

FORUM on EDUCATION

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A Message from the Chair

Jack M. Wilson

This must be a time of celebration in the APS and AAPT. One of our own, Carl Wieman, has won the Nobel Prize in Physics. Carl is a very active member of both APS and AAPT and is a significant contributor to the community of educational physicists as well as the research community. This is indeed symbolic of the dualistic nature of the APS Forum and dual nature of so many university faculty. In the last newsletter I discussed the release of the National Research Council's most recent decadal survey of physics. (Physics in a New Era: An Overview; Physics Survey Overview Committee, Board on Physics and Astronomy, National Research Council; 208 pages, 7 x 10, 2001. <http://www.nap.edu/catalog/10118.html>). Carl was a tireless leader throughout the lengthy process. Together Carl and I slogged through many revisions of the section.

Why is this important? There is always a tension between research in physics and education in physics. There are those who see the tension through polarized perspectives as research versus teaching. Some of those are the research faculty who see teaching as simply another obstacle to their research productivity while others are educators who devalue research and see it as the enemy of education. This tension plays out in many faculty members lives nearly every day. Should the non-tenured faculty member get involved in educational innovation? Should physics departments devote resources to the introductory courses or just put the students in large lectures and teach them with the fewest faculty and the largest number of TA's? Should educational activities receive as much weight as research in the appointment/promotion/tenure process? These are the kinds of balances that must be struck by faculty and administrators in the universities.

When AAPT spun out of APS in 1930, it was because of that tension. When the APS formed the Forum on Physics Education and did so in collaboration with AAPT, it was precisely to reduce these kinds of tensions. Strong leadership from APS and AAPT officers over the years have reinforced this unity of physics.

At the recent inauguration of Lawrence Summers as the 27th President of Harvard, this tension was evident. According to the Chronicle of Higher Education a former economics professor at Harvard, Mr. Summers pledged to hire more faculty members to strengthen undergraduate teaching at Harvard. He also said that

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Harvard's professors needed to continually examine their teaching to find ways to improve. He said the faculty and administration should be "thinking carefully about what we teach, and how we teach." In addition, Mr. Summers said he wanted to improve the science education of all undergraduate students, even if they were studying the humanities. While most Harvard students are familiar with Shakespeare's works, he said, "it is all too common and all too acceptable not to know a gene from a chromosome." Reportedly, the revitalization of undergraduate education was an important factor in Summers' selection.

That is why it is important. There have always been those in the universities who felt that research and teaching are not at opposite ends of some spectrum. Instead they see them as interdependent as the heart and the brain. It makes no sense to trade one off against another. A healthy organism demands that both be healthy and functioning cooperatively.

Carl epitomizes that kind of a faculty member who values

both aspects of his career and devotes time, energy, and resources to advancing each. The APS Forum symbolizes this link and endeavors to support those like Carl, and so many of the rest of you, who care deeply about the advancement and the unity of physics.

By singling out Carl Wieman, I certainly do not intend to slight his colleagues Wolfgang Ketterle, and Eric Cornell, but simply to recognize Carl's dual contributions as a model to which we might all aspire. Congratulations Carl Wieman, Wolfgang Ketterle, and Eric Cornell.

Jack Wilson is Chair of the Forum on Education. He is the founding Chief Executive Officer of UMassOnline, the University of Massachusetts Virtual University. Prior to this he was the J. Erik Jonsson '22 Distinguished Professor of Physics, Engineering Science, Information Technology, and Management and was the Co-director of the Severino Center for Technological Entrepreneurship at Rensselaer. At RPI Dr. Wilson led a campus wide process of interactive learning and restructuring of the educational program.



Join the AAPT at Half Price

The American Association of Physics Teachers is offering APS members a special half-price membership offer. If you've never belonged to AAPT and are interested in finding out more about what makes the association tick, take advantage of this discounted rate for your first year of membership.

Members receive discounts on purchases from our Products Catalog, as well as discounts on AAPT National Meeting registration. The next meeting will be in Philadelphia, January 19-23, and will feature sessions on the Web and Physics First. Members also choose a subscription to the *American Journal of Physics*, *The Physics Teacher*, or both.

To take advantage of this special offer, visit <http://www.aapt.org/halfprice>. More information, email aapt-memb@aapt.org.



Teaching on the Web

Thomas D. Rossing

"Teaching on the Web" can mean many different things, ranging from the use of the Internet or a local network for homework and quizzes to courses that are taught entirely on the Internet, sometimes from a remote site. There are obviously advantages and disadvantages to using the Web, and there are probably as many different opinions about it as there are teachers who have tried it or who have avoided it. One thing is certain: we can't just ignore the Web in physics teaching.

In the November issue of *The Physics Teacher* are letters to the editor from three teachers about their experiences teaching online. They vary widely, as you might expect. One teacher lectured online and included a lot of graphics to complement the online lectures. She is planning to integrate online simulations (Java applets) into her weekly lessons. Another teacher comments that "We do not use anything fancy—no video, no voice transmission, no broadband methods. Instead, we have very lively, constant (seven days a week) discussions about the reading for the week." Each student is required to submit

at least three public postings per week. The third teacher has had experience with students getting together online to work on a lab as a group, but finds that this "does not always work well."

I am just getting my feet wet, testing the waters online. I have used two different course delivery systems (Blackboard and WebCT) in my courses, and I have attended several workshops to learn about other systems and especially about the experience of other physics teachers. I intend to employ Blackboard again next semester, not because I think it is the best system but it is the only system my university supports. Unless a physics teacher is willing to devote a lot of time to writing Applets and other necessary course development, it is probably the criterion that most physics teachers will use to select a procedure.

In my course in Acoustics, Music and Hearing, I require a pre-test be submitted online several hours before each unit (chapter) is discussed. Then the students submit their home-

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work online, and get immediate feedback, of course. I give an exam on each module (3 or 4 chapters) plus a final exam in a proctored setting in the computer laboratory. The class meets twice a week to discuss the material and especially any difficulties they are having. Attendance at these “voluntary” sessions averages 50–60% which isn’t that much different from attendance at lectures in other introductory classes.

One of the big advantages of Web teaching is that supplementary material, especially video and audio clips, can be placed in proper context online. I often show an appropriate video in class and then urge the students to view it online a second time (unfortunately Blackboard does not keep track of individual “hits” so I don’t know which videos they view).

This newsletter includes several articles by physics teachers who have had considerable experience with teaching on the Web. We hope that they will be useful to other teachers who wish to incorporate the Web into their physics courses. We hope that our readers who do not presently teach will also find them interesting since this is such a rapidly developing area of education. Perhaps they will stimulate discussion in this newsletter. Again, we remind you that we would like to have more Letters to the Editor!

Thomas D. Rossing is Professor of Physics at Northern Illinois University, DeKalb, IL. He has been an editor of the Forum Newsletter for six years.

Motivating Students to Learn Physics Using an Online Homework System

John Risley

The Issue - A major task of physics teachers is to encourage students to solve physics problems. Traditional tools such as textbooks, lecture time, tutorial centers, and tests can help, but more creative effort is required to give them the practice they need to master new concepts and applications. Although we identify important problems for our students to consider, assign a schedule, and answer questions to help guide them through the intricacies of an expert solution, students are reluctant to expend the time and energy required to complete the work.

If these assignments are not graded, at best the students will simply look over the list of problems. We can tell students that solving these problems will help them on tests, but in reality little is done except last-minute cramming the night before the exam. Routine assignments with deadlines are necessary for most students to learn physics. But this work **must** be graded if it is going to encourage students to spend time working through the exercises. Grading is a chore, and many teachers simply do not have the time or resources to grade papers carefully.

This critical grading task can be virtually eliminated by using online homework grading systems. Students will receive immediate feedback, and instructors can offer more frequent, shorter assignments to keep students up to date on the course material.

A robust, multifeatured system with a richly endowed question database is critical to successful online grading. One such system is WebAssign, a web-based homework delivery, collection, grading, and recording service available to teachers, professors, and instructors who want to provide more effective encouragement to their students learning physics, see <http://webassign.net>.

WebAssign - WebAssign delivers, collects, scores, and records student work. Teachers make up assignments by using their own questions or choosing questions from leading physics textbooks. WebAssign is a project in the department of physics at North Carolina State University (NCSU). It is supported by a team of programmers, content specialists, editors, designers, and instructors. New features and improvements are deployed continuously to provide the best possible assessment system. Agreements with textbook publishers are in place that allow WebAssign to deliver problems from class-adopted textbooks. New agreements are sought continuously as new textbooks and editions are published.

The origins of the WebAssign code stem from work conducted by Larry Martin, a physics professor from North Park University in Chicago, and Aaron Titus, a graduate student in physics education research at NCSU. Larry Martin wrote a comprehensive web-based homework system using a flat file architecture. He created the `<eqn>` tag, which is a way to incorporate powerful Perl functionality into questions and answers. This tag allows you to randomize numbers, variables, and many other programming features such as logic statements, define variables and arrays, etc. In May 1996, Aaron Titus created a web-based assignment system using a database of questions and answers delivered by a Macintosh server. This system was used with 300 students at NCSU. Martin and Titus collaborated in 1997–1998 to develop the basic functionality of the current WebAssign system. This merger led to a very robust, multi-featured application.

Many individuals are involved with WebAssign so that the features instructors want can be added to the system. A high level of responsiveness demands a concerted effort by faculty, programmers, editors, and technical support associated with the project. WebAssign is offered as a fee-based subscription service to teachers at universities, secondary schools, and educational institutions to provide viable funding for this work.

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WebAssign offers many key features that are important for physics teaching. The most significant is the quality of its **question** types. **Numerical** questions can be randomized with answers that depend on the calculated values, and even answers that depend on values that the student enters. Students receive the same set of questions, but each will have different values. **Symbolic** questions allow a formula to be entered, again with randomization of numbers and variables. **Java applets**, such as the Physlets from Wolfgang Christian at Davidson College, can be deployed to offer a very different kind of problem to solve. These simulations bridge the gap between questions about a static drawing to a laboratory measurement, while maintaining the advantage of automatic grading. A file-upload question type is available for grading Excel spreadsheets, Word documents, a MatLab worksheet, or any other type of file. Multiple-choice, multiple-select, and fill-in-the-blank questions are also available.

All questions in WebAssign can utilize Martin's powerful `<eqn>` tag, which allows a teacher to write code in Perl and have it evaluated in WebAssign. This important development also enables teachers to write questions that can analyze students' experimental parameters and their resulting calculations. With the full power of a programming language hidden just beneath the question, physics teachers can offer all sorts

of logical statements and conditions for questions and answers.

