Chapter 3

Teaching

3.1 Overview

Over the past six years I have continued to grow and improve as a teacher. During my first five years at Berry I made a transition from a traditional lecture style of teaching to a more student-centered, active learning approach in my introductory physics courses. In the past six years I have expanded my student-centered teaching to upper level physics courses, as well as introductory astronomy courses. My experience with these methods has grown to the point that I am now educating others about how to use these methods. I have given invited presentations and workshops on innovative teaching methods, published my curricular materials online, and even published peer-reviewed journal articles describing activities I have developed for my courses.

In addition to developing new teaching methods, I have worked to expand the physics and astronomy curriculum at Berry by creating several new courses. These new courses include an upper level physics laboratory course, an upper level computational physics course, and a new astronomy course for non-science majors. These efforts to expand the curriculum have been supported by a one year sabbatical leave during the 2009-2010 academic year (to develop a new astronomy course) and a Summer Course Development Grant during 2011 (to develop a computational physics course). In addition to these new courses, I have taught several special courses (Honors, WI, directed studies) during this time period.

All of the courses I have taught were well received by students. My student evaluation numbers are very strong (see Appendix B for all of my student evaluations for the period 2006-2012). During this time period I have not had a single course in which my average evaluation score for Overall Quality of Teaching or Overall Quality of Course was below 4. The written comments on my student evaluations are quite positive as well, with several students indicating that I am the best teacher they have had at Berry (including students in my courses for non-science majors). Because of the consistently high quality of my teaching I was honored with the 2009 Berry College Teaching Excellence Award.

I would like to highlight the fact that I took over teaching Berry's introductory astronomy courses in Fall 2008. At the time there was some concern expressed by the administration about my teaching these courses, because my background is in physics, not astronomy (although I completed significant coursework in astronomy as an undergraduate). However, my astronomy teaching has been an unqualified success. I transformed the Copernican Revolution course to make it more student-centered, and as noted above I developed an entirely new astronomy course during my 2009-2010 sabbatical. Not only have I received positive feedback from Berry students about these courses, but I am also garnering national and international attention for the way I teach astronomy.

In summary, during the past six years I have not only continued the pattern of excellent teaching that I set during my first five years at Berry, but I have taken my teaching to a higher level. I have become a strong advocate for using the history of science to teach science to non-majors. I have become a recognized leader in using computers to teach astronomy and physics. Closer to home, I have become known to Berry students as a demanding but excellent teacher at all levels of the curriculum. I expect to expand on these roles during my remaining career at Berry.

3.1.1 Courses Taught

Here I provide an overview of the courses that I have taught at Berry. Table 3.1 provides a list of the courses I have taught as part of my normal teaching load, the number of students enrolled, and the number of credit/contact hours for each course. Note that there is no data for the 2009-2010 academic year because I was on sabbatical during that year. Below I provide a brief description of the four general categories of courses that I have taught. More detailed information about many of these courses can be found later in this section.

Courses for Non-science Majors: I taught 3 sections of PHY 101: Introduction to the Physical World, and 3 sections of the corresponding lab. I taught 4 sections of AST 120: The Copernican Revolution, with 4 sections of the corresponding lab. I also taught 3 sections of AST 121: The Discovery of Galaxies, and 3 sections of the corresponding lab. One of the sections of AST 121 was an Honors section. These courses primarily serve non-science majors.

General Physics with Algebra: I taught two sections each of the PHY 111 (General Physics I with Algebra) and PHY 112 (General Physics II with Algebra) courses, as well as 7 sections of the PHY 111 and 112 laboratories. These courses are required for several science majors (Biology, Chemistry) as well as a variety of professional schools (in medicine, veterinary medicine, pharmacy, and physical therapy). However, these courses do not serve students majoring in physics or dual-degree engineering.

Upper-Level Physics Courses: I have taught 7 lecture sections and 2 lab sections of upper-level physics courses. These courses include PHY 302 (Classical Mechanics I), PHY 310 (Measuring the Fundamental Constants), PHY 321 (Computational Methods in Physics), PHY 402 (Classical Mechanics II, later Classical Mechanics), and PHY 430 (Quantum Mechanics). These courses serve physics majors and minors.

"Extra" courses: During this time period I twice taught BCC 100. I also taught two summer directed studies during these years. These courses were not part of my normal teaching load and are not shown in Table 3.1.

