Philosophy of Teaching and Learning

In the following section Dr. Elster expresses her thoughts about her role as teacher as it relates to her efforts in undergraduate nonmajor, undergraduate major and graduate instruction.

From the beginning I want to stress that these thoughts are by no means fixed or complete, my ideas and perceptions are evolving with the expansion of my horizon within different educational systems, and I am certain this process will continue.

At the outset, I would like to offer my perception of the present university situation. I see the biggest challenge facing today's university being the dichotomy between the need for universal education and the promotion of excellence. For centuries, the university has been considered a place where unconstrained intellectual curiosity and the pursuit of excellence are cultivated. The university as a popular institution is a rather new perception. This conflict between reality and nostalgia may be one of the reasons why the education of large numbers of undergraduate students has sometimes been undervalued. Quite recently, ideas of distance learning and web-based instruction address this issue from a specific point of view. In addition to coping with the structural challenges of a 21th century university, professors face increasing public uneasiness with higher education and a distrust of our intellectual pursuits. Furthermore, as scientists, we face a decrease in scientific literacy and lack of public interest in science and technology.

It is not simple to define my role as teacher in this complex system. Learning is a lifelong experience, for a student as well as for me. Learning and discovery are satisfying experiences, and I perceive as one of my roles as teacher to help students walk along both these roads.

I think that one of the main responsibilities and missions of a scientist is to convey the joy involved in understanding nature, and also its relevance to our everyday life. As such, my teaching (be it in the classroom, during a tutorial session, advising graduate students or while giving a seminar or colloquium) tries to emphasize looking at the 'greater picture' at the various levels. I try to share my enthusiasm for science and the significance of our being able to form a coherent picture of how nature works, a picture obtained from systematic observation, logical reasoning and (in the case of physics in particular) a simplifying mathematical language. In this regard, a main challenge is to motivate the student to look for this coherent picture.

Of course, teaching physics depends to a large extend on the audience. Thus, I will discuss introductory level physics and advanced (graduate) physics in different sections. In a physical science course, which has enrollments of typically 70 to 100 students, I try to convey *that physical phenomena are part of our daily life, and that we can understand phenomena of music, color, and light with the help of a few basic physical principals and laws. Here I see an important part of my role as teacher explaining to the students how science works, even if mathematical details or many of the subtleties are not discussed. I believe, that especially in a physical science course it is important to convey the process of discovery as much as the subject itself. Thus I considered the physical science course PSC105 as being well suited to introduce interactive learning tools as being offered through web-based material. In a separate section I will reflect on my experience with web-based instruction, which consists of the development and implementation of web-based, interactive course material for the physical science course PSC105. I taught the course 1994 and 1996, and developed the web-based material between 1996 and 1998.*

1. Introductory Level Physics

At the introductory level the challenge of teaching is greatest, because physics demands a kind of reasoning, visualization and abstraction that is not encountered in most other fields. At Ohio University, introductory physics is offered in the Phys 201-203 sequence and the Phys 251-253 courses. I have lectured both, Phys 202 and Phys 253, once. The class size was about 50 students each time. The content of both courses deals with electromagnetism, optics (wave phenomena), and in the case of Phys 202, heat and thermodynamics. The difference is the audience and the depth of presentation of the material. The students taking Phys 202 are primarily life science majors (pre-meds, biological science), pre-physical therapy and physiology majors, and a broad assortment of other areas ranging from mathematics to forensic chemistry and accounting. Those taking Phys 253 are physics or engineering majors, and some chemistry majors. Naturally, the interest, preparation and motivation of the students taking Phys 202 as well as Phys 253 is quite diverse, and only few of the students have selected physics as their primary interest. For the majority of the students those courses are required, but not necessarily one of the courses of their interest.

Because of a sense on the part of many students that the course is just a necessary hurdle, it is essential to provide well organized and interesting *lectures to enhance student involvement in the course. To minimize difficulty with the abstract quality of the material, I try to emphasize the aspect of discovering the laws of nature by using many demonstrations. The department maintains a good collection of demonstrations, and I perform several each quarter. I also take advantage of on-line 'canned' demonstrations and java-applets, which I collected over time. As far as explaining with demonstrations is concerned, I use them in both, Phys 202 and Phys 253, in roughly the same fashion, since I believe that the path of discovery of the laws of nature should be taken at all levels.*

In addition to the minimum requirement of delivering a rigorous treatment of the material in the lecture, one has to work to establish a genuine interest and enthusiasm on part of the students. Here demonstrations and interaction with the students helps in establishing a positive learning climate.