A hallmark of WebAssign is its extensive database of questions from leading physics **textbooks**. In WebAssign, it is easy to create elaborate multipart questions, which can represent exactly the questions found in textbooks. Coding questions is an intensive task, requiring careful attention to detail and accuracy. An incorrectly coded answer algorithm can cause much grief with students, so the WebAssign team responds quickly when these kinds of problems arise.

WebAssign supports textbook questions with a quick turn-around time for reported error. This responsiveness sets WebAssign apart from other online homework systems.

The questions coded into WebAssign are virtually an exact replica of the original question, using the same figures and pictures that appear in the **textbook**. As teachers, we know how easily the scope of a question can change with just a slight alteration in wording. By working with leading publishers, WebAssign has taken a strong position on providing the very highest quality set of textbook questions.



WebAssign's Publishing Partners

WebAssign offers numerous student communication links for the teacher. In addition to offering the capability to email one student, a group of students, or the whole class, WebAssign has a "help desk" that allows students to request help with a specific assignment. A teacher can respond to these questions efficiently because a full display of the assignment, along with the student's responses and correct answers, is available from the help desk. This is much better than having students send you an email about an assignment that you then have to look up!

Reporting grades is an important component in a teacher's list of responsibilities. WebAssign shows all scores, down to each individual problem, for any and all assignments. All of the

relevant statistics are available for any question or assignment, such as average, mean, max/min, standard deviation, or index of discrimination.

One Example - Each teacher can adapt WebAssign to suit his or her particular needs. This is what makes WebAssign such a powerful tool. For example, I will outline how Bob Beichner and I use WebAssign for both of our introductory calculus-based **physics courses** at NCSU. This course is taught in the SCALE-UP classroom with the able assistance of Jeanne Morse, my TA. (Our more typical lecture courses with laboratories also make heavy use of WebAssign, but without the added advantage of having computers in the classroom.)



Each week we assign two homework problem sets. They are due one hour before class. (We have found that midnight deadlines don't work, since many students start the assignments in the middle of the night, and a deadline too close to the start of class results in students coming to class late!) On Mondays, the assignment consists of three to four easy questions from the textbook, usually focusing on new material that we have not covered in class. This forces students to read ahead and prepare for the upcoming class. Students are certainly better prepared now. The Wednesday assignment covers the more difficult questions and might have four to six questions. At the start of each class, we often have lively discussions about the homework. For students who had difficulty, these discussions bring them up to speed and they usually ask for an extension to resubmit their work so they can get a perfect "100." I generally allow extensions. I want to encourage my students to spend more time learning physics, and with WebAssign an extension doesn't require any more time from me to grade their work. (WebAssign easily facilitates extensions, and you are notified whether or not the student has seen the answer key.)

On Fridays, we give in-class quizzes using WebAssign. We have a classroom filled with computers so the task is very efficient. WebAssign has security controls that allow you to restrict access until a password is given in class and allow only certain computers access based on IP subnets.

We often have in-class activities, similar to a laboratory, but shorter. To encourage students to think about the work before coming to class, we post a prelab assignment on WebAssign that is due before the lab. The formal lab is a group effort, written in Word or some other word processor. Any member of the group can upload it into WebAssign as a file-upload type. The TA is able to read the electronic reports, assign a score in WebAssign, and give comments to the group that be-

come a permanent record for each student. We also assign a few problems about the lab that can be graded automatically. WebAssign allows you to create automatically graded questions that ask the student to enter their measured values, assess them for reasonableness by setting a large tolerance, and then use their measured values to calculate some physics property. The essential data taking and analysis can be graded accurately and automatically. If you give students multiple submissions, they can correct mistakes made during data acquisition as they complete the analysis portion of the lab. It is also possible to freeze the acquired data in one assignment and then use that data in the analysis section so that students are less likely to fudge their results!

Computer simulations are a very effective way to get students to interact with physics concepts. The trouble, though, is that students will not use the simulations effectively unless you ask them some leading questions that can only be answered through careful observation. If you do not ask students to turn in their observations for grading, the students do little work. We have used a number of java applets for in-class activities that are graded either on the spot or just after the class is over. Again, by automatically grading the students' work, you can be certain that they have been engaged in the learning opportunity.

Finally, we use WebAssign for high stakes testing. Here, the benefits of automatic grading are obvious. For a typical 50-minute exam, we deploy about ten questions, many with sub-parts. They range from very simple calculations and multiple-selection conceptual questions to difficult computations. To encourage students to think hard about the content of the test, we allow two "free" submissions. This way, if students make a simple mistake in their calculations, they can correct it with

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the second submission. To encourage struggling students, we offer additional submissions but with a loss of 3 points, out of 100 maximum, for every additional submission. We are happy with the results. Students who know the material receive high scores and those who are not putting in the appropriate effort get low scores. Student surveys indicate a high degree of satisfaction of WebAssign tests over our standard multiple-choice tests.

We recognize that our use of WebAssign is not entirely typical. However, we have seen that it saves time while motivating students to do the work. What more could we ask?

John Risley, professor of physics at North Carolina State University, is well known for his research on the utilization and effectiveness of computer technology to teach physics. He is editor of Physics Academic Software, a cooperative effort with APS, AIP and AAPT, and he is director of WebAssign. His email address is: John_Risley@ncsu.



The Physics Illumination Project: Conceptual Homework on the Web

Ron Greene

Physics Illuminations consist of a simple interactive component (such as a Java applet) packaged with brief descriptive text. Most are qualitative in nature and naturally incorporate student assessments, so that they work well as automatically graded conceptual homework. Their positive impact upon learning has been demonstrated by the fact that over 100 students in three different classes employing no in-class interactive engagement methods showed conceptual learning comparable to that of the interactive engagement classes reported by Hake.¹⁻² (Further tests with other instructors are currently underway with the support.)

In-class active learning methods have been widely studied and are generally believed by physics education reformers to substantially improve student understanding of basic physics concepts. However, because of the extensive attention that has been paid to in-class methods, it is unlikely that substantial further improvement can be made on that front (other than convincing more instructors to use an interactive approach). By contrast, comparatively little attention has been paid to what can be done with homework to improve student conceptual learning. For typical students, learning through out-of-class study is probably only weakly correlated with learning through interactive in-class techniques; consequently, the combination of effective homework with interactive engagement methods may help us further improve student learning in introductory physics.

Listed below are a number of my conclusions about what is needed for effective web-based homework, based on my experience with Physics Illuminations. (Others have previously discovered some of these items in the context of in-class learning studies.)

- Most students will use on-line learning materials only if such use directly affects their grade. Giving them evidence that students who voluntarily use the materials

score higher on quizzes or exams is not a sufficient inducement.

- An applet should be accompanied by text to accommodate less explorative learning styles. However, such text should be very brief for students to take the time to read it.
- The opportunity to score well on homework encourages a high rate of participation, and consequently more learning. This is one of several arguments for relatively simple, single-focus learning items.
- Applets that focus on a single topic and limit the number of variable parameters are more likely to be effective. Most students are overwhelmed by an applet that gives them control over many variables, since they have not internalized the scientific approach of studying the effect of one variable at a time.
- Approaching a concept from different directions (with different applets) helps solidify the learning of that concept.
- Students can learn effectively through repetition. Applets that present students an “unlimited” number of random cases are particularly suitable for computer-aided learning.
- It is not necessary to show students what they did wrong if the software can give multiple random cases of simple tasks. Students will read the accompanying text (if it is brief) to find out what they need to do or what they might be doing wrong. Of course, immediate feedback is essential, but that is a given in computer-assisted learning.
- For complicated tasks, such as problem solving, and tasks where few cases are available, context-sensitive feedback is likely to be necessary. This is a much more difficult research and programming problem, requiring substantial understanding of learning (by both human and machine). Thus, it is important to break such tasks into simple sub-tasks to whatever extent is possible.

Improving student learning of physics through the use of more effective homework is still a relatively unexplored area. If you

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are interested in getting involved in this exploration, check out the open source Physics Illumination Project (www.uno.edu/~rgreene/pip.html). I welcome participation by non-programmers as well as programmers.

Partial support for this project is provided by the National Science Foundation's Course, Curriculum, and Laboratory Improvement Program under grant DUE-0088695.

1. Ronald L. Greene, "Illuminating Physics via Web-Based Self-Study," *Phys. Teach.* **39**, 356-360 (Sep.

2001).

2. Richard R. Hake, "Interactive Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses," *Am. J. Phys.* **66**, 64-74 (1998)

Ron Greene is a Professor of Physics at the University of New Orleans. During his career he has had varied research interests, among them plasma spectroscopy, semiconductor physics, and machine learning. This last area has evolved into studies in computer-assisted instruction.



The Evolution of Web-Based Activities in Physics at Illinois

Tim Stelzer and Gary Gladding

Five years ago, the Department of Physics at the University of Illinois undertook a complete revision of the introductory courses. The details of this revision have been reported in the paper "Parallel parking an aircraft carrier" in the FEd newsletter, summer 1997. A key component of the course revisions was the implementation of web-based homework and an on-line grade book system. In this article, we will describe the evolution of this system to include delayed feedback homework, "Interactive Examples" with sophisticated help sequences, and preflights for "Just-In-Time Teaching".

The Department of Physics has been using computer-based homework for more than 25 years¹. As part of our course revisions, we exported our Novanet-based exercises and grade book to the web. This move dramatically increased accessibility of our material for both students and faculty, and it has been very well received.

The original homework problems, which are still being used, typically consist of a physical situation about which the students answer several quantitative questions. A help button is also available which reveals hints to the problem's solution if requested. For example one problem reads: *Two electrons and two protons are located at the corners of a square as shown in the figure. Calculate the x and y components of the electric field at the center of the square, and the x and y components of the force on the left proton due to the other three charges.*

The student can enter their answers in a textbox and hit the submit key. The computer immediately indicates which responses are correct and which are wrong. The student can then rework the incorrect responses and resubmit them, repeating the process as many times as necessary until all the answers are correct.

Our experience with this type of homework is similar to that chronicled at North Carolina State². Students enjoy the flexibility of doing the homework from any web browser. They also appreciate the immediate feedback and typically continue with a problem until they have everything correct. Indeed,

student scores on the web-based homework are very impressive. Often students come to office hours and say, "I know the x-component of the electric field is supposed to be zero, but why?" This illustrates one of the strengths of immediate feedback. Students are provided with the opportunity to immediately identify their misunderstandings while the problem is fresh in their minds, which greatly increases the incentive to confront their difficulties and clarify their understanding.

