New Methods for Teaching Introductory Physics to Non-Majors

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Abstract

Physics for a New Millennium is a recently developed second-tier course in the Natural Sciences portion of the General Education core of courses at American University. Students enrolled will have first completed a one-semester foundation course in introductory physics, *Physics for the Modern World*. The content of the new course includes the topics of Electricity & Magnetism, Light & Color, and Quantum Physics. In this paper a brief overview of the curriculum developed for both courses will be outlined. Emphasis will be placed on the interactive teaching and learning strategies developed and employed in the second-tier course. Selected strategies used to assess student understanding will also be described. These strategies include a unique writing activity that allowed students to participate in all aspects of preparing a formal paper for publication and presentation at a professional conference. Finally, feedback from students pertaining to their perceptions regarding the course will be highlighted.

I. Introduction

Traditionally, physics is taught in a typical lecture-style format in which the instructor provides information to the students by talking to them. Visual stimulation in a traditional classroom typically includes notes written by the instructor on a chalkboard or overhead projector and occasional demonstrations of the phenomena. This style of instruction focuses on the instructor, the only active participant in the class. Hence, in a traditional classroom, students are often passive participants. Although optimum for some students, this mode of instruction is deficient in many ways for others. One outgrowth of much research in physics learning is the basic idea that in order for meaningful learning to occur, the learner must be given an opportunity to actively interact with the material to be learned [1 – 3].

What do we want our students to know and be able to do after a semester or two of introductory physics? This question may sound simple, but is actually quite challenging. Once we have determined what we want our students to know, we must figure out a way to help him/her learn it. The issue is not as simple as describing the motion of an object from point A to point B! Tobias [4] suggested that for the physics community as a whole, the question really becomes "what works?" In answering this question, Tobias described as one of the most challenging issues discovering what works best, first theoretically and then practically, as curricular and instructional strategies.

When students enter the physics classroom, they bring with them their personal world views. Individuals form their understanding of the world around them based on their own personal life

experiences. The challenge for physics instructors is to help students uncover what part or parts of their world views are scientifically sound and which are not. This process of discovery is, in part, the essence of conceptual change teaching. The part of students' world views that are not scientifically sound are referred to by many researchers as misconceptions. Misconceptions are generally thought of as those conceptions that students bring with them into the classroom that essentially differ from that of the scientist. Other terms are also used to describe student misconceptions such as "preconceptions," "naïve conceptions," and "alternative conceptions."

Conceptual change is important in physics learning because each student sees the world through his/her own lens. Dykstra [5] revealed that presenting students with a Newtonian view of the world is usually not enough for students to reach the point where they are able to change the way they think about how the world works. Providing students with learning situations that afford them time to wrestle with concepts on their own is vital. As a result, students often experience "cognitive disequilibrium" or "cognitive dissonance," as their existing schemas or world views or challenged. In this state of discomfort, the learner recognizes existing schemata that are inadequate to explain the experience [6].

Scott, Asoko, and Driver [7] described strategies that can be used to promote conceptual change. The first centers around the issue of cognitive conflict and ways that conflicting perspectives can be resolved. The second considers strategies (such as the use of metaphors and analogies) which facilitate the construction of ideas that start by building upon the learners' existing ideas. These researcher suggested several teaching strategies designed to bring about conceptual change. An example of one such strategy is the connection of new topics via linkages to other "real world phenomena." Putting unfamiliar material into a familiar context is helpful in terms of promoting conceptual change.

Research within the cognitive domain involves studies that regard the complex sequences through which an individual begins to learn, then understand and process new and difficult information. Of additional interest is understanding how students use their existing knowledge as they attempt learn and understand new information. Studies of human cognition have emerged in recent years within the community of physics education researchers. Redish [8] succinctly stated "If we are to make serious progress in reaching a larger fraction of our students, we will have to shift our emphasis from the physics content we enjoy and love so well to the students themselves and their learning" (p. 802). Redish suggested that as teachers, we want to build upon students' understanding of the content into an accurate and effective mental model. For most individuals, the development of a mental model occurs through a process of making connections between new information to be learned and past personal experiences.