In both courses, a one hour midterm and a two hour final exam are given combining all section of the course. We have found that the average scores on the final exams are remarkably consistent across the various sections taught by different faculty members (within a few points). This suggests that the physics department as a whole is providing a rather consistent treatment of the material independent of the particular instructor. In both courses, there are weekly quizzes, in Phys 202 lasting about 10-15 minutes, in Phys 253 there are 2 quizzes (group and individual) taking the entire lecture. Though the quizzes in Phys 253 should be proctored by Teaching Assistants, I was present during all group quizzes, since I took this time as opportunity to get feedback from the student about possible learning difficulties, and pick up what I should emphasize in the lecture in more detail.

The department of Physics and Astronomy has pioneered the use of computer-based homework in the service courses, the so called 'CAPA' (Computer Assisted Personalized Assignment) system. In this approach, each student is given a unique assignment, different in detail from all other students. The advantages of CAPA from the student perspective are: (1) immediate information about whether a solution is correct and (2) the opportunity to work at the problem until it is perfect. Usually about 70% of the students have close to perfect scores on the CAPA homework. This strongly suggests that students spend additional time on the course material. A teacher's advantage of CAPA is that it is possible to monitor the 'progress' of the students in solving their problems within the system, and diagnose their difficulties very quickly. This allows immediate adjustment in the lecture.

Very different from lecturing to a large number of students in an introductory physics course is the lecturing in small groups. Physics majors who pass Phys 253 take in their next year Phys 351 and 352, modern and quantum physics, essentially physics of the 20th century. I have taught Phys 351 three times, and corresponding Honors Tutorial Courses two times. The enrollment in Phys 351 has been 5 to 8 students. With such a small group, teaching takes on quite a different character. Specifically in 'modern' physics, I try to convey to the students a spirit of discovery, and give a feeling for the puzzles that occupied the great minds in physics in the 1920's, when quantum mechanics was invented. A fine pedagogical tool for this has been provided by the Consortium for Upper Level Physics Software (CUPS). Here the students can simulate key experiments that lead to quantum mechanics as well as illustrate abstract concepts and build intuition. I usually give the students 3-4 'laboratory homework' from the set of CUPS simulations, one of which they *have to present in class. I found the student presentations as well as the written reports very successful in developing the student's communication skills, which is very important for their future careers. I apply similar methods in the tutorials, however tutorial students have more challenging requirements as far as analytical skills in problem solving is concerned.*

During my time at Ohio University I had five undergraduate students involved in research projects with me. I supervised two Honors Tutorial Bachelors Theses and had three undergraduate students in a Summer Research Internship. I consider this 'apprenticeship' an integral part of the education of physics majors, since it gives them at an early stage the possibility to experience work as a physicist, to apply some classroom knowledge to a project of their own, and to develop creativity. In all cases I experienced that the students were highly motivated to carry out their own project and some of the results had publication quality, which were pursued.

2. Advanced Physics

Teaching advanced courses in physics offers a very different set of challenges than the elementary counterparts. At the graduate level I consider it important to make connections between different subfields of physics to give the students an understanding of the larger pictures in physics. In addition to acquiring textbook knowledge, I consider it equally important to involve students in small classroom projects, whenever suitable, to encourage the development of creativity and problem solving abilities within a larger context using a variety of techniques. I also encourage students to keep alert of progress in other fields and avoid being progressively confined to only their projects and their specific field of Ph.D. research. I believe this is important, since in today's rapidly changing employment market a broader education as well as flexibility are valuable assets.

In addition to acquiring knowledge specific to physics, I consider it as important that students at the graduate level start from their first year on developing skills in presenting and communicating their knowledge not only in exams but more importantly to their peers. They will need these skills to compete in a global economy. The professional physicist spends a considerable amount of time making presentations to various audiences and writing proposals at various levels. Thus, good communication and writing skills are essential. For this reason I incorporate small projects with written and oral presentation in the course work whenever appropriate, as early as the first year of graduate study.

During the last five years I developed three new graduate courses, a two quarter sequence in quantum mechanics (required for all physics and astronomy graduate students), a course in relativistic (advanced) quantum mechanics, and a course in nuclear theory. I also continued to teach one quarter of mathematical methods before one of my colleagues took over.