A disadvantage to immediate feedback is that it eliminates the incentive for students to check their own work. Students find it is much more efficient to attempt a problem and let the computer tell them if they're right. Indeed, a common mode of operation is for students to enter "0" for all of the questions and submit their answer. Since frequently several components of a vector are indeed zero, the computer will immediately identify these as correct, eliminating the need for students to think about these questions. They then focus their efforts on the "real" problems. To reinstate the incentive for students to check their work, we added one problem to each assignment that has delayed feedback. Students are permitted to resubmit and change their answer to this question as many times as desired up to the deadline. But, similar to hand-graded homework, they don't receive any feedback about the correctness of their answer until after the deadline for making changes has passed. These new delayed-feedback problems seem to have had the desired effect of forcing students to thoughtfully and carefully check their work, and we have observed a strong correlation between students' performance on these questions and their performance on exams.

Another common experience we noticed with students' interaction with web-based homework is that of students often asking for the help to be displayed before they even read the problem! As a result, the "helps" were being viewed as part of the problem statement. Indeed, we believe an important shortcoming of most computer homework is that the help and feedback mechanisms are typically a monologue, despite the educational research findings that a dialogue is more effective. To help address this shortcoming, we have developed web-based exer-

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cises called Interactive Examples (IEs) that are designed to actively engage the students in a Socratic dialogue and promote concept-based problem solving. In each of these IEs, students are asked a single, somewhat challenging quantitative question. If the student can successfully answer this question, credit is given for the exercise and some optional "follow-up" conceptual questions are asked to test this understanding. If the student cannot successfully answer the initial question, a help dialogue, which takes the form of a series of additional questions, some conceptual and some quantitative, guides the student to develop a problem-solving strategy to answer the initial quantitative question. Eventually, as the student makes use of the help given in the computer responses, he or she is able to arrive at a correct solution to the initial question. The amount of help needed varies with the student. The software is also designed to allow the student to interrupt the dialogue and answer the initial question at any time, thereby reducing the tediousness often associated with web-based homework questions. The student can also continue to ask for help and be led to deeper and deeper levels of interim questions. Once the student has successfully answered the initial question, a recap of the strategy is presented, and finally, optional follow-up questions are posed to allow the new knowledge to be tested and applied. We have developed over 50 IEs for use in our introductory courses, and you may view them at <http://www.physics.uiuc.edu/tycho/index.html>.

Students have received these new IEs enthusiastically. We have conducted informal interviews and anonymous surveys, and an independent team from our Office of Instructional Resources has conducted focus groups to assess student satisfaction. The reports are all consistent. Students find IEs intuitive and important to their understanding of physics. A typical comment from a student is: "it actually helps you when you're stuck to not only get the problem right, but helps out knowing how to do the same thing again and feeling confident in the physics behind the problem. This is a must. it would definitely help me do better in this class. it's like having a personal TA to assist you with every problem when you get stuck."

Another nice feature of IEs is that every submission a student makes while working through the problem is logged. We have used this information to study how students interact with the IEs, and our preliminary analysis is promising. Most students ask for some help initially, but are able to solve the problem without using all of the help available. As we continue to study these logs, we will continue to refine the IEs and assess their effectiveness.

All of our homework and grade book utilities are written as Perl scripts in a package we call *Tycho*. We continue to adapt these drivers based on our experiences as well as advancements in physics education research. Most recently, we modified *Tycho* to accommodate the introduction of preflights for Just-In-Time Teaching³ into our courses.

Preflights consist of multiple-choice and text box questions that students must answer prior to each lecture. These preflights encourage students to preview the material before lecture and also provide an opportunity for the lecturer to identify student difficulties with the material. In order to assist the lecturer in efficiently extracting information from the student's responses, we have incorporated a sophisticated preflight module into our grade book. In addition to providing statistics for each of the multiple-choice questions, the module also offers powerful filtering options to quickly identify common student difficulties. The faculty has been very pleased with this functionality, and preflights are now being implemented in several of our advanced, as well as introductory, courses.

Through our experiences of improving the introductory courses at Illinois, we have learned several important lessons. First, developing quality materials always requires a significant investment of both time and money. It is imperative that we combine our experiences and resources in this endeavor. Whenever possible, we have borrowed material directly from, or based our work on ideas from, the physics education community. In a similar spirit, we encourage others to take advantage of our experiences and materials and assimilate them into their courses. You may view all of our work at www.physics.uiuc.edu/tycho/index.html, or contact us at tycho@uiuc.edu.

1. D.J. Kane and B. Sherwood, "A Computer Based Course in Classical Mechanics" *Comp. and Educ.* **4**, 15-36 (1980); L. M. Jones, D.J. Kane, B.A. Sherwood and R.A. Avner, "A final exam comparison using computer based instruction," *Am. J. Phys.* **51**, 533-538 (1983); L.M. Jones and D.J. Kane, "Network use in central management of large university physics courses," *J. Comput. Based Instr.* **19**, 77-81 (1992); L.M. Jones and D.J. Kane, "Student evaluation of computer-based instruction in a large university mechanics course," *Am. J. Phys.* **62**, 832-836 (1994).
2. Scott Bonham, Robert Beichner and Dueane Dardorf "Online Homework: Does It Make A Difference?" *Physics Teacher* **39**, 293-296 (2001).
3. Gregor M. Novak, Evelyn T. Patterson, Andrew D. Gavrin, and Wolfgang Christian, *Just-in-Time Teaching: Blending Active Learning with Web Technology* (Prentice Hall, Upper Saddle River, NJ, 1999).

Tim Stelzer and Gary Gladding are in the Department of Physics at the University of Illinois (Urbana-Champaign). Tim is a researcher in the physics education group, and is currently working on the development and evaluation of interactive examples. Gary is an experimental high-energy physicist who has devoted a significant fraction of his time to physics education in the last five years, and led the introductory course revision effort at Illinois.

Time-dependent Permeable Interface and IT-based Physics Education*

Jin S. Kim^a and Keum H. Lee^b

Education with interface and feedback. Any system of interest is part of a larger whole. There is an interface between the system of interest and the rest of the whole. No interface is perfectly insulating so the system interacts with the rest, and the two develop together as one feedback system with changing interface. An educational system/activity, surrounded/divided by interfaces, is often characterized by space (classroom, school, country, etc.) and time (class period, academic year, era, etc.) variables and/or more complex ones (class subject, ethnicity, culture, etc.). Hence the time-dependency and permeability of interfaces must be taken into account for a better result. Thus, any education system should have a feedback mechanism reflecting the societal change/need, and physics education is no exception.

Education is an interactive process involving knowledge exchange between the educating and the educated. Developing societies emphasize quantitative expansion of the educated population and productive teaching with fewer streamlined courses. However, demand for a higher quality and diversified offering follows when the paradigm shifts from teaching to learning, including interactive-engagement (IE) among teachers and students.

Paradigm of physics education. The current wave of science education reform is driven in part by a post-cold-war restructuring of the global economy and focuses on a more scientifically literate society. Since physics is the foundation of modern science and technology, physicists are in a unique position to educate people in the basic concepts of modern science. Engineers need better education in physics and industry needs well-trained physicists. However, data indicate that we are not doing what we should. A drastic change in physics education is in demand. Effective solutions have already been offered, yet go unnoticed by large segments of our community. Physics education can be more productive.

Research shows a wide gap between what a teacher teaches and what the students learn and active-learning (AL), including interactive-engagement (IE), is the key to narrowing this gap. Although AL without IT is possible, the catalytic role of IT is well established. IT use is a must for resource sharing at a distance and for IE among the teachers and students in real-time.

IT-based and active-learning solutions. In this era of knowledge-based economies, equal access to scientific knowledge is a fundamental prerequisite for sustainable development and keeping world peace. The use of new IT in promoting AL and IE modes of education, particularly through networking, will contribute greatly to improving educational quality for all, regardless of any barrier such as space and time, available funds/experts among institutions/countries. It is no wonder that the Science Agenda – Framework for Action (World Conference on Science, Budapest, 1999) stresses the UNESCO's

leading role in spreading IT use for science education.

The curricular solutions given below for introductory physics are distinguished in that they are research-based and often using state-of-the-art IT. The list is not exhaustive, merely representative.

- Advancing Physics¹ is a new course (with CDs) for AS and A level developed by the Institute of Physics (UK).
- Just-in-Time Teaching² enhances interactivity and responsiveness among faculty and students, via web-based assignment turned in just in time so the faculty can adjust his/her next lecture reflecting such inputs.
- Peer Instruction³ actively involves students in large lecture courses by interspersing brief mini-lectures with conceptual questions.
- Physics by Inquiry⁴ is an inquiry-based course and it also can be used with a lecture-based course.
- RealTime Physics⁵ is a complete set of interactive micro-computer-based labs.
- Tools for Scientific Thinking⁶ consist of a small set of interactive microcomputer-based labs.
- Tutorials in Physics⁷ are a complete set of carefully designed tutorials and may be used as labs/recitations.
- Workshop Physics⁸ is an activity-based course without lectures.

Educational resource sharing. The use of IT for education is too big a job to be done by a few people or done in a short period of time and needs organized concerted efforts. It needs continual updating, should be operated as a feedback system, and needs help from non-physics experts. You need a depository and clearinghouse for all the materials for resource sharing and quality assurance.

In resource sharing among different educational units, be it inter-institutional or international, dedicated human effort is essential for its success since the educational paradigm is position and time dependent. The one-model-fits-all approach is not appropriate and diversity has to be accepted. The Asian Physics Education Network⁹ has been working for resource sharing to improve university physics education in the Asia-Pacific region, with recent AL emphasis. It is to be noted that the Korean Physical Society has recently been reorganized for strong emphasis on education and strives for educational resource sharing at the national as well as international level.¹⁰

- 1) <http://post16.iop.org/advphys>
- 2) G. M. Novak et al., *Just-in-Time Teaching* (Prentice Hall, 1999).
- 3) E. Mazur, *Peer Instruction* (Prentice Hall, 1997).
- 4) L. C. McDermott et al., *Physics by Inquiry*, (John Wiley & Sons, 1996).
- 5) D. Sokoloff, P. Laws and R. Thornton, *RealTime Physics* (Vernier Software, 1995).
- 6) D. Sokoloff and R. Thornton, *Tools for Scientific Think-*

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- ing (Vernier Software, 1995).
- 7) L. C. McDermott et al., *Tutorials in Introductory Physics* (Prentice Hall, 1998).
 - 8) P. Laws, *Workshop Physics Activity Guide* (John Wiley & Sons, 1997).
 - 9) <http://www.swin.edu.au/physics/aspen/>
 - 10) *AAPT Announcer*, Vol. 31, p. 10 (Summer 2001).