Arons [9] has also indicated that students in introductory physics courses display very basic cognitive difficulties. He further asserted that instructional materials have not traditionally been of much use in helping students overcome these difficulties. The courses described in this paper were designed with these very issues in mind. The instructional strategies used in these courses were developed, in part, to aid students in eliciting and confronting their misconceptions by providing students with "non-traditional" learning activities and experiences.

In the sections that follow, a summary of the curriculum as well as an overview of some of the teaching strategies used in two introductory physics courses for non-majors will be described. These courses include a foundation course, *Physics for the Modern World*, and a new, second-tier course, *Physics for a New Millennium*. Particular attention will be given to a learning strategy provided students in the *Physics for a New Millennium* course. This discussion will be followed by a summary of feedback received from students regarding their perceptions of the new course.

II. The Introductory Physics Curriculum for Non-Majors at American University

As part of the General Education requirements towards graduation at American University, students are required to take a 2-semester sequence of courses in Curricular Area 5, the Natural Sciences. Students first choose to take a foundation course in either the Biology, Chemistry, Psychology, or Physics Departments. Students who elect to take their foundation course from the Physics Department will enroll in *Physics for the Modern World*. Upon completion of the foundation course, students choose from six second-tier courses designed to complement and build upon the topics learned in *Physics for the Modern World.* One option students have is to enroll in *Physics for a New Millennium*, a new, second-tier course designed to give students an opportunity to explore cutting-edge science (and engineering) topics in more depth. Each of these courses will now be discussed in the sub-sections that follow.

Physics for the Modern World

The introductory foundation course for non-science majors at American University in Washington, D.C. is a one-semester, algebra-based course entitled *Physics for the Modern World* (PMW). Topics covered in the PMW course typically include Kinematics, Newton's Laws, Conservation of Momentum and Energy, Rotational Motion, Fluid Mechanics, Waves, and Sound. Although traditional in its content, the course is not taught in a "traditional lecture format." Numerous teaching strategies have been developed which correspond to the accommodation of students' needs and diverse learning styles [10 - 14]. One such strategy involves the use of writing [15]. A significant amount of research conducted in the sciences and in engineering suggests that the active process of writing can be an effective teaching and learning tool [16 – 24]. In addition, the PMW course includes strong conceptual and problem solving components.

Physics for the Modern World is a 3-credit course and consists of a lecture and a laboratory component. Students meet twice a week for class sessions that are 75 minutes long. On alternate weeks students meet for a two-hour laboratory. Approximately 120 students, with 60 students in each of two sections, enroll in the course each semester. Many students who enroll in *Physics for the Modern World* are liberal arts majors. A typical class consists of a mixture of students from the College of Arts and Sciences, the School of Public Affairs, the School of International Service, and the Kogod College of Business Administration.

Due to the wide range of majors in the course, one could assume that the diversity of students enrolled in *Physics for the Modern World* closely parallels the diversity of students enrolled at American University. The 1995 - 96 American University catalog describes its student

population as being "... cosmopolitan and multicultural ..." [25]. The spring 1999 classes of *Physics for the Modern World* included students from 24 states and 25 countries. Nearly 40% of the class is made up of international students.

Physics for a New Millennium

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 will have taken the foundation course *Physics for the Modern World* (PMW). The 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 curriculum for the new course includes: Electricity & Magnetism, Light & Color, and Modern Physics. The PNM 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 hands-on activity-oriented session. These activity-oriented sessions were designed and developed based on results from current research in physics education.

During the activity-oriented sessions, students are able to perform a number of interactive, hands-on, investigative activities. For example, students can explore the topics of Electricity & Magnetism by building electric circuits and motors. The topics of Light & Color and Modern Physics are 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 [26]. Using the quantum model of the atom, students can investigate various properties of gas lamps, incandescent bulbs, and light-emitting diodes (LEDs) using the VQM materials. In addition, students are also exposed to materials with luminescent properties. The VQM materials provide students an opportunity to explore light spectra through hands-on activities. In addition, students are exposed to various computer simulation tools such as the "Spectroscopy Lab Suite [27]."