Detailed mathematical calculations and derivations are a key issue in advanced theoretical physics courses. Often these mathematical arguments, independent of how elegant they may be for a person who masters the subject, are lengthy and involved, and it is easy for a student to get lost in the details and miss some of the overall reasoning. Therefore, I wrote out all my lecture notes in meticulous detail and made them available for downloading from the class home page (www.phy.ohiou.edu/˜ elster/phys611). These lecture notes can be viewed as a 'special' book accompanying the lecture. There are many textbook out on the market covering quantum mechanics; however I found that there is no single textbook written in such a way that it exactly matches the topics in the manner I want to cover them. This was another motivation for writing up my lecture notes. The students can use them together with a list of recommended textbooks from the library, to complement their studies. I consider it important that during the lecture the students concentrate on my reasoning of a specific topic rather than focusing on transcribing every detail. I am aware of different learning styles and that for some students it is very beneficial to transcribe everything; however, in general I found that students appreciated having the lecture notes available. The homework problems, thought lengthy at times, are designed to complement the lecture material or to work out a specific problem, for which the general approach was presented in the lecture.

In the case of the nuclear theory course matters were entirely different. The course covered topics in few-nucleon dynamics at the edge of actual research. Thus, there is no textbook covering the material. The chapters on the nuclear force are in part a summary of my own research over the last 15 years in that area of physics, the chapters on few-nucleon systems evolved from lectures W. Glöckle presented while being Rufus Putnam Professor at Ohio University, and contain pieces of our current collaborative research work. From this point of view, the lecture notes can be considered original work. I also used the notes as study material in special study instruction for advanced graduate students. The lecture notes for quantum mechanics (www.phy.ohiou.edu/˜ elster/phys611), relativistic quantum mechanics (www.phy.ohiou.edu/˜ elster/phys735), and nuclear theory (www.phy.ohiou.edu/˜ elster/phys755) are included in the appendix.

3. Supervision of Graduate Students

Facilitating the professional development of graduate students is an important element of a faculty members work in the Department of Physics and Astronomy. In this sense Ph.D. work can be considered as an apprenticeship, in which the student gradually develops and perfects the skills to formulate and manage a problems of their own, present it to peers at meetings and in journals. I see my role as teacher to guide the students through the apprenticeship so that by the time they graduate, they have the necessary skills to start a *successful physics career, be it in an academic or industrial environment.*

Usually I expose a beginning Ph.D. student to a smaller scale project, which they can oversee and 'own' in a relatively short amount of time. This project can be of the same scale as a project for a Honors Tutorial Thesis or a Master's project. Normally it involves parts of my research, where the really difficult aspects are already solved by me or my collaborators. I consider it as psychologically advantageous for a beginning research student to see the results of their work after a couple of months, to give them some assurance that they can succeed with more complex problems and at the same time get a thorough but still not overly demanding introduction into their field of research. I am careful to lead the Ph.D. student to problems, which are likely to produce publications. During my time at Ohio University I have 18 publications with graduate students and undergraduate students.

I regularly provide funds from my grants to allow my graduate students to attend meetings and workshops during their Ph.D. work and present their results, and encourage them to work on their presentation and communication skills. The exposure to major meetings is an important part of the general education of a graduate student and will be beneficial to their future employment. It was a great pleasure for me that my current Chinese graduate student was awarded a prize for the best graduate student presentation at the graduate student workshop on computational physics held at the Ohio Supercomputer Center.

4. Web-based Learning and Teaching

With the increase in bandwidth, fast Internet access, and the advent of Internet2 discussion grew on how this new medium Internet could benefit the educational community. A focus group for web-based education was created in 1996 among the users of the Ohio Supercomputer Center and the State put out financial initiatives to support exploration of the Internet for educational purposes. At the time the enthusiasm for web-based education was great. However, ideas and perceptions on the possibilities and limitations of the Internet as educational medium were rather nebulous. I found ideas being put forward intriguing and wanted to face the challenges of developing web-based learning tools in a realistic situation.