*Supported by Korea Science and Engineering Foundation

^aSecretary of Education, Korean Physical Society

(jim@moak.chonbuk.ac.kr)

^bChair, Asian Physics Education Network (khl@moak.chonbuk.ac.kr)

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Just-in-Time Teaching: The Best of Both Worlds

Gregor M. Novak

"...it appears that how the students *approach* general education (and how the faculty actually *deliver* the curriculum) is far more important than the formal curricular content and structure." Alexander W. Astin [4]

Just-in-Time Teaching, JiTT, is a pedagogical technique that combines the best features of traditional in-class instruction with the exciting new communication channels opened by the World Wide Web technologies. Over the past five years we have developed a teaching strategy dubbed "Just-in-Time Teaching" which makes use of the feedback loop between in-class and out-of-class teaching and learning. While this is still a work in progress, we can point to dramatic improvements in retention rates and to significant attitudinal and cognitive gains as well. Encouraged by the participants at national workshops (sponsored by, among others, The National Science Foundation, Project Kaleidoscope and the American Association of Physics Teachers) we have produced a book on the subject [1]. JiTT is now used in over one hundred courses across the US and in a few countries abroad. These courses span all the science disciplines and some in the humanities. Just-in-Time Teaching will be the subject of a Chautauqua Short Course in June 2002. For more information, examples of JiTT materials and a partial list of JiTT adapters and courses please visit our web site <http://jitt.org>.

The JiTT strategy is aimed at many of the challenges confronting instructors and students in today's classrooms. Student populations are diversifying. In addition to the traditional nineteen-year-old recent high school graduates we now have a kaleidoscope of "non-traditional" students: older students, working part-time students, commuting students, and, at the service academies, military cadets. At a minimum these students face time management challenges. They come to our courses with a broad spectrum of educational backgrounds, interests, perspectives, and capabilities that call for individualized, tailored instruction. They also need motivation and encouragement to persevere in what for many is a bewildering, unfamiliar task. Consistent, friendly support often makes the difference between a successful course experience and a fruitless effort, and often it even

means the difference between graduating and dropping out [2]. We are now becoming increasingly sensitive to these issues thanks to the recent work in education research that has also made us more aware of learning style differences and of the importance of passing some control of the learning process over to the students. Active learner environments yield better results but they are harder to manage than lecture oriented approaches [3]. It can be argued that that the ancient method of mentoring, a student learning under a watchful eye of a teacher, would be the best strategy to deal with these problems. It is obviously impractical in the age of mass education, but it is an ideal to be kept in mind. With the help of World Wide Web technology, JiTT is a modest attempt at mimicking some features of mentoring.

To confront these challenges, the Just-in-Time Teaching strategy pursues three major goals:

1. To maximize the efficacy of the classroom session, where human instructors are present.
2. To structure the out-of-class time for maximum learning benefit.
3. To create and sustain team spirit. Students and instructors work as a team toward the same objective, to help all students pass the course with the maximum amount of retainable knowledge.

Although Just-in-Time Teaching makes heavy use of the web it is not to be confused with either distance learning (DL) or with computer aided instruction (CAI.) Virtually all JiTT instruction occurs in a classroom with human instructors. The web materials, added as a pedagogical resource, act primarily as a communication tool and secondarily as content provider and organizer.

JiTT web pages fall into three major categories:

1. Student assignments in preparation for the classroom

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- activity. WarmUps and Puzzles, discussed in this article, fall into this category.
2. Enrichment pages. In physics we title these pages “What is Physics Good For?” – “GoodFors” for short [5]. These are short essays on practical, everyday applications of the physics at hand, peppered with URL links to interesting material on the web. These essays have proven themselves to be an important motivating factor in introductory physics service courses, where students often doubt the current relevance of classical physics, developed hundreds of years ago.
 3. Stand alone instructional material, such as simulation programs and Mathematica exercises.

WarmUps and Puzzles are short, web-based assignments, prompting the student to think about an upcoming topic and answer a few simple questions prior to class. It can be seen from examples below that some of these questions, when fully discussed, often have complex answers. We expect the students to develop the answer as far as they can on their own. We finish the job in the classroom. These assignments are due just a few hours before class time. The responses are collected electronically and scanned by the instructor in preparation for class. They become the framework for the classroom activities that follow. In a typical application, sample responses are duplicated on transparencies and taken to class. In an interactive session, built around these responses, the lesson content is developed. Instructors employ a variety of techniques to analyze the student responses ranging from a cursory scan just before class to elaborate scoring [6].

Students complete the WarmUp assignments before they receive any formal instruction on a particular topic. They earn credit for answering a question, substantiated by prior knowledge and by whatever information they managed to glean from the textbook. The answers do not have to be complete, or even correct.

Puzzle exercises are assigned to students after they have received formal instruction on a particular topic. They serve as the framework for a wrap-up session on a particular topic.

The WarmUps, and to some extent the Puzzles, are designed to deal with a variety of specific issues. In physics, these can be roughly categorized as follows.

- Developing Concepts and Vocabulary
- Modeling -- Connecting Concepts and Equations
- Visualization in General and Graphing in Particular
- Estimation, Getting a Feel for Magnitudes
- Relating Physics Statements to “Common Sense”
- Understanding Equations – the Scope of Applicability

In other disciplines, the issues addressed may range from accommodating different learning styles to specific cognitive objectives.

In preparing WarmUp assignments for an upcoming class meeting we first create a conceptual outline of the lesson content. This task is similar to the preparation of a traditional passive lecture. As we work on the outline we pay attention to the pedagogical issues that we need to focus on in the classroom. Are we introducing new concepts and/or new notation? Are we building on a previous lesson, and if so, what bears repeating? What are the important points we wish the students to remember from the session? What are the common difficulties typical students will face when exposed to this material? (Previous classroom experience and education research can be immensely helpful here.) Once this outline has been created we create broadly based questions that will force students to grapple with as many of the issues as possible. We are hoping to receive, in the student responses, the framework on which we build the in-class experience. Students leaving a JiTT classroom have been exposed to the same content as their peers in a passive lecture, with two important added benefits. First, having completed the web assignment just before class time, they were ready to actively engage in the classroom activities. Secondly, they leave the classroom with a feeling of ownership, since the interactive lecture was based on their own wording and understanding of the relevant issues. To close the feedback loop, the give and take in the classroom suggests future WarmUp questions that will reflect the mood and the level of expertise in the class at hand. Thus, from the instructor’s point of view, the lesson content remains pretty much the same from semester to semester. From the students’ perspective, however, the lessons are fresh and interesting, with a lot of input from the class.

We have conducted numerous surveys looking for cognitive as well as affective outcomes. It is clear from students’ comments that they consider the electronic exchanges intimate and personal. Most JiTT pages contain a space for students’ thoughts and concerns. The concerns are addressed immediately, in class, to everyone’s benefit and they are often followed by multiple email exchanges between the instructor and the student who raised the issue, occasionally followed by a personal visit in the instructor’s office. These sentiments are echoed by a large number of JiTT adopters, many of whom consider the enhanced personal interaction with their students one of the primary reasons to adopt the JiTT pedagogy.

Technology is a tool. The benefits, or harm, derived from it depend on the use. The Internet is primarily a communication tool, as is the printing press. JiTT pedagogical strategy makes use of the ubiquity and speed of this extraordinary communication channel to prepare the student and the teacher for a richer and more personal face-to-face encounter in the classroom. The on-going feedback loop provides the instructor with a fairly detailed profile of the student audience, both as a group and as a collection of individual human beings with special needs. The resulting classroom experience gives the students the comfortable feeling that the instructor is aware of their mental state and their needs as they unfold through the semester. While, in principle, this kind of information could be

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collected on paper, the process would not be as effective. The space and time barriers involved (when do you collect the paper submissions and where?) would be frustrating. A comparison with letter writing versus a telephone conversation is not unfair. The immediacy of a telephone conversation with quick turnaround of ideas bonds in a personal way. Similarly, bringing to class students' responses while they are still warm creates a dialog atmosphere where each student can feel that they own a part of the lesson. The not infrequent email exchange after class enhances this feeling. In the 1984 report by the Study Group on the Conditions of Excellence in American Higher Education the following quote appears: "Learning technologies should be designed to increase, and not to reduce the amount of personal contact between students and faculty on intellectual issues." To a large extent, using the Internet technology in the way it is used in a JiTT-based course honors the spirit of this advice.

We hope that adapting a JiTT strategy will motivate faculty to reach beyond their particular discipline and engage in a dialogue with colleagues in other disciplines with whom their share the responsibility to nurture a common student body. In the current pedagogical climate that emphasizes active collaborative learning, cross-disciplinary projects that focus on the learning process rather than subject matter content are likely to make significant contributions to educational reform. Today's students must be made aware of the interconnectedness between the disciplines they study. Interdisciplinary courses and programs are being offered to meet these needs. The vehicle for the delivery of successful interdisciplinary courses must be the learning process. Content, important as it is, should be added only after the delivery process has been developed.

As noted by Astin in his book on the college experience [4], when thinking about teaching and learning, academics tend to focus on the content rather than process, sometimes exclusively. When new technologies emerge, teachers usually ask: "How can this help me deliver factual information from my field of expertise better, faster, more efficiently?" JiTT asks the question: "How can the new tool help students take more responsibility for their own learning under mindful expert supervision?" When the teaching and learning issue is presented this way, many faculty (particularly younger faculty) find a lot to talk about. Comparing notes across disciplines benefits all. The content-based interdisciplinary barriers, rooted in the myopic emphasis on content, disappear and a physicist can learn from a biologist. Suddenly we are reminded the object of the verb to teach is students not physics or biology. Reading books

like Astin's helps, but it is not an absolute necessity. Just focusing on the process of teaching and learning and away from content will get the inter-disciplinary discussion started.

