Teaching Philosophy, Methodology, and Related Information

Sean J. Bentley, Dept. of Physics

Teaching Philosophy:

Effective teaching in science and engineering can be broken down into three basic components. The first is the transfer of important concepts, not details, to the students. Too often, students, particularly those new to a field of study, spend most of their study time trying to memorize facts and formulas without being able to separate the key ideas from details. It is paramount upon an instructor to emphasize these concepts, because a student who truly understands the basis of a subject will always be able to find and apply the needed formulas, while students who lack this basic understanding will leave the course with zero gain.

The second component of effective teaching is showing the students how to solve problems. Once they have been equipped with the needed concepts and the resources to find the needed details of the problem, they must learn how to apply this knowledge. This can be a very challenging task, because there is no single way to approach real problems. A teacher must therefore be able to present problems and their solutions in a variety of ways to account for the different learning styles of the individual students.

In many cases, if an instructor succeeds in not only teaching their students the important concepts but also enables them to apply those concepts to solve problems, they would be justified in being satisfied. Ultimately, however, I feel that there is a third element of teaching that is crucial, especially at the advanced undergraduate and graduate levels. For the students to be able to fully appreciate the field, they must be taught to ask the new and important questions. It is vital for them to be able to solve problems posed by others, but I feel that the greatest result of effective teaching is a student who is able to successfully continue study in the field on their own.

Implementation to Courses at Adelphi, Including New Course Development:

I have had the pleasure to apply and further develop my teaching philosophy in the 6 years I have taught at Adelphi University. In teaching a wide range of courses spanning from non-major physics to a special topics in advanced quantum mechanics, I have developed my teaching style, focusing on interaction with the students. I have had the opportunity to completely restructure several courses and develop new ones in the form of special topics and independent study courses, as well as help plan a new M.S. curriculum with a concentration in optics that included several new advanced courses (which unfortunately is on hold due to the current lack of teaching manpower in the department). I have also recently created a new general education course to be offered for the first time in the 2009-10 academic year, *Basic Science behind the Headlines* (0156-120), in which the students will explore topics such as global warming, alternative energies, and terrorism to name a few. This semester, at the request of the students, I am teaching *Theoretical Physics* (0156-302), a course which builds on the senior students' knowledge of physics and math methods to allow them to solve "real" problems. My primary teaching responsibilities have been in mathematical methods in physics, analog and digital circuits, and quantum mechanics during the academic year, and freshman physics in the summer, but I have taught many other courses as seen in the list included later in this document.

I always feel that teaching is the most important component of my career. I make every effort to make the education of our students as excellent as possible. I have already made many efforts to improve and develop the departmental courses and curriculum, as well as develop my own teaching style and methods. I feel that as successful as I have been, to keep my teaching dynamic, engaging, and effective, I must continually work to further evolve my methods and course materials.

One key area I continually work on is development of my courses. For *Digital Circuits* (0156-244), I have updated the course by obtaining equipment for programmable digital devices. By teaching the techniques of programmable devices in lecture and having the students apply these techniques in the laboratory, it greatly enhance the students' skills and make the class much more useful and modern. As part of the course, each student is required to write the hardware code and program the device to create a real-time clock. To be able to start from zero knowledge of digital circuits and in one semester generate something of that complexity and practicality greatly interests and excites the students. To best fit the more modern scope of the course, I have also selected a new textbook to use with the course. I continue to supplement the text to give the students a broad background.

For the mathematical methods courses (0156-211 & -301), I am continually working to make these as useful as possible for the students. As all of the physics majors, including the pre-engineering students, take the first semester while only those working towards the B.S. take the second semester, I reorganized the distribution of the material between the two courses such that the first semester focuses on the more applied mathematics useful to engineers and the second semester deals with more of the material needed to pursue advanced theoretical studies. I also give a fraction of the homework problems that require Mathcad, a mathematical package that allows students to solve complicated problems beyond what they could solve by hand. It is worth noting that several of the students who have taken the math methods courses from me and then gone on to the engineering program at Columbia have told Prof. Rao and me that the courses were the most useful they took while at Adelphi. While such feedback is very nice, it is also encouraging to continue to make the courses better.

For the two semesters I taught *Quantum Mechanics* (0156-428), I introduced more reading and a new text. One of the issues that is a great challenge with any physics course, and particularly one of such an advanced level, is teaching at the level where the top students are adequately challenged without losing the other students. While I refuse to compromise the level of education I provide for our top students, I continually try to test new methods to keep the rest of the class involved, engaged, and able to reach the appropriate level of mastery. These include things such as more applied computer-based problems, more readings on interesting contemporary research, and group assignments that mix students of a variety of backgrounds and skill levels, to name but a few.