Overall I have taught 44 sections of 15 different courses. A summary of my teaching load during the past six years is given in Table 3.2. This data should make it clear that I have "carried my weight" in spite of the fact that I teach in a small department with few majors. While my upper-level physics courses are usually small (3-15 students), I consistently teach much larger classes (with up to 44 students) for non-majors.

3.1.2 Summary of Student Evaluations

Selected student comments, histograms of my numerical evaluations, and my complete student evaluations (including numerical scores and comments) are available in Appendix B. Here I provide a summary of the numerical data.

Table 3.3 shows my Quality of Instruction and Quality of Course scores for all of my classes except BCC 100 and directed studies. Also shown is the average GPA for the grades I assigned in each class. I would like to point to two major patterns that are evident in this table. First, my students are consistently satisfied with the courses I teach. My lowest average Quality of Instruction score during this time period was 4.2, and my average score was below 4.5 for only two courses. My lowest Quality of Course score was 4.0, and only half of my scores were below 4.5 (note that laboratory sections are not rated on Overall Quality of the Course). Second, the GPAs for my courses indicate that I am a demanding instructor. I assigned grades in 23 courses (laboratory sections do not receive separate grades), and of these only 7 had GPAs above 3.0. The courses with GPAs above 3.0 were invariably upper level physics courses with relatively small enrollments, and I would note that my grades were not that high in all of my upper level physics courses. Inspection of my course evaluations shows that students generally consider the level of intellectual challenge in my courses to be high.

Appendix B contains histograms of my Quality of Instruction and Quality of Course evaluation scores during the past six years. The data are grouped into three categories: Courses for Non-science Majors, Algebra Based Physics Courses, and Upper Level Physics Courses. These histograms clearly indicate a pattern of sustained excellence in my teaching over the past six years.

Course	Number of Students	Credit Hours	Contact Hours	Course	Number of Students	Credit Hours	Contact Hours
Fall 2006	72	7	10	**Spring 2007**	72	10	11
PHY 111 A	30	3	3	PHY 101 A	20	3	3
PHY 111 LA	17	1	2	PHY 101 LA	20	1	2
PHY 111 LB	13	1	2	PHY 112 A	17	3	3
PHY 310	12	2	3	PHY 430 IA	15	3	3
Fall 2007	94	8	10	**Spring 2008**	78	10	11
PHY 111 A	44	3	3	PHY 101 A	23	3	3
PHY 111 LA	22	1	2	PHY 101 LA	23	1	2
PHY 111 LB	22	1	2	PHY 112 A	27	3	3
PHY 302 A	6	3	3	PHY 402 IA	5	3	3
Fall 2008	54	6	8	**Spring 2009**	98	11	13
AST 120 A	22	3	3	AST 120 A	23	3	3
AST 120 LA	22	1	2	AST 120 LA	23	1	2
PHY 310 A	10	2	3	PHY 101 A†	23	3	3
				PHY 101 LA†	23	1	2
				PHY 430 IA	6	3	3
Fall 2010	76	8	10	**Spring 2011**	61	7	8
AST 121 D†	24	3	3	AST 120 A	29	3	3
AST 121 LD†	24	1	2	AST 120 LA	29	1	2
AST 121 HC†	14	3	3	PHY 430 IA	3	3	3
AST 121 HLC†	14	1	2				
Fall 2011	65	7	8	**Spring 2012**	135	10	14
AST 121 A*	27	3	3	AST 120 A	28	3	3
AST 121 LA*	27	1	2	AST 120 LA	28	1	2
PHY 321	11	3	3	PHY 112 LA	29	1	2
				PHY 112 LB	26	1	2
				PHY 112 LC	13	1	2
				PHY 402 IA	11	3	3

† lecture and lab are listed as a single coure in VikingWeb, but are shown separately here for clarity
* includes one student who took on Honors version of this course

Table 3.1: List of courses taught at Berry College, Fall 2006 to Spring 2012

Course	Number	Contact Hours	Students	Credit Hours
Regular Classes	15	45	353	1059
Laboratories	19	40	397	419
WI Classes	5	15	40	120
Honors Classes*	1	3	15	45
BCC 100	2	0	39	39
Directed Studies	2	0	2	6
Total	44	103	846	1688

* These numbers include one student who took an honorized version of AST 121, in addition to the AST 121 H course.

Table 3.2: Teaching load summary

3.2 Expanding the Curriculum

One of my greatest contributions to the college has been the development of innovative new courses in physics and astronomy. In addition, I have regularly taught several special courses that are central to the college's mission. My efforts to enhance the curriculum at Berry are described below.