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 their understanding of the highly technology-rich 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 written paper for publication and presentation at an actual conference.

III. The New Millennium Conference

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 as well as presentation. 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 the 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 them the "experts."

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

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.

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!

Approximately one week after the submission of their abstracts, students were informed (electronically) that their abstracts had been accepted. 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 with them to this appointment. This 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.

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. 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/)**.

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 her feedback and comments. 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 camera-ready 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 also re-reviewed by the instructor.

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*:

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

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. 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).

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 Arts and

Sciences. Both deans indicated that they 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 terms of the new course (PNM) as well as in preparing their written papers for publication and presentation at *The New Millennium Conference*. Feedback received from students via written questionnaires is also shared.

IV. Feedback from Students

Student Perceptions regarding the *Physics for a New Millennium* Course

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 that my expectations were met. I remember writing on the original questionnaire that I wanted to explore physics in my everyday life and I'm finding some of the things we are learning very relevant.
- I definitely believe that we have learned ways to apply physics to everyday life. First, using batteries and electricity, and then through the light activities. I have really enjoyed doing both these topics. There have been numerous times that I have taken something we did in class and showed it to my roommate, who is not a "physics person." However, he has been fascinated by some of the things we have done.
- I feel I am directly involved with the learning process and not just watching a teacher from afar.
- I absolutely believe that my expectations have been met for this course. I wanted to broaden my knowledge in physics and apply it more to everyday life. The use of hands-on activities not only helped me understand a given concept, such as batteries and charges, but kept me more enthusiastic on learning more.

On the same questionnaire students were also asked whether or not their expectations of their instructor were being met. Typical student responses included:

- I strongly feel that you met all my expectations. Your constant use of hands-on activities as well as demonstrations in front of class keeps me involved in the discussion. I must also say that I learn more in this course than any other. The workload is of course, time consuming, but well worth it.
- I think the topics we have studied have stimulated both me and the class to think and ask questions beyond the material presented. I like the fact that you, the instructor, are so willing to answer and come back to our (my) questions. The class stimulates my thinking.

- I think that you are meeting these expectations. The hands-on activities allow us to think for ourselves.
- 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.
- I definitely think that you, as an instructor, have prompted me to think about physics on my own and to apply it to my life. But also, I feel that you have prompted me to think about many applications that I would never have thought of before.

Finally, students were asked whether or not they felt they had met the expectations they had set for themselves at the beginning of the semester. Typical student responses included:

- Yes, I have actually worked harder to do better on my homework assignments, not only to get a better grade but also to learn the material.
- I think I could always work harder and do more than is required.
- I feel that I am doing most of the work, honestly for me, I am doing very well. I do a little procrastinating, but I am trying to stay on top of things.
- I think I am meeting my expectations. I have done all the homework and only missed one class. I think that the amount of work I receive in this class is fair and what I expected at the beginning of the semester.
- I am proud of myself for meeting my expectations for myself. I am not used to such a large workload, but I have adjusted.

Student Perceptions regarding *The New Millennium Conference*

Near the beginning of the semester, the students were quite apprehensive about the prospect of preparing a formal written paper. 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 via *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.

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.

V. Summary and Conclusions

Traditional paper and pencil assessments do not always provide a clear picture as to what a student has actually learning in a course. Providing students with alternative learning experiences, such as those designed for use in the *Physics for the Modern World* and *Physics for a New Millennium* courses, can allow students additional, effective vehicles through which to learn physics. Furthermore, the use of hands-on activities has proven to be an effective way to help students make links between the content they are learning and real world applications. These linkages are essential in terms of bringing about conceptual change in the minds of students. In addition, these alternative experiences can provide unique opportunities for instructors to assess student learning outside the boundaries of the traditional classroom.

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.

Making topics within the domains of science and engineering accessible to *all students* is of critical importance, especially in terms of the highly technological society in which we live [28]. The courses described in this paper, as well as the activities developed within these courses, have been designed to bring these important topics to non-majors. The teaching and learning strategies employed in these courses may have broad and far-reaching implications for teaching all students, majors and non-majors alike.

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