Integration of Research into Teaching:

A good balance of teaching and research is important, as neither can be truly great if the other is neglected. As my research is largely experimental, I strive to have the undergraduates in the department directly involved in all aspects of the work. Thus, I directly use my research as a teaching tool. As the students go through the physics curriculum, they are able to tie the things they learn in the classroom to the work they do in the lab, and I have frequent discussions with them on the relations. However, the details of my research are beyond what would be introduced at the level of the required courses, so I integrate it into special topics and independent study courses.

I have had the opportunity to teach several independent studies, often with my research students on topics directly related to the research. In the current semester I have independent studies on quantum optics and nonlinear optics with two outstanding freshmen doing research with me. These are very advanced topics, but I am breaking down the material so that they can see the concepts and apply them to what they see in the laboratory.

One of the best experiences (both related to integration of research, but also overall in my enjoyment of teaching) was the special topics course, *Quantum Mechanics II*, which I taught in the fall of 2006. For the format of the course, one class period each week I would teach in the “traditional” manner, while in the other class each week we would have a round-table discussion on advanced readings related to experimental work of the last 20+ years in quantum optics. Many of the topics from my research were discussed in detail. I would enjoy teaching a course such as that regularly, but we do not have enough seniors each year to make that possible. The course, which I hope to teach again in the near future, was of significant interest that I gave a very well received talk on it at a recent major conference (S. J. Bentley, “Quantum optics round-table teaching,” *Quantum Optics/Quantum Engineering for Undergraduates Symposium*, Optical Society of America 92nd Annual Meeting, Rochester, NY, October 2008).

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Views on and Applications of Technology in Teaching:

Having had a highly technical education in electrical engineering and optics, and teaching courses fundamental to advanced technology, many find my views on technology in teaching surprising. I strive to use those technological tools which I feel meaningfully promote the students' understanding of the material being presented (as I will describe in more detail below), but I absolutely feel there is no good alternative to direct question-and-answer, person-to-person interaction when it comes to teaching material as complex and problem-based as physics and engineering tend to be. I feel that all too often technology is used for technology's sake, and often leads to an unnecessary level of detachment between the students and the instructor. I have heard many students complain about courses taught in which a professor simply puts up PowerPoint slides, reads them with little or no additional explanation, and considers that a valid presentation of material. While this may work in a non-mathematical setting or when presenting material to experts in a field, it is a recipe for disaster in trying to present physics to the average student. Thus for the majority of my classes, my tools are my chalk, my notes, and my mind, as I try to maintain a constant interaction with and feedback from the class, doing examples, asking and answering questions, and most importantly seeking if they are understanding the principles. If it seems one example is sufficient to get an idea across, I won't waste time with more, but if it takes three or four, then I will do that many rather than moving on to new material while many in the class are stuck on the last topic.

Let me now focus on how I do use technology in the classroom, how I have the students use it, and a (perhaps surprising) way in which I do not let the students use it. First, for some problems it is nice to show the students a simulation of a physical problem that cannot readily be shown otherwise. As an example, for the quantum mechanics course, I used a set of "Physlets" which are computer simulations of physical phenomena. These Physlets often managed to show a wonderful and simple dynamic picture of a complicated physical principle. In a similar fashion, in the mathematical methods courses, I will often use Mathcad to generate beautiful 3-D graphs that would be impossible to draw on a chalk board. In the digital circuits course, I often introduce various portions of the VHDL computer language, and will project the editor interface while also showing them directly how the generated program works on the FPGA educational board.

Clearly the analog and digital circuits courses are intrinsically technological, but beyond the direct and obvious implications, there are ways I have the students use technology in several of the courses. One primary tool is again Mathcad. While the majority of the problems I give are to be worked by pen and paper, I give a variety of problems that require the student to use Mathcad. I feel it is valuable to have the mix, as the students must gain a comfort level with real-world tools such as Mathcad, but also require a fundamental understanding that goes well beyond the computer. I assign Mathcad-based problems in all of my sophomore-senior level courses. For the *Theoretical Physics* course this semester, half of the points on both the mid-term and final are numerical problems to be done by the student on computer prior to the exams.

One place where I deny the students the use of technology is that no student in my mathematical methods courses is allowed to use a calculator on the exams. While I strongly encourage the mastery of high-level scientific calculators on the homeworks and on exams in my other courses, I want the students to be able to demonstrate a fundamental understanding of the mathematics on the math methods' exams. Important areas that I feel have been weakened in the modern student versus even just 15 years ago when I was taking similar courses are the ability to perform order-of-magnitude calculations and the related skill of a "back-of-the-envelope" calculation. Many mistakenly think that computers and calculators have eliminated the need for such skills, but in reality the fact that we can ultimately calculate almost anything makes even more important the ability to pre-screen what we should calculate. I hope to instill in the students the importance of such methods, and have them develop the skills in my classes.

