF RESPONSES TO QUESTION 1

On a scale of 1 – 7 (with 1 being the lowest and 7 being the highest) please rate how helpful the overall peer review process was to you. Please expand upon your rating by providing your thoughts about the overall peer review process.

# AVERAGE RATING: 5.6 SUMMARY OF STUDENT RESPONSES

- By having other students go over your paper they could provide useful feedback. The best way they did this was to remind you of your audience and make you fully explain your topic clearly and thoroughly.
- My peer review process was very helpful. The person who reviewed my work took the time to read my paper and understand what I was discussing, as well as trying to think of other directions I could take my paper in. The person served as a second set of eyes in regard to grammar and spelling, while they also helped with topic issues and possibilities to improve and expand.
- Whoever reviewed my paper focused too much on the grammar and not enough on the physics. I was more offended by her annoying analysis of my word choice than what she had to say about the physics. Not helpful.
- I think it helped a lot to get our papers peer reviewed, allowing for two people to catch any mistakes and to correct or make improvements.
- The peer review helped determine whether the paper was clear and understandable to an average person without a strong background in physics. Reviewing a fellow student's paper let me know what mistakes to look for on my own. At the same time, I felt that the instructor's feedback was more useful than the peer review.
- I think that the peer process is important because you're reading someone's paper that is in the same boat as you. They're also waiting until the last minute to put the finishing touches on their paper just like you did; there's something about that that bonds you together. It also gives you another perspective on your own writing other than holistically sometimes; professors just read the papers to grade it's nice to have a person's view who isn't going to be the one grading you.
- Having a peer review process in addition to the professor's review was extremely helpful. Not only did I get to enjoy reading another student's paper (and thus got more "out of" their presentations) but I was more eager to address the issues the peer brought up than the professor's comments. The peer review made the paper more a group learning process than just a student-teacher dynamic.
- I found that by reading another student's paper, I was not only able to gain confidence in my work, but also able to pick out techniques that they used to explain things that would be useful in my paper. The one downside to the peer review is that I feel my peers would always be more lenient than a professor or TA perhaps. The good side is they provided insight from a student's perspective, which might not have as much detailed knowledge on a subject as a professor would, which helped me to find the areas of my paper that needed further explanation. However, I feel that without feedback from Prof. L, my paper wouldn't have improved nearly as much as it could have.
- Gave me insight about my paper that I otherwise would not have received.

Table 2 (on the following page) provides a summary of students' responses to question 2. Student responses revealed that they relied more on the instructor's feedback in regards to the technical content of their papers, noting that the instructor obviously knew more physics than the students did. On the other hand, some students indicated that the peer review was very useful in terms of helping them clarify their writing to make it more understandable for the intended audience. The instructor's comments were also seen as more useful in terms of helping students overall presentations of their written papers.

 TABLE 3

 Summary of Responses to Question 2

# On a scale of 1 – 7 (with 1 being "no comparison to" and 7 being "very similar to") please rate how helpful the feedback you received on your second draft (which involved the peer review) was to you in comparison to the instructor-given feedback you received on the first draft.

# AVERAGE RATING: 3.8 SUMMARY OF STUDENT RESPONSES

- The instructor's comments were more focused on the actual science while the students did a lot of commenting on format. Where it became helpful from the student's standpoint was that they pointed out where the science being described was confusing and needed further clarification.
- I think the instructor's feedback was very helpful, although I got a lot of "awkward" remarks that I wasn't sure what to do with.
- Teacher feedback was much more helpful. Gave ideas for expanding on physics concepts and not on grammar and writing skills as much.
- I honestly don't recall the second set of feedback. I think that it was very similar to the first set, except with a few grammatical and spelling changes that differed from before.
- The instructor feedback was the first review of the paper, so it needed more work to begin with. The instructor was much more detailed than the peer and recommended information to add to the paper. The instructor also knows more about physics and the format and style of scientific papers, so she was able to give very helpful comments on the physics concepts in the paper as well as the formatting details. The peer review, on the other hand, was much sparser in its comments and did not contribute significantly to the overall direction or format of the paper. This could be because the paper had already undergone significant edits from the instructor review.
- Like I mentioned before, it's helpful to have another perspective that isn't the one that's going to be grading your paper in the end. Having the teacher grade the first paper is helpful because they provide feedback on what you're originally not getting across initially I found that with the second peer review feedback the students find things that you need to elaborate more on because they haven't researched the topic and need to understand better.
- The instructor feedback was more helpful because it told me what she was looking for in the paper. The peer feedback just pointed out what I missed.
- The peer reviewer definitely had more of an eye for content issues, where as the instructor feedback was more likely to focus on structure and technical issues. The peer was more likely to write questions as comments, questions about what exactly things in the paper meant or questions asking that more information be given especially if they became interested in the topic. Also, if the peer reviewer liked something, or was particularly struck by some fact or topic, they were more likely to make a note stating so. This was very encouraging. The instructor, on the other hand, would consistently make notes about technical issues, which they clearly knew more about than the peer reviewer. This was helpful because it contributed to the overall presentation of the paper.
- As I explained above, the type of feedback was helpful in that it came from a person, who lacking specific knowledge on a given topic, could tell you where you need to better clarify details, but in the overall scheme of things, the comments from Prof. L. were more helpful, in my opinion, because they were much more detailed.