New Courses: Since 2006 I have developed and taught three entirely new courses at Berry. Two of these courses are upper-level physics courses, both of which were created in response to suggestions from external reviewers, while the third course is intended as a General Education course for non-science majors.

- **PHY 310: Measuring the Fundamental Constants** is an upper level physics laboratory course. I decided on the experiments for this course, created all of the curricular materials, and purchased most of the equipment needed for the experiments.
- **PHY 321: Computational Methods in Physics** is an upper level computational physics course. I developed this course with the help of a Summer Course Development Grant (see Appendix C). Although we used an existing textbook for this course, I wrote a partial draft of a new textbook for this course and developed all of the curricular materials (tutorials, project assignments, computer simulations). My syllabus and sample materials for this course can be found in Appendix D.
- **AST 121: The Discovery of Galaxies** is a General Education course for non-science majors. I developed this course while on sabbatical during the 2009-2010 academic year. I wrote a completely new textbook for this course and developed a complete set of curricular materials (class activities, computer simulations, homework assignments, essay assignments, etc). This unique course guides students through the historical development of ideas about galaxies and cosmology, from Ancient Greece to the triumph of Big Bang cosmology in the 1960s. For more information about my sabbatical (including reviews of my textbook) see Appendix C. My syllabus and sample curricular materials for AST 121 can be found in Appendix D.

Honors Courses: I taught a designated Honors section of AST 121 in Fall 2010. Student in this course completed a slightly modified version of the activities from the regular AST 121 course, but in addition they read several primary source articles by important astronomers throughout history. The students were required to write essay responses to some of these readings, in addition to discussing these readings in class. I also taught an Honorized version of AST 121 for one student in Fall 2011.

WI Courses: I regularly teach two of the three WI courses offered by the physics department: PHY 402 I (Classical Mechanics) and PHY 430 I (Quantum Mechanics).

Course	**Quality of Instruction**	**Quality of Course**	**Avg. GPA**	**Course**	**Quality of Instruction**	**Quality of Course**	**Avg. GPA**
Fall 2006				**Spring 2007**			
PHY 111 A	4.52	4.38	2.64	PHY 101 A	4.72	4.53	2.57
PHY 111 LA	4.69	NA	NA	PHY 101 LA	4.58	NA	NA
PHY 111 LB	4.92	NA	NA	PHY 112 A	4.67	4.65	2.72
PHY 310 A	4.58	4.50	3.20	PHY 430 IA	4.67	4.75	2.73
Fall 2007				**Spring 2008**			
PHY 111 A	4.63	4.43	2.66	PHY 101 A	4.79	4.53	2.59
PHY 111 LA	4.57	NA	NA	PHY 101 LA	4.68	NA	NA
PHY 111 LB	4.63	NA	NA	PHY 112 A	4.88	4.76	2.97
PHY 302 A	5.00	4.83	3.22	PHY 402 IA	5.00	5.00	3.34
Fall 2008				**Spring 2009**			
AST 120 A	4.72	4.84	2.77	AST 120 A	4.55	4.40	2.44
AST 120 LA	4.65	NA	NA	AST 120 LA	4.58	NA	NA
PHY 310 A	5.00	5.00	3.22	PHY 101 A	4.61	4.28	2.67
				PHY 101 LA	4.33	NA	NA
				PHY 430 IA	5.00	4.83	3.28
Fall 2010				**Spring 2011**			
AST 121 D†	4.6	4.2	2.82	AST 120 A	4.5	4.3	2.41
AST 121 HC†	5.0	4.4	3.12	AST 120 LA	4.5	NA	NA
				PHY 430 IA*	NA	NA	3.53
Fall 2011				**Spring 2012**			
AST 121 A	4.6	4.2	2.83	AST 120 A	4.5	4.1	2.73
AST 121 LA	4.6	NA	NA	AST 120 LA	4.5	NA	NA
PHY 321 A	4.6	4.0	2.97	PHY 112 LA	4.9	NA	NA
				PHY 112 LB	4.6	NA	NA
				PHY 112 LC	4.5	NA	NA
				PHY 402 IA	4.2	4.2	2.76

NA indicates a laboratory section for which students do not receive a separate grade, and which does not receive an evaluation for "Quality of Course"
† during the Fall 2010 semester the laboratories for AST 121 and AST 121 H were not listed separately from the lecture courses
* I received no evaluations for PHY 430 I in Spring 2011 because there were too few students enrolled in the course

Table 3.3: Summary of numerical teaching evaluations

Directed Studies: I taught two PHY 490 (Directed Study) courses during consecutive summers. The first was on the philosophy of science and was co-taught with Dr. Michael Papazian. The second focused on recreating early experiments on atmospheric pressure.