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Gregor Novak is Distinguished Visiting Professor of Physics at the United States Air Force Academy and Professor of Physics at Indiana University Purdue University Indianapolis. He is co-author of the book Just-in-Time Teaching: Blending Active Learning with Web Technology (Prentice Hall 1999.) email:gnovak@iupui.edu

Physlets: Web-based Java Applets for Physics Education

Wolfgang Christian, Mario Belloni and Melissa Dancy

Overview

“Good educational software and teacher-support tools, developed with full understanding of principles of learning, have not yet become the norm.” *How People Learn: Brain, Mind, Experience and School* from Committee on Developments in the Science of Learning, National Research Council National Academy Press, 1999.

The impact of instructional software on mainstream physics instruction has, at present, been minimal. At American Association of Physics Teachers (AAPT) meetings in the 1980s, it was common to see participants sharing floppy disks and trading software for the computer-enabled educational reform that everyone knew was sure to come. It didn't, at least not in the form envisioned by the conference participants. Little of the early educational software was adopted by the mainstream teaching community and almost none of it is still being used today. In contrast, printed material from the much earlier post-Sputnik curricular reform movement — the Berkeley Physics series, for instance — is still available and useful to physics educators, although the pedagogy upon which it was based has gone out of fashion. Will this scenario be repeated? Are we doomed like the Greek hero Sisyphus to forever push computational physics up the hill of curriculum reform only to have it roll back down again? Can we expect a widespread adoption of computation in current curricular reform initiatives? And, if so, what strategies should we adopt to insure that computational-rich curricula being developed today will be adopted and be in widespread use a decade from now? Our approach has been to develop curricular material that couples a software design philosophy with physics education research (PER). It is based on open Internet standards such as Java, JavaScript, and HTML as well as research into the effectiveness of computer-based physics instruction.

Physlets – “Physics applets” – are small, scriptable Java applets that can be used in a wide variety of applications [Christian 2001]. Because of their dynamic interactivity, Physlets are ideally suited for interactive engagement methods [Hake 1998, Sokoloff 1997, Thacker 1994] such as Just-in-Time Teaching [Novak 1999], Peer Instruction [Mazur 1997], and Tutorials [McDermott 1998]. In addition, Physlets can also be used as traditional lecture demonstrations and can be given as end-of-chapter homework.

We have developed over one thousand Physlet-based problems over the past four years in support of a number of introductory physics texts. A selection of these problems is available on the CD that accompanies the Physlets book. More importantly, the Physlets upon which these problems are based are freely distributable for non-commercial educational purposes and are now being adapted to support various curriculum reform initiatives.

Physlets and PER

Physics Education Research, PER, informs us that technology

does not necessarily lead to improved learning and that we are just beginning to understand how technology is best used. For technology to have a long lasting impact on science education, it will need to be based more on successful pedagogy than on the latest software and hardware. For example, streaming video is currently a hot technology, and both traditional broadcasters and software companies are competing to establish themselves in this market. However, research has shown that merely watching video has little effect on student learning, and it is unlikely that streaming video will change this result. Small cognitive effects have been shown to occur using video clips if the showing of the clip is accompanied with in-class discussion or if the clip is used for data taking and data analysis [Beichner 1997]. Two PER researchers, Aaron Titus [Titus 1998] and Melissa Dancy [Dancy 2001], have used Physlets to study the effect of animation on student assessment and student problem solving ability.

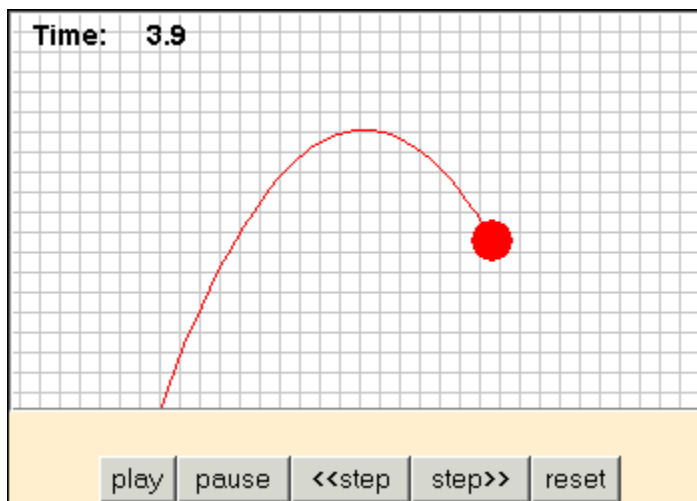


Figure 1: A media-focused projectile motion problem

Titus measured student attitudes and problem-solving approaches while they were solving Physlet-based problems. The study distinguished between media-enhanced problems where multimedia is used to present what is described in the text, and media-focused problems, where the student must use multimedia elements in the course of solving the problem. Titus found that media-focused problems are fundamentally different from traditional physics problems, and Physlets are ideally suited for these types of problems. Consider an example from kinematics. A traditional projectile problem states

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the initial speed and launch angle and asks the student to find the speed at some point in the trajectory. This problem can be media-enhanced by embedding an animation in the text, but this adds little to the value of the problem. Alternatively, this same type of problem could be written as a media-focused Physlet problem as shown in Figure 1 where the student is asked to find the minimum speed along the trajectory. In this case, no numbers are given in the text. Instead, the student must observe the motion, apply appropriate physics concepts, and

make measurements of the parameters he or she deems important within the Physlet. (A mouse-down enables the student to read coordinates.) Only then can the student “solve the problem.” Such an approach is remarkably different from typical novice strategies where students attempt to mathematically analyze a problem before qualitatively describing it (an approach often called “plug-and-chug” and characterized by a lack of conceptual thought during the problem-solving process).

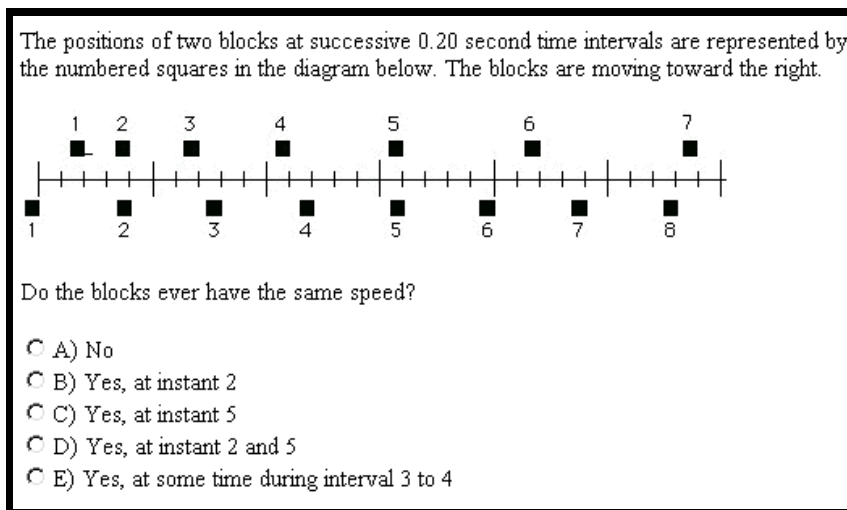


Figure 2: A text-based Force Concept Inventory question

Dancy used Physlets to probe students' conceptual understanding by using a standard diagnostic instrument, the Force Concept Inventory [Hestenes 1992], in which all thirty static pictures (see Figure 2) were replaced by Physlet-based animations (see Figure 3) [Dancy 2001]. Both quantitative and qualitative data was collected from hundreds of students using the Physlet-based version and the results were statistically analyzed. The study showed that Physlet-based problems are less likely to elicit memorized responses because they allow stu-

dents to respond to what they see, rather than what they read. Physlets tap into students' intuition and deeply-held misconceptions by eliminating the additional step of translating from words or graphs. In general, students had a better understanding of the intent of the questions when viewing an animation and gave an answer that was more reflective of their actual understanding. We speculate that this may be because the animation looks more like real life than something from a physics textbook.

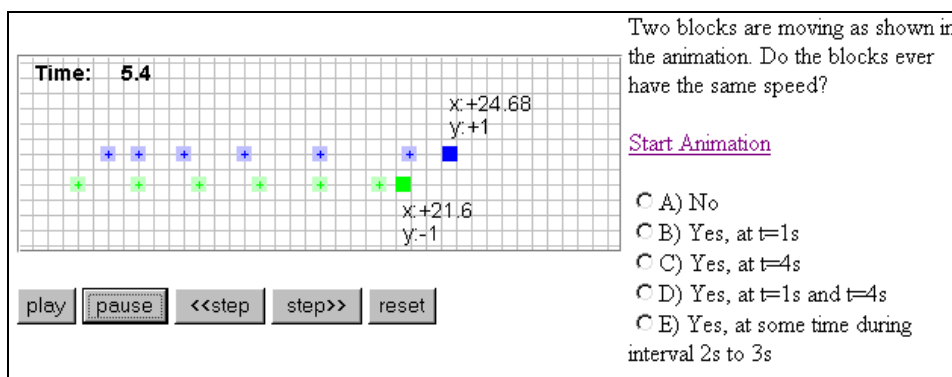


Figure 3: A Physlet-based Force Concept Inventory question.

Both the Titus and the Dancy studies indicate that while computer-based animation can be used for cosmetic and motivational purposes, they are most effective under the following conditions:

- The animation is integral to the question.

- The student must interact with the animation to obtain data.

The effectiveness of Physlets likely depends on many factors such as how well the task targets known student difficulties, how students use visual cues given by the Physlet, how impor-

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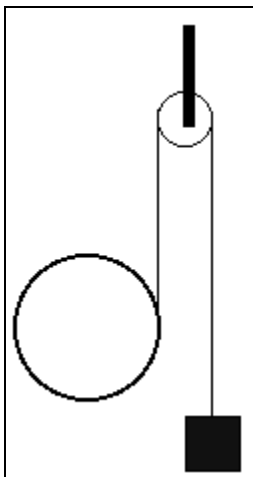
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tant visualization is to the given task, and the appropriateness of the Physlet to the given task. Nevertheless, both studies show that conceptual understanding is key to solving Physlet problems. Without strong conceptual understanding, students are prone to guess, search for the “right” equation, and lack direction.