It is interesting to note that the student respondents seemed to take this activity as something more than just an academic exercise. None of the student respondents mentioned the grade they received on the peer review. Instead, their responses indicate the value of the peer review in terms of helping them enhance and clarify the content of their papers.

## VII. SUMMARY AND CONCLUSIONS

Critical to both the peer- and instructor- reviews is the feedback the students receive. The benefits of instructor- (as well as peer-) feedback are numerous. This written feedback is absolutely essential. Numerous studies have pointed out the importance and value of prompt and thoughtful feedback to students [32 - 36]. The instructor-student relationship is quickly fostered and enhanced. Because students are given prompt critical and detailed feedback, they take the writing activities very seriously. The quality of student work is clearly improved. Furthermore, the writing activities serve to motivate many students to go above and beyond what is required purely for the sake of learning physics.

All aspects of the conference paper activity, from submission of an abstract to the formal submission of a camera-ready copy of their paper for publication and presentation, allow students the opportunity to link the active process of writing to sound, scientific content. In addition, these activities allow students to demonstrate their understanding of a topic or set of topics using their individual learning styles. This type of writing activity also provides the instructor with an additional assessment tool outside the bounds of traditional assessment measures.

The peer review process served not only to give students an opportunity to receive critical feedback from a second person, but it also allowed them an opportunity to provide critical feedback to a classmate. This type of activity is a somewhat more non-traditional type of assessment in the sense that the instructor is not the only one providing students with feedback. Student respondents to the questionnaire found a different value in the critique they received from their peers as opposed to that which they received from the instructor. Interestingly, the students did not disregard the feedback they received from their peers thinking that it didn't really matter because they weren't being graded by their peers. Rather, the majority of student respondents found that the feedback they received had a unique flavor to it that allowed them to make additional enhancements and revisions to their final paper.

Important to note is the fact that the PNM course was designed with non-majors in mind. However, the writing strategies 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 learn to like physics!).

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 can allow students a chance to demonstrate their understanding in a way traditional assessment measures do not permit. Hence, the inclusion of a writing component into a course for non-majors (as well as majors) has enormous potential within science and engineering communities. Finally, the inclusion of a peer review component is useful, both in terms of the feedback it generates for the students, and in the experience it provides students over and above simply solving the problems at the end of a chapter in a physics book.

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The author would like to thank all of the awesome students in her spring 2008 PNM class. In particular, those students who provided many thoughtful and robust comments regarding their overall experiences with the conference paper activity. Your keen insight provided me with an opportunity to continue to enrich this experience for future classes. Many thanks to all of you!!

# IX. REFERENCES

- 1. Jones, T. H. & Paolucci, R. (1998). The learning effectiveness of educational technology: A call for further research. *Educational Technology Review*, (9), 10 14.
- 2. Arons, A. B. (1990). *A Guide to Introductory Physics Teaching*. New York: John Wiley & Sons.
- 3. Halloun, I. A. & Hestenes, D. (1985). The initial knowledge state of college students. *American Journal of Physics*, <u>53</u>(11), 1043 1055.
- 4. McCloskey, M., Caramazza, A., & Green, B. (1980). Curvilinear motion in the absence of external forces: Naïve beliefs about the motion of objects. *Science*, <u>210</u>, 1139 1141.
- 5. McDermott, L. C. (1984). Research on conceptual understanding in mechanics. *Physics Today*, <u>37</u>, 24 32.
- McDermott, L. C. (1991). A view from physics. In M. Gardner, J. Greeno, F. Reif, A. H. Schoenfeld, A. diSessa, and E. Stage (Eds.), *Toward a Scientific Practice of Science Education* (pp. 3 30). Hillsdale, NJ: Lawrence Erlbaum Associates.
- 7. Knight, R. D. (2002). *Five Easy Lessons: Strategies for Successful Physics Teaching*. San Francisco, CA: Pearson Education, Inc., publishing as Addison Wesley.
- 8. Connolly, P. & Vilardi, T. (1989). *Writing to Learn in Mathematics and Science*. New York: Teachers College Press.
- 9. Countryman, J. (1992). *Writing to Learn Mathematics: Strategies That Work*. Portsmouth, NH: Heinemann Educational Books, Inc.
- 10. Hein, T. L. (1998). Using student writing as a research and learning tool. *AAPT Announcer*, <u>27(4)</u>, 79.
- 11. Hein, T. L. (1999). Writing: An effective learning tool for non-science majors. *AAPT Announcer*, <u>29</u>(2), 114.
- 12. Kirkland, W. L. (1997). Teaching biology through creative writing. *Journal of College Science Teaching*, <u>26</u>(4), 277 279.
- 13. Mullin, W. J. (1989). Writing in physics. *The Physics Teacher*, <u>27</u>(5), 342 347.
- 14. Rice, R. E. (1998). 'Scientific writing' A course to improve the writing of science students. *Journal of College Science Teaching*, <u>27(4)</u>, 267 272.
- 15. Sharp, J. E., Olds, B. M., Miller, R. L., & Dyrud, M. (1999). Four effective writing strategies for engineering classes. *Journal of Engineering Education*, <u>88</u>(1), 53 57.
- 16. Kalman, C. S. (2007). *Successful Science and Engineering Teaching in Colleges and Universities.* Bolton, MA: Anker Publishing Company, Inc.
- 17. Larkin-Hein, T. (2001). Writing as a Teaching and Learning Tool in SMET Education. *Journal of SMET Education: Innovations and Research*, <u>2</u>(1&2), 25 35.
- 18. Larkin, T. L. (2007, March). *Writing: A Global Active Learning Tool in STEM Education*. International Conference on Engineering and Computer Education (ICECE 2007), Santos/Monguaguá, Brazil, Plenary Session II.