3.3 Active Learning

During my first five years at Berry I made a substantial change in my approach to teaching. In my first few years I gave traditional, instructor-centered lectures and assigned standard homework problems from the textbook. But after learning about new, student-centered approaches to teaching I made a transition to a method in which students are active participants in the classroom. During the past six years I have refined and improved my active learning methods, and expanded these methods to new courses. The remainder of this section details the methods I have used to implement active learning in several of my courses.

3.3.1 Astronomy

In both the AST 120 course (which I inherited when Paul Wallace retired from Berry in 2008) and the new AST 121 course I developed, I use a tutorial-based approach to teaching. Students work in small groups to answer a series of questions that guide them through an understanding of new material. Many of these tutorials involve the use of computer simulations, the vast majority of which I created myself. Over 30 of these astronomy simulations have been published on the Open Source Physics web site (`www.compadre.org/osp/`) and I have been invited to give workshops on my astronomy teaching methods at national and international conferences. A paper describing one of the activities I developed for AST 121 was recently accepted for publication in a peer reviewed teaching journal.

I would like to emphasize that these curricular materials are not a rehash or slight modification of curricular materials developed by others. The AST 120 and 121 courses are unique courses that guide students through the historical development of astronomy so that they can learn what science is and how it functions, in addition to learning astronomy content. The textbooks for these courses were developed at Berry (by Paul Wallace for AST 120, and by me for AST 121), and so the curricular materials I have developed are genuinely new. I have become a strong advocate for teaching such historical science courses to non-science majors, and I hope to see my curricular materials adopted by other colleges in the future. My curricular materials are already available online at `facultyweb.berry.edu/ttimberlake/copernican/` and `facultyweb.berry.edu/ttimberlake/galaxies/` (see printouts of these pages in Appendix C).

Student response to these unique courses and innovative curricular materials has been quite positive (see course evaluations in Appendix B), in spite of the high level of intellectual challenge. Syllabi and sample curricular materials for these courses can be found in Appendix D.

3.3.2 Tutorials in Upper Level Physics

I have employed a similar tutorial approach in two of my upper level physics courses. In PHY 321: Computational Methods in Physics, students work through a series of problems using the *Maxima* computer algebra system or build and explore simulations using the *Easy Java Simulations* programming environment. Although students mostly work on their own, they are allowed to ask each other (and me) for assistance. Completing these tutorials prepares the students to complete computational projects on their own. In PHY 430I: Quantum Mechanics, students work in small groups to solve a series of problems. I also use occasional tutorials in PHY 402I: Classical Mechanics.

I have received very positive feedback from students (through course evaluations and private comments) about the PHY 430I tutorials. The feedback on PHY 321 was positive, but not as strong. However, I have only taught that course once. I hope to make significant improvements to the course before I teach it again in Fall 2013. My PHY 430I tutorials have garnered some national attention, as I was asked to give a presentation about my teaching approach in this course at a national meeting of the American Association of Physics Teachers. My tutorials for PHY 430I are available on the web at `facultyweb.berry.edu/ttimberlake/active_quantum/` (see the printout of this page in Appendix C). Syllabi and sample curricular materials for these courses can be found in Appendix D.

3.3.3 Modified Moore Method

Another approach I have used in teaching upper level physics courses is the Modified Moore Method. This method involves students presenting solutions to homework problems at the board. Most of the class time is spent on these presentations, with the other students and me critiquing the presentation. This method has proven effective in other physics courses (notably those taught by Chuck Lane) and it has worked reasonably well for me in PHY 302 and 402I. Student response has been mostly positive. I am uncertain whether I will continue to use this method in the future, or switch to the tutorial approach that has been so successful for me in other courses.

3.3.4 Student Research

Probably the best form of active learning in which a student can engage is real research. I have conducted several research projects with students during the past six years. Some of these projects involved technical research that was conducted over the course of a summer and led to publications in major journals. Others were smaller-scale projects conducted during a portion of the academic year and resulting only in presentations at the Berry Student Research Symposium or another student conference. All of these projects, though, have played an important role in educating the students who participated. More details on my research with students can be found in Chapter 4.