Just-in-Time Teaching

Although the media-rich content and interactivity provided by technology such as Physlets can be pedagogically useful, it can lack the human dimension that is important to effective teaching. Computer Assisted Instruction (CAI) has already been tried on very elaborate proprietary systems. It is unlikely to be improved significantly by being ported to the Internet. To be truly effective, the communication capabilities of the computer must be used to create a feedback loop between instructor and student. A new and particularly promising approach known as Just-in-Time Teaching, JiTT, has been pioneered at Indiana University and the United States Air Force Academy and further developed at Davidson College [Novak 1999]. It employs a fusion of high-tech and low-tech elements. On the high-tech side, it uses the World Wide Web to deliver multimedia curricular materials and manage electronic communications between faculty and students. On the low-tech side, the approach requires a classroom environment that emphasizes personal teacher-student interactions. These disparate elements are combined in several ways, and the interplay produces an educational setting that students find engaging and instructive. The underlying method creates a synergy between the Web and the classroom to increase interactivity and allow rapid response to students' problems.

Figure 4: JiTT Yo-Yo Puzzle Question: Make yourself a yo-yo by wrapping a fine string around a thin hoop of mass M and radius R . Pass the string around a pulley and attach it to a weight, whose mass is exactly half the mass of the hoop. Then release the system from rest. Describe the subsequent motions of the yo-yo and the weight. You may use equations to arrive at your answer, but you must state your result in plain sentences.



The JiTT pedagogy exploits an interaction between Web-based study and an active-learner classroom. Essentially, students respond electronically to carefully constructed Web-based assignments, and the instructor reads the student submissions “just-in-time” to adjust the lesson content and activities to suit the students' needs. Thus, the heart of JiTT is the “feedback loop” formed by the students' outside-of-class preparation, which fundamentally affects what happens during the subsequent in-class time.

Although JiTT can be implemented fully using technically simple Web-based assignments, incorporating Physlet-based

questions can heighten the extent to which student understanding can be probed and encouraged. The JiTT strategy as applied in physics education is richer for the incorporation of Physlets. Consider, for example, the puzzles shown in Figures 4 and 5. These puzzles involve nearly the same physics, but what is required of the student in order to solve each puzzle is quite different. In each case, the student must understand the concepts of moment of inertia, torque, angular acceleration, angular velocity, and the relationships between those quantities. In each case, it also behooves the student to draw “extended” free body diagrams to consider the forces and torques involved. The dynamic puzzle, however, requires some visual analysis and understanding of how the speed with which the mass falls is related to the physics quantities such as angular momentum and moment of inertia. Students are expected to analyze each situation, apply the relevant physics, and answer specific questions. The faculty member then prepares a lecture in response to the student submissions.

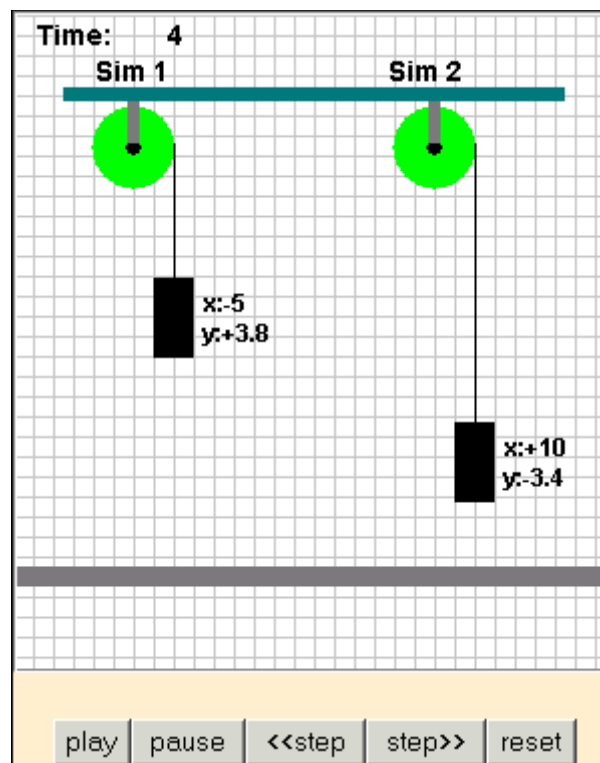


Figure 5: Physlet-based JiTT Moment of Inertia Puzzle Question: Rank simulation 1 and simulation 2 from least to greatest in terms of the moment of inertia of the wheel, the tension in the string, and the total angular momentum about the wheel's axle after 4 seconds. The hanging weights have identical mass.

Conclusion

Based on our results, we believe that Physlets can be a valuable tool for creating interactive curricular material designed around the needs of the student. We have used Physlets to alter existing curricular material. However, we believe the greatest potential of Physlets will come from using Physlets to

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ask (and answer) questions in ways which cannot be done on paper [Belloni 2001]. (See also Figure 6.)

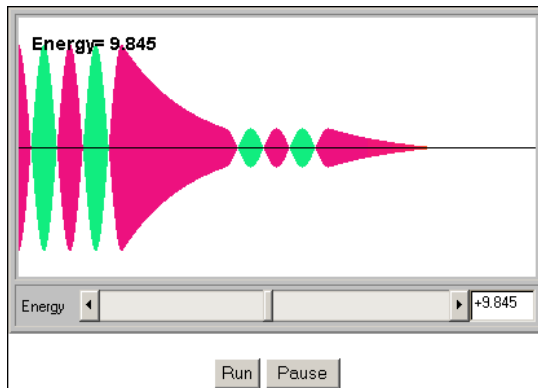


Figure 6: Physlet-based JiTT question regarding the quantum mechanical barrier problem. Students are asked to find the potential energy by varying the energy and examining the shape of the free-particle wave function.

The best media-focused problems cannot be correctly solved using “plug-and-chug” methods. The fact that data is not given in the text of the problem requires that students apply proper conceptual understanding to the solution before analyzing data. Therefore, it also seems that Physlet problems may be useful for encouraging a “concept-first” approach to solving problems, where students consider the concepts or principles to be applied to the problem before making calculations. This quality seems to make Physlets well suited for evaluating students’ application of conceptual understanding to numerical problems and helping instructors and students identify student weaknesses in conceptual understanding.

Acknowledgements

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Wolfgang Christian, Mario Belloni and Melissa Dancy are at Davidson College, Davidson NC 28036. W. Christian is a Professor Physics. His research interest is in the area of computational physics and instructional software design. He is co-author of Physlets: Teaching Physics with Interactive Curricular Material (2001), Just-in-Time Teaching (2000), and Waves and Optics (1995). M. Belloni is an Assistant Professor of Physics and his research interests are in theoretical physics and physics education. M. Dancy is a Visiting Assistant Professor with research interests in physics education and instructional technology.

Science is a lot of fun with hands-on activities

Yoshio Kamishina

Abstract

A boring science class could be changed into one that is full of fun with hands-on activities. Some examples of such activities are demonstrated. These are integrated with subjects like physics and music. The themes of hands-on activities here are limited to mechanical resonance phenomena and characteristics of rotational motion.

1. INTRODUCTION.

The lecture demonstration used to be – and in many countries still is – central to school science teaching, but it has now been replaced in many schools with the ubiquitous class experiment.

Traditional science museums contain collections of, usually old, scientific and technological objects, often enclosed in glass cases, with concise notes explaining their origins and significance. The visitor is expected to walk around, to look, to absorb the information and to move on. The visitor's role is passive, and there is no opportunity to interact with the exhibits. These museums are worthy of conservation. However, many museums are developing a hands-on science section or are changing into interactive science museums.

In a primary school, where an integrated approach to curriculum has been adopted, the subject of science does not exist in isolation. Subjects in the curriculum are not limited by boundaries; rather it is the interdependency of subjects, which is utilized in the learning process. Even in secondary schools, an integrated approach to curriculum can also be effective. In the present paper, some examples of hands-on experiments, which integrate physics and music, and physics and play are described.

Second, a toy frog swing. I have developed a model that represents the movement of a real swing as closely as possible by using a toy rubber frog (Fig. 2). The legs are made of rubber and fold so that the frog is in sitting position when the air pressure is low in the body of the frog (Fig. 3). When air is pumped into the body through a plastic tube inside the hanging rope, the frog stands up on the seat due to the higher air pressure in the legs (Fig. 4).

2. RESONANCE PHENOMENA

2-1. A toy frog swing

In our daily lives, phenomena of resonance are commonly observed.

First, a tricky experiment that is a feat of magic using conical pendulums. Three different conical pendulums are hung from the same bar with their symmetry axis on a vertical line (Fig. 1). Each pendulum is of different length, and therefore has a different natural frequency. You can cause any one of the pendulum bobs to swing while the other two remain at rest. The trick is very simple. When you move the bar gently forward and backward at the

same frequency as that of the pendulum you want to move, only this bob will swing. The others will not move. This is a simple example of resonance phenomenon.

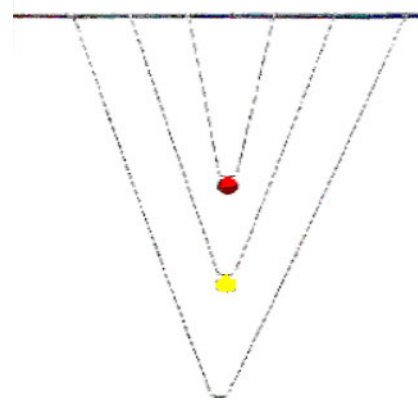


Fig. 1 Three sets of conical pendulums



Fig. 2 A toy frog swing

In this way, you can propel the frog to swing by working a rubber pump. The swing is driven by air pressure through the fine tube connected to the rubber ball pump. When you press the pump, the toy frog stands up on the seat and the length of rope is effectively shortened. A swing can be thought of as a kind of pendulum, and it has own natural frequency determined by the length of the rope. So, if you gently push the back of the frog, the swing rider, at the same frequency as the natural one of the swing, the amplitude of the swing's movement gets larger and larger. This is also a resonance phenomenon. Remember the movement when you played on a swing. You just repeat standing up and sitting down on the seat. Even if nobody pushed you, you could propel the swing by timely up and down movements. Changing the length of the rope, that is the parameter of the system that determines the natural frequency, energizes the swing. This kind of excitation is called parametric. The characteristic of parametric excitation in a swing is that the frequency of excitation, that of pressing the pump in our case, is twice the natural frequency of the swing. When you press the pump twice in a swing cycle, the frog is most energized. Needless to say, you have to press the pump in phase with the frog's swinging. If you do it out of phase, the amplitude of the swing gets smaller and the swing finally stops.

2-2. Musical instruments

Other good examples of resonance phenomenon are various kinds of musical instruments. All non-electronic musical instruments make use of resonance phenomena to amplify the sound volume. However, here we will discuss only wind instruments.