In 1994 I had the opportunity to teach a physical science class (color, light, and sound) offered by the department to fulfill Tier II requirements of non science majors. Physical science courses typically have an enrollment of more than 100 students and are taught in large lecture halls. Most students have little exposure to physics in their prior studies, often feel uncomfortable with the material, and need a lot of guidance through it. To me, this course seemed well suited to exploring the possibilities and challenges of web-based learning. At the same time Ohio University began a drastic improvement of Internet access for all students, first in Alden Library and Computer Services, then in the dormitories.

Simultaneously, Internet access and modern projection technology was installed in the large lecture halls. Thus the infrastructure was being put into place to give students easy Internet access, outside and inside the classroom.

From 1996 through 1998 I taught Physical Science 105 four times, and during this time I progressed with the development and implementation of web-based learning materials in different stages. In my opinion it was a good strategy to progress in specific stages (I will call them phases) so that students could get used to the new medium along the development, some of the university technology setup could get debugged, and I could have some feedback and gain experience during the different stages of development.

Phase I: When I first taught the course in a regular, traditional lecture setting in 1994, I had organized the material according to chapters, every chapter covering a specific topic and spanning about four hours of lecture. In this form the amount of the material and the topics had been well received by the students (average rating of the instructor by the students 2 in a scale from 1-5, where 1 is the best). When starting the development of the web-site http://capa6.phy.ohiou.edu/~ psc105, I kept this overarching structure, and filled in the chapters with illustrative graphics and descriptive text. A particular emphasis was the choice of images. They should convey information in a clear and concise fashion, and be relatively small for easy downloading. During the lecture I used those images for explanation, with the descriptive text being a supplemental guide through the material in the chapter. In this first stage the web-site was like a textbook delivered by the web, it was an old idea packaged in a fancy and up-to-date format.

Phase II: One of the advantages of the web is the easy incorporation of cinematography. In a physical science course it is essential to illustrate the laws of nature with simple examples and demonstrations. The department owns the 'Video Encyclopedia of Physics Demonstrations', which I had used before to incorporate demonstrations into the lecture. Though one can argue about the difference of live demonstrations over prefabricated ones, for a large lecture hall prefabricated movie clips have the advantage that we can watch details like on TV, and I can halt, explain, discuss, and repeat sections if necessary. The advantage of a web-lecture is that demonstrations and animations delivered as Quicktime or mpeg movies can be easily incorporated. (As an aside, today this would be even easier, since OhioLink provides the Video Encyclopedia on-line). During the lecture I showed and explained the clips 'as usual'. However since they were available in the web-lecture, students had the opportunity to watch them over again, when working through the material. In addition to animations, I incorporated interactive Java applets, an example of these lets students change the position of an object before a lens interactively and observe how the image changes. At the time there already existed a small collection of applets on educational sites in the US, *Germany and Japan.*

To summarize, it was during that phase that I made the deliberate attempt to incorporate different types of visual and audio-visual material into the web-presentation, since different students learn by different means. I considered it especially important to include short demonstrations either as movies or Java applets since approximately half the students in the course have had limited exposure to physics in their previous education and need a variety of visual examples to grasp the concepts conveyed in the lecture. I consider it important that students have the additional opportunity to review the material together with demonstrations outside the classroom.

Phase III: Non-science majors often shy away from science or underestimate their own capabilities of understanding science. I try to convey that learning science/physics is a lot like acquiring skills in sports: Everybody can achieve after developing some 'muscles' (learning concepts) and some 'techniques' (logical and mathematical structures). This learning, however, requires constant practice, drills, and exercise, just like any sport. When I started teaching Physical Science 105, the course had no homework component. Though the introductory physics course in the department all used the CAPA (Computer Assisted Personalized Assignment) environment, I decided not to use it here. One reason was that a physical science course has a considerably smaller numerical content compared to the introductory physics courses. Another reason was that CAPA at that time was only at the beginning level of being delivered via the web. Thus, Dale Mitchell, then the department's computer education support technician, designed a homework component using cgi-scripts and HTML, and I developed a set of homework problems for it suited for the physical science level. Later a computer science graduate student, Lu Tong, developed a web-based homework utility, which was baptized OU-prof, and which was in service for about 4 years. (In fact, OU-prof was initially supported by a Technology Initiative Package grant from Ohio University awarded to Prof. Jung.)