3.4 Technology

During my time at Berry I have been a pioneer in integrating technology into the physics and astronomy curriculum. Although I do use VikingWeb extensively for posting curricular materials, online quizzes and essays, and keeping track of grades, my use of technology extends far beyond this single tool.

During my first five years at Berry I worked to incorporate computational methods into two physics courses (PHY 302 and 402I). In these courses I taught students to use the *Mathematica* computer algebra system to solve physics problems. However, the *Mathematica* license became prohibitively expensive and it was not portable. Many students no longer had access to *Mathematica* once they graduated from Berry. In 2011 I developed the new PHY 321 course, which introduces physics majors to an open-source (and free) computer algebra package called *Maxima*, as well as an open-source simulation programming environment called *Easy Java Simulations* (EJS). Students in PHY 321 and 402I now use *Maxima* and EJS extensively to solve physics problems and simulate physical systems.

My growing expertise with EJS has helped to transform other courses that I teach. I developed a series of simulations for teaching the statistical interpretation of entropy in my PHY 101 course. A paper describing these simulations and the activity I developed to go with them was published in *The Physics Teacher*. When I began teaching astronomy I developed an extensive set of simulations for those courses. Students use my simulations, as well as other open-source software (such as *Stellarium*) as part of their in-class tutorial activities. Most of my students enjoy using these simulations and feel that they provide valuable assistance in learning the course material.

3.5 Scholarship of Teaching

My efforts to develop innovative courses and curricular materials have led me to become deeply involved in the scholarship of teaching. During the past six years I have published three articles that I would describe as primarily pedagogical (for details see Chapter 4). I have written a textbook for my new AST 121 course. Although this book has not been published, I am currently working with an editor at Yale University Press to develop a proposal for publishing a modified version of the book. I also have a contract with Springer to ao-author (with Wilson Mixon, Jr.) a textbook on using the *Maxima* computer algebra system to teach classical mechanics.

Thirty-eight of my computer simulations have been published in the Open Source Physics collection at `www.compadre.org/osp/`, and nearly all of my curricular materials are available online. My contributions to the Open Source Physics project are discussed in a letter from Mario Belloni, Professor of Physics at Davidson College, which can be found in Appendix C. Appendix C also contains a list of my published simulations and printouts of the web pages I created to make my curricular materials publicly available.

I have been invited to give presentations and workshops at national and international conferences regarding my teaching materials, and particularly my astronomy simulations. I am the primary contributor of astronomy simulations to the Open Source Physics project. Because my simulations are open-source (and can be redistributed by others), you can simply "Google" my name and find my simulations at free software sites like `brothersoft`, `softpedia`, `downloadatoz`, and `downloadplex` as well as the various ComPADRE digital archive sites (`www.compadre.org`).

3.6 Continued Development

By no means is my development as a teacher complete. I am still learning and growing as a teacher, and I anticipate making many improvements to the courses I teach. Appendix C provides a list of the teaching conferences and workshops I have attended during the past six years, and I plan to regularly attend meetings of the American Association of Physics Teachers in the future. I have been a frequent attendee at Center for Teaching Excellence events and campus book discussions at Berry, and I plan to continue that trend as well. I also try to stay current with developments in physics and astronomy teaching by reading articles in pedagogical journals like *American Journal of Physics*, *The Physics Teacher*, and *Science & Education*.

In addition, I am a founding member of Active Learning at Berry (ALAB), a group of faculty at Berry who are exploring non-traditional, student-centered teaching methods. We read books about student-centered teaching and discuss the books as a group. We also provide feedback and support for each other as we implement non-traditional teaching methods in our courses. I created a blog for our group (`berryactivelearning.blogspot.com`) and I am currently working with other ALAB faculty to develop a web site for our group.

Although I will continue to learn and grow as a teacher in the coming years, I have now reached a point where I am able to instruct others even as I continue to learn. My long-term goal is to help transform the way science is taught to non-science majors. I want to initiate a move away from courses that focus on the factual output of modern science and toward courses that engage students in the process of doing science. I believe the best way to engage students in the process of science is to have them work through the steps that were taken in making the greatest breakthroughs in the history of science. I will continue to advocate for this approach by improving and publishing my curricular materials for AST 120 and 121, as well as publishing articles in pedagogical journals and giving presentations at conferences.