First, a pipe tuning fork is used to demonstrate sound resonance phenomena. A pipe tuning fork is made of a square metal pipe with one end shaped like a tuning fork (Fig. 5). For the purposes of this demonstration, I prepared two pipe tuning forks. The lengths of the tuning fork parts are the same; therefore the pitch of the sound will be the same. However, the lengths of the rest of the pipes are different. When you hit the longer tuning fork with the

end of pipe open, the sound is loud, and if you close the end of pipe, the volume decreases. On the other hand, when you hit the shorter pipe tuning fork with the end of pipe open, the sound is small, and when you close the end of the pipe the sound gets loud. These two pipe tuning forks clearly show the difference of the resonance conditions of an open-end pipe and a closed end pipe. A semi-quantitative explanation of the difference is as follows. Let the sound velocity be v , the length of the pipe L , the frequency of the sound in resonance with the pipe f , that is the pitch of the sound. The simple theory ignoring the open end correction of the resonance condition of sound in the pipe tells as follows. The resonance condition is given by the formula $f = v / 2L$ for an open-end pipe, while $f = v / 4L$ for a closed pipe. The length of the shorter pipe is adjusted as the sound is loud when the end of the pipe is closed, while that of the longer one is adjusted as it is loud when open for the same pitch of sound.

Next, the principle of making sound in wind instruments. In a wind instrument, the sound is a vibration of air column in the instrument. Wind instruments are roughly grouped into three families: the oboe family, the trumpet family and the flute family. In oboe type instruments, blowing and vibrating a reed or double reeds make the sound. Clarinets and saxophones belong to this family. A model of a reed instrument can be easily made using a plastic drinking straw and a small piece of overhead projector transparency sheet. You can verify that the pitch of the sound gets higher when you shorten the straw. In the trumpet family, sound is made by the vibrating lips of the player, pushed against the mouthpiece (Fig. 6). So, it is rather difficult to make sound. Trombones and French horns belong to this family. In the flute family, sound is made by blowing against the edge of the hole in the side of the pipe. There are many kinds of flutes such as bass flutes, alto flutes, piccolos, fifes, recorders and Pan flutes. A model of a Pan flute can be made using a set of test tubes made of glass or plastic (Fig. 7). You can change the pitch of each tube by changing the length of air column in the tube.



Fig. 3 A sitting frog on the seat



Fig. 4 A standing frog on the seat

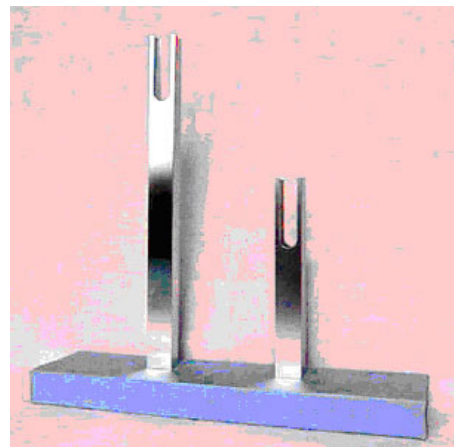


Fig. 5 A pair of pipe tuning forks



Fig. 6 Mouthpieces (left: trumpet, right: trombone)

In all musical instruments, pitch of sound varies when you change the length of the pipe. The method of changing the length is different depending on the type of instrument. A trombone is straightforward. In flutes, recorders, oboes, and so on, you change the length of the pipe by closing and opening holes in the pipes. The lengths of the vibrating air columns in trumpets and French horns are manipulated valves that add or subtract segments

3. CHARACTERISTICS OF ROTATIONAL MOTION.

3-1. A top

A top is one of the most popular toys not only for children but also for adults (Fig. 8). Why does a top fall down so easily when it is not spinning, while it is in a very stable state when it spins fast? It is a natural question. However, it is rather difficult to answer for primary school pupils and even secondary school students. To understand the mechanism of the stability of a rotating top, you have to learn about the concepts of Angular Momentum, Torque, Conservation of Angular Momentum, Moment of Inertia, and so on. These concepts are too difficult for children to understand. So, I tried to answer the question without using these difficult concepts and mathematics. Instead, I used many demonstration and hands-on experiments to help the students understand these concepts through experience.

The center of mass

The lower the center of mass of an object, the more stable it is when at rest. However, this is not the case when an object is moving. It is not necessarily stable when its center of mass is in the lowest position. For example, think of a simple pendulum. The bob swings and the center of mass goes up and down periodically, and the average position of the center of mass is higher than when the pendulum is at rest. As another example, I showed a couple of bobs connected by a string through a short tube. Hold the tube vertically and keep the upper bob on the tube, with the other bob hanging by the string connected to the upper bob. When these bobs are at rest, the lower bob stays at the lowest position and this form is the most stable. If you rotate the upper bob in the horizon-

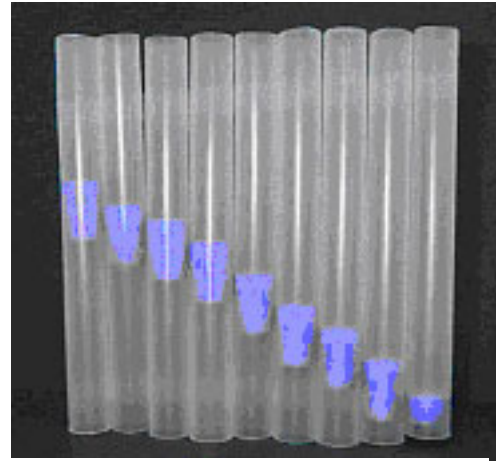


Fig. 7 A model Pan-flute

tal plane, the lower bob rises as the upper bob moves faster, and the center of mass of the system is also lifted, which means that motion raises the center of mass of the system.

Angular momentum and torque

The physical quantity characteristic of rotational motion is *angular momentum* L , which is defined as $L = \mathbf{r} \times \mathbf{P}$, where \mathbf{r} is the position vector relative to a point in space, \mathbf{P} is the linear momentum, and \times is the cross product (vector product). If there is no external force exerted on a system, angular momentum is conserved, and therefore, the direction of rotating axis does not change. To understand this law qualitatively, I showed an improved gyroscope. In this improved gyroscope, another axis perpendicular to the rotating axis is attached to the outer frame of a usual gyroscope (Fig. 9a, 9b). When you suspend the improved gyroscope from chains or strings at the attached axis, it is held effectively at the center of mass against gravity. As a result, neither gravity nor other external force is acting on it. In this situation, when you spin it rapidly, the direction of the rotational axis never changes even if its frame is moved at random. This is because of conservation of angular momentum. Most students are surprised and impressed by this phenomenon. They should recognize it as a characteristic of rotational motion. Next you set the rotational axis of a rapidly spinning improved gyroscope in the horizontal plane and hang a weight at one end of the axis. The axis still remains in the horizontal plane and rotates around the vertical line. If the procedure is repeated while the gyroscope is at rest, the axis drops as soon as the weight is attached. The force acting on the rotational axis is perpendicular to both the direction of gravity and that of the rotation axis. This kind of force is called a torque, and the motion is called *precession* from an astronomical term. Students should understand this as another characteristic of rotational motion. That's why a rapidly spinning top hardly falls down as the rotational axis rotates around the vertical axis, that is a precession.

3-2. A tippy top

Among a variety of tops, a tippy top is most popular. At a

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glance, a tippy top is hardly distinguishable from normal tops (Fig. 10a, 10b).

A top usually rotates steadily around the rotational axis and the rotational axis rotates around the vertical axis as everyone knows. However a tippy top turns upside down while rotating (Fig. 11). The big difference between them is that the usual top falls down when at rest while a tippy top doesn't. It is stable at rest. This means that the center of mass of a conventional top is situated higher and it is therefore unstable at rest, while on a tippy top the center of mass is at the lowest position at rest. Roughly speaking, rotational motion progressively lifts the center of mass of a tippy top, and finally turns it over. The mechanism by which the axis of rotation gradually moves up or down in addition to a precession, moving in a circular cone about the vertical axis, is in large part connected with the action of friction at the point of contact with the floor. The quantitative explanation of this mechanism is too difficult for students to understand.

The qualitative explanation is more suitable for children. To reproduce the motion of a tippy top, I showed a 2-dimensional tippy top consisting of a large ring and a small ring both made of metal wire (Fig. 12). The two rings are attached at a point with the small ring inside the large one on the same plane. The role of the smaller ring is to shift the center of mass of the system away from the center of the large ring. When you rotate the large ring around the vertical axis connecting two centers of both rings with the small ring at the bottom, the system acts like a tippy top. While when you do the same thing but with the small ring at the top it acts like a conventional top. The difference in behavior is the position of the center of mass of the system.

4. CONCLUSION

Physics toys are very good teaching tools. If you make practical use of them and give children proper explanations about the reasons for the behavior of the toys, most children will have fun with physics. It is very important for children to handle the toys themselves. They learn to understand physical concepts not only by reading books and listening to lectures but also from their experiences in daily life. For elementary school pupils, the latter learning method is much more prevalent, and they very often have misconceptions. However, it is worthwhile to mention that pre-conception is not misconception. Teachers should lead them to scientific conception from non-scientific preconception. As a useful teaching strategy, teachers should offer children proper toys as teaching materials, and let them have first hand experience. Most importantly, children must feel that science is a lot of fun.

Hands-on experiments are really instructive in science education especially for elementary and secondary school pupils.

Yoshio Kamishina is at the Department of Physics, Faculty of Education, Shimane University 1060 Nishikawatsu-cho, Matsue city, Shimane 690-8504 Japan

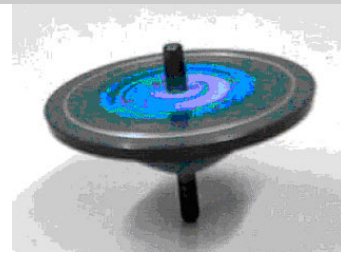


Fig. 8 A conventional Japanese top

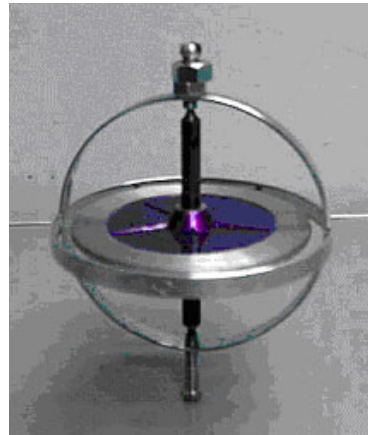


Fig. 9a A gyroscope



Fig. 9b An improved gyroscope



Fig. 10a A normal top (spinning)



Fig. 10b A tippy top (at rest)



Fig. 11 A tippy top (spinning)

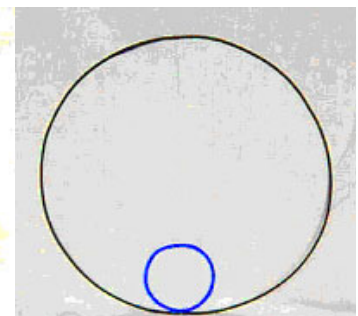


Fig. 12 Two-dimensional tippy top

The Blame Game in Teacher Preparation

Fredrick Stein

It was easy for the statewide gathering of deans to place the blame for the general lack of preparation of their incoming students in science and mathematics. "It must be the fault of their K-12 teachers. Of course, who else has such a pivotal role in the students' learning?" But, it didn't take long for the assembled academic leaders to realize that the majority of the science and mathematics teachers in their state were educated at *their* institutions.