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Overview of additional activities related to my teaching:

- Serving as the faculty advisor for the Adelphi Physics Club (now since 2003), with the club being awarded three consecutive Outstanding Chapter Awards (given to only the top ~5% of all chapters each year) under my guidance.

- Serving as the mentor for the physics students in the National Science Foundation TOP program, which is a current NSF-funded scholarship and enrichment program for science students.

- Serving as the university mentor for a pre-engineering program (part of *Project Lead the Way*) at Bellmore-Merrick Central High School District.

- Presented a talk on special educational methods I used in a course I developed and taught (Quantum Mechanics II): "Quantum optics round-table teaching," *Quantum Optics/Quantum Engineering for Undergraduates Symposium*, Optical Society of America 92nd Annual Meeting, Rochester, NY, October 2008.

- Authoring an advanced text: S. J. Bentley, *Introduction to Quantum Imaging: Ghost Imaging, Ghost Diffraction, and Quantum Lithography*, Taylor & Francis/CRC Press, Boca Raton, FL.

- Co-chairing the Adelphi University Research Conference, which will highlight the academic activities of over 100 Adelphi students this year.

- Involved in the current general education discussion, including having authored an alternative proposal to try to lead to a compromise in the current divide.

- Applied (as PI) for funding for a program that would train Adelphi education students, establish partnerships between Long Island high schools and science museums, and overall promote science and mathematics education: *MSP-Start: Science and Math Applied Real-problem Teaching (SMART)*, $299,012, National Science Foundation (**in review**).

- Serving as senior personnel on a funding request that would involve taking top Adelphi physics students to an advanced laboratory experience at the University of Rochester as part of a unique course and curriculum development project: *CCLI-Phase II: Diverse Partnership in Teaching Quantum Mechanics and Modern Physics with Photon Counting Instrumentation*, $499,319, National Science Foundation (**in review**).

- Served as Educational Chair of an international engineering conference, in which I helped develop a pre-college program, the details of which are to be published: S. E. Watkins, M. A. Huggans, and S. J. Bentley, "Pre-college outreach at a technical conference," (accepted for publication in the International Journal of Engineering Education).

- Focusing much of my committee work on activities directly related to the students' education, including the College and Senate Academic Affairs committees and the Pre-Medical Council.

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Courses Taught at Adelphi:

- Physics 111--College Physics I: Lecture—Summer 04, 05, 06, 07, 08
  Lab—Fall 03 (2 sections); Summer 04, 05, 06, 07, 08
- Physics 112—College Physics II: Lecture—Summer 04, 05, 08
  Lab— Summer 04, 05, 08; Spring 06, 07
- Physics 113—Physics for Science Majors I: Lecture—Summer 05, 07, 08; Fall 08
  Lab—Summer 04, 05, 06, 07, 08; Fall 05
- Physics 114—Physics for Science Majors II: Lecture —Summer 05, 08; Spring 09
  Lab—Summer 04, 05, 08; Spring 07
- Physics 211—Introduction to Mathematical Methods in Physics—Fall 03, 04, 05, 06, 07, 08
- Physics 216—Modern Physics—Summer 04
- Physics 243—Analog Circuits: Lecture and Lab—Fall 04, 06, 07, 08
- Physics 244—Digital Circuits: Lecture and Lab—Spring 04, 05, 06, 07, 08, 09
- Physics 301—Mathematical Methods in Physics—Spring 05, 06, 07, 08, 09
- Physics 302—Theoretical Physics—Spring 09
- Physics 322—Advanced Physics Laboratory: Lecture—Spring 07
  Laboratory—Spring 04, 07
- Physics 390—Special Topics:
  Quantum Mechanics II—Spring 06
- Physics 428—Quantum Mechanics—Fall 05, 06
- Physics 490—Independent Study:
  - Modern Optical Physics—Fall 03
  - Experimental Optical Physics—Spring 04
  - Introduction to Quantum Optics—Spring 04
  - Introduction to Thermodynamics, Electronics, and Optics Lab—Summer 04
  - Engineering Mathematics—Fall 04
  - Introduction to Quantum Physics—Fall 04
  - Experimental Quantum Physics—Spring 05
  - Optics—Spring 05
  - Solid State Physics—Spring 05, 07
  - Experimental Nonlinear Quantum Dots—Spring 05
  - Partial Differential Equations—Spring 07
  - Introduction to Quantum Entanglement—Spring 09
  - Introduction to Nonlinear Optics—Spring 09