- 19. Larkin, T. L. & Budny, D. (2008, June). *Student Writing: An Active Learning Tool in Physics and Engineering Education*. Annual Conference of the American Society for Engineering Education, Pittsburgh, Pennsylvania (Session 2480). Article published in the electronic proceedings.
- 20. Budny, D. & Larkin, T. L. (2008, September). Using a Professional Conference Setting to Use Writing As An Active Learning Tool. Proceedings of the 37th International IGIP Symposium, Session WG3 Mathematics and Natural Sciences in Engineering Education, Moscow, Russia.
- 21. Larkin, T. L. & Budny, D. (2008, October). *Peer Review from a Student Perspective*. IEEE/ASEE Frontiers in Education Conference, Saratoga Springs, New York. Article published in the electronic proceedings, Session F2C, pp. 14 - 15. IEEE Catalog Number: CFP08FIE-CDR. ISBN: 978-1-4244-1970-8. Library of Congress: 79-640910. ISSN: 0190-5848.
- 22. Hein, T. L. (1999). Using writing to confront student misconceptions in physics. *European Journal of Physics*, <u>20</u>, 137 141.
- 23. Tobias, S. (1990). *They're not dumb, they're different: Stalking the second tier*. Tucson, AZ: Research Corporation.
- 24. Tobias, S. (1989). In Paul Connolly and Teresa Vilardi (Eds.), *Writing to Learn Mathematics and Science*. New York: Teachers College Press.
- 25. Rimer, S. (2009, January). At M.I.T. Large Lectures are Going the Way of the Blackboard. New York Times.
- 26. Hein, T. L. (1995). *Learning style analysis in a calculus-based introductory physics course*. Annual conference of the American Society for Engineering Education (ASEE), Anaheim, CA (Session 1480).
- 27. Hein, T. L. & Zollman, D. A. (1997). Digital video, learning styles, and student understanding of kinematics graphs. *AAPT Announcer (Addendum)*, <u>26(4)</u>, 3.
- Hein, T. L. & Budny, D. D. (1999). *Teaching with STYLE: Strategies that work*. Electronic proceedings of the annual conference of the American Society for Engineering Education (ASEE), Charlotte, NC (Session 3280).
- 29. Hein, T. L. & Budny, D. D. (1999). *Research on learning style: Applications in science and engineering*. Electronic proceedings of the International Conference on Engineering and Computer Education (ICECE), Rio de Janeiro, Brazil.
- Hein, T. L. & Budny, D. D. (1999). *Teaching to students' learning styles: Approaches that work*. Electronic proceedings of the Frontiers in Education (FIE) Conference, San Juan, Puerto Rico. IEEE Catalog number 99CH37011. ISBN 0-7803-5643-8.
- Larkin—Hein, T. & Zollman, D. (2000). Digital Video, Learning Styles and Student Understanding of Kinematics Graphs. *Journal of SMET Education: Innovations and Research*, <u>1</u>(2), 17-30.
- 32. Larkin, T. L., (2007, March). *Writing: A Global Active Learning Tool in STEM Education*. International Conference on Engineering and Computer Education (ICECE 2007), Santos/Monguaguá, Brazil, Plenary Session II.
- 33. Brown, S. & Knight, P. (1994). *Assessing learners in higher education*. London: Kogon Page.
- 34. Gastel, B. (1991). *Teaching science: A guide for college and professional school instructors.* Phoenix, AZ: Onyx Press.
- 35. Harmelink, K. (1998). Learning the write way. The Science Teacher, 65(1), 36 38.
- 36. Wiggins, G. (1997). Feedback: How learning occurs. AAHE Bulletin, 50(3), 7 8.