I consider the home work component to the course quite essential, since in trying to solve problems the students work through the lecture in more depth and develop a working familiarity with the material. After a quarter using our homework utility as voluntary supplement in 1997, I introduced the homework component as a mandatory part of the course in Spring 1998, and met a strong resistance from the class, with students arguing that 100-level courses should not have weekly homework. By the next time the course was taught, the homework was becoming a slightly more accepted feature. However, it took another year for the homework component to become a fully integrated part of the course.

In the Fall quarter 1998 all the above mentioned components of the course were completed. The course had become a self-contained package, and I taught it for the last time *that quarter. A CD-Rom with the material from 1998 is included in the appendix, the currently implemented, updated version of the course can be found under http://capa6.phy.ohiou.edu/˜ psc105.*

Once the course material was developed at this level, I considered possible next steps. One possible avenue was to turn the course into the a true self-paced distance learning course. Its modular structure (chapters) fits nicely into a self-paced structure. To add a new dimension I proposed with Prof. Opper adding narrative as a primary means of delivery using streaming audio synchronized with the HTML pages of the lecture. The proposal is included in the appendix since it gives more technical details about the status of the physical science course in 1998. This proposal for a Technology Initiative Package from Ohio University was well received and ended up right on the cutoff line where funding was no longer available. From the reviews it was clear, that the existing web-components were already rather advanced compared to other proposed projects, and only 30% of the proposed projects could be funded. Another aspect of the proposal was the plan to make the material available to instructors at Ohio University Branch Campuses who also teach the course. This aspect turned out to be successful, at present the lecture is being tested at the OUSouthern Campus.

A specific issue raised early on with respect to web-based learning and teaching, and also raised in the reviews of the above mentioned proposal, is the question of sustained maintenance of on-line course material, and the concern that on-line material will be useless once the developer stops attending the product. Fortunately, in the case of physical science 105 this has not turned out to be a concern. I always had envisioned that after I stopped development work on the web-based learning material, it would turn into a tool, which is available to other instructors to use according to their own ideas about teaching the course. Since its structure is modular, it is quite easy to pick and choose different parts. Until now two different instructors have used the material in quite different ways. Prof. Opper edited parts of the web-material to better match her way of teaching the course and uses all features of the on-line material. Prof. Wilen on the other hand chose to work only with the homework aspect of the course. From this point of view I consider the continued utilization of the on-line material, or aspects thereof, as teaching tools in addition to the much improved acceptance by the students, the true success of two years of development work.

Along this vein I would like to comment on the change within the Ohio University student body. When I started using the web as teaching tool I needed to give an introduction to the use and features of a web-browser since many students in the class were not familiar with the web. Today web-browsers are commodity tools mastered by all students. Similarly, web-based homework is perceived by the students as just something physics does, i.e. some-

thing perfectly normal. This is a tremendous difference compared to the situation only four years ago, and stands for the much improved computer and technology literacy of all Ohio University students.

Another question to ponder is, what would be different, if I would start this work today instead of 1996. Or a different way to put the same question, what did five years of web-based learning and teaching initiatives change. A first observation is, that by now all major textbooks on introductory physics supplement their textbooks with multimedia or interactive learning CD-Roms, and web-based learning material. This indicates that the commercial market took over the development of multimedia teaching tools, which are financially lucrative, and it is up to the instructor to pick and choose. 'The Physics Classroom and Mathsoft Education and Engineering, Inc.' (www.physicsclassroom.com) offers online physics modules for education in high schools, some of which are similar in character to my 105 online chapters. Thus, today I most likely would not have to develop so much on my own. I could visit for example the Multimedia Educational Resource for Learning and Online Teaching (MERLOT) (merlot.cdl.edu), which is a free and open resource designed primarily for faculty and students in higher education, and browse their collection of online learning materials and structure my course with prefabricated modules according to my pedagogical perceptions. Certainly, for me the development of the web-based learning and teaching material was an enlightening experience about the challenges of web-based teaching materials. However, today the same work would be different and easier as far as technical aspects are concerned, since there are a lot more already finished modules available. I should also mention, that during the last year, the homework utility OU-prof was retired, and all it's problems were converted to be used with the CAPA utility. This was most reasonable, since by now CAPA has all the features built in, which were missing 1996. Thus, there was no reason anymore for the department to maintain this software utility with department resources. In closing, it is also interesting to notice that bold statements about a statewide web-based educational system have become more modest. This may be attributed to the realization that the cost of the technology infrastructure to support this is higher than anticipated.