If it is true that teachers "teach as they were taught," then to improve physics and physical science learning in K-12, universities must model effective teaching/learning approaches in courses for prospective teachers, which include prospective chemistry, biology, mathematics, and elementary teachers (most of whom will teach science).

Currently, 28 percent of our nation's high school students take at least one course in physics. Although this is a significant improvement over the last decade, many of our high school physics courses are still modeled after university and college courses that are not inquiry-based and do not develop good conceptual understanding. The ongoing and overwhelming need for in-service teacher enhancement programs in physics at the most basic level points to the failure of programs in our colleges and universities to prepare students adequately for teaching.

Two recent national reports have made recommendations that are embodied in the PhysTEC project. The Glenn Commission's report, *Before It's Too Late (2000)* calls for "strategies to identify exemplary programs of teacher preparation around the country, and find ways to encourage others to multiply their successes." The NRC report, *Educating Teachers of Science, Mathematics, and Technology: New Practices for the New Millennium (The National Academy of Sciences, 2000)*, recommends that, "colleges and universities should reexamine and redesign introductory college-level courses in science to better accommodate the needs of future teachers." They further "envision master teachers in partner school districts [having] adjunct faculty appointments in the partner two- and four-year colleges and universities." The master teachers would "take on a much more significant role in the mentoring of future teachers." The PhysTEC proposal identifies the Teacher-in Residence to fulfill this need.

In response, the American Physical Society (APS), in partnership with the American Association of Physics Teachers (AAPT) and the American Institute of Physics (AIP), identified preservice teacher preparation as a key issue for the physics community and in 1999, they approved a joint statement in which they, "urge the physics community, specifically physical science and engineering departments and their faculty

members, to take an active role in improving the preservice training of physics/science teachers."

PhysTEC, the Physics Teacher Education Coalition, was proposed as the mechanism to greatly increase the role of physics departments, in collaboration with education departments, to radically improve the science preparation of future teachers. On August 23, 2001, a five-year, \$5.76 million grant was awarded by the National Science Foundation to APS, in partnership with AAPT and AIP. On September 13, the Fund for the Improvement of Postsecondary Education (FIPSE) in the U.S. Department of Education awarded a three-year, \$498,000 grant to enhance the evaluation, induction, and dissemination components of the PhysTEC program.

These two grants will enable the professional societies to create a nationwide Coalition among college and universities. Beginning with six institutions in 2001, PhysTEC will add a seventh PPI site in 2004 and, with the help of the APS 21ST Century Campaign grow from 7 to 17 sites by 2006. After that, we expect to expand to over a hundred sites across the country. To succeed, however, *the individual PPIs'* vision for the PhysTEC program must coalesce.

PhysTEC's three goals are:

- To encourage physics departments, in collaboration with departments of education to dramatically improve the preparation of physics, physical science, and elementary teachers who must teach physical science, and to provide the institutions with the support and technical assistance necessary to undertake the task.
- To disseminate widely the outcomes, scholarship, and exemplary programs of study through the resources, national conferences, workshops, and publications (including electronic) of the APS, AAPT, AIP.
- To produce more and better-prepared science teachers who are committed to student-centered, inquiry-based approaches to teaching and learning, including the objectives and process skills associated with the expectations of the national reform movements such as the *National Science Education Standards (NRC) and the Benchmarks of Project 2061 (AAAS)*.

The program incorporates exemplary components of past NSF-supported projects that have proven to be successful in making long-term positive changes in teacher preparation. Others include:

- A Teacher-in-Residence program that provides for a local K-12 science teacher to become a full-time participant in

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- assisting faculty with both team-teaching and course revisions
- A long-term, active collaboration between the physics department, the education department, and the local school community
 - The redesign of content and pedagogy of targeted physics courses based on results from physics education research as well as utilization of appropriate interactive technologies
 - The redesign of content and pedagogy for elementary and secondary science methods courses with an emphasis on inquiry-based, hands-on, approaches to teaching and learning
 - The establishment of a mentoring program for TIRs and other master teachers designed to meet the needs of an induction experience for novice science teachers. This includes the participation of physics faculty in increasing and improving a wide array of school experiences

Richard Ingersoll (University of Pennsylvania) has obtained data that shows that school staffing difficulties are primarily the result of a “revolving door”—where large numbers of teachers depart teaching for other reasons, such as job dissatisfaction...” In other words, *retention* is more critical in solving the shortage problem than recruitment. After four years, fully *one third* of all teachers leave the teaching profession. The PhysTEC response is to extend a mentoring program into the schools for the PhysTEC teachers to reinforce the student-

centered, inquiry-based, hands-on approaches to teaching and learning from the moment they enter the classroom.

“PhysTEC begins with an initial set of six primary institutions that share a strong commitment to revise their teacher preparation programs,” according to PhysTEC principal investigator Fredrick Stein. “This includes improving the preparation of both elementary and secondary science teachers.” The six institutions are:

Ball State University
Oregon State University
University of Arizona
University of Arkansas
Western Michigan University
Xavier University of Louisiana

Several obstacles still exist to the success of PhysTEC. Two of the most obvious are enticing faculty members at research universities to turn their creativity toward improving teaching, and persuading physics departments and schools of education to communicate and work together. In both of these, the direct involvement of the key physics professional societies can play a major role in producing positive, lasting changes in the way universities interact with undergraduate students and thus, their prospective teachers.

Fredrick Stein is Director of Education and Outreach for American Physical Society. He has been a professor, dean, foundation director and early Peace Corps volunteer (teaching PSSC in Spanish). His background is in chemical physics; now, science education (particularly teacher preparation) and philosophy of science.



Where Should We Go With Advanced Placement?

W. Lichten

Introduction

Self-evaluations of educational programs are not always reliable. AP, a program that has a major impact on United States high school curricula, lacks appraisal. AP targets have grown from a small ivy-league elite to a much wider population. AP has not successfully served this broader group. In the College Board's words, “AP courses provide an opportunity for students to complete college-level studies while still in secondary school and to receive advanced placement, credit, or both, in college . . . are intended for students who have . . . the skills and motivation to complete college-level course work during their high school studies . . .” Furthermore, “There is a strong and consistent relationship between PSAT/NMSQT scores and AP examination grades . . . PSAT/NMSQT exams can also be very useful for high schools in identifying . . . students who may be successful in AP. . .”

The College Board's 1-5 qualification scale, with 2 “possibly qualified” and 3 “qualified” no longer holds, as many colleges now require a 4.

Figure 1 shows the PSAT-pass relation for two AP scores, 3 and 4 in for the Calculus AB test, widely taken by students headed for calculus-based physics. Parenthetically, AP has little direct effect on U.S. college physics. Algebra based Physics B usually does not qualify. Calculus based Physics C qualifies, but the numbers are small (ca. 15,000 for Mechanics and half as much for Electricity and Magnetism). However, over 150,000 AP calculus exams are taken annually, comparable to introductory calculus-based physics enrollments. I have found that math background is the best predictor of success in physics courses. The average college-bound student (PSAT≈50) has a poor chance of success for a passing grade of 3 and even less for a score of 4. Until recently,

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“curving” (Lurie, 2000) concealed the AP scale’s slide, which is linked to college grade inflation.

The “Equity-Excellence” Dilemma.

At first, only a few very able students took AP tests. To widen AP access, the College Board admitted less skilled persons, which lowered the success rate. The College Board then had Hobson's choice:

1. meet college standards and preserve excellence, or
2. curve the exam grades to encourage more participation and equity.

The first choice, undesirable for the College Board, limits program size. The second choice, undesirable for colleges, lowers quality. Figure 2 shows outcomes in the Calculus AB exam. Practically all students with top PSAT scores, the group AP originally served, qualify. For less able students, the percentage yield of qualifying exams drops. The overall pass rate is less than 50% (Lichten, 2000).

The College Board plans to double the number of exams by the year 2010. To do so, it must recruit AP test takers largely from the vast middle and bottom of the distribution. The failure rate would go even higher. The value added by this expansion would be very low.

The Place of AP Today

AP is "standard" at highly selective colleges (Russo, 2000), where practically everyone arrives with several 4s and 5s. But for most students with 1s, 2s, and 3s, the AP calculus AB test serves for *placement* (standard vs. remedial) rather than as *advanced placement*. Correspondingly, in some high schools there are two tracks: advanced placement and remedial.

Highest Math studied in HS	% of All HS Grads in This Group	% of HS Grads in This Group Who Earn BA	Projected Gain in % BAs by Shifting Group 1 up one rung
Calculus	6.4	79.8	
Pre-calc	5.9	74.3	0.3
Trig	11.3	62.2	1.4
Algebra 2	28.3	39.5	6.4
Geometry	17	23.1	2.8
Algebra 1	20	7.8	3.1
Pre-Algebra	11.1	2.3	0.6

Table I. College outcomes for high school graduates with varying degrees of math education to four-year colleges and projected outcome upon raising the level of math education by one rung on the ladder. Modified from Table 6 of Adelman (1999).

In nonselective, inner-city, predominantly minority high schools failure in AP is the rule rather than the exception. In fact, it is not unusual in such schools for the entire class to fail the AP exam, a heavy price for increased access.

"... a clever teacher sets a student's work, and the expectations for it, at a level where some modicum of legitimate success is possible... at an arm's length from the student, but no further."... TheodoreSizer

A Feasible High School Curriculum

Three quarters of U.S. high school graduates enter college, but many arrive unprepared. Nearly half take a remedial course, one-third fail to make it into the sophomore class, and less than half graduate. A major reason for this weak performance is the high school curriculum. (Adelman, 1999) who found that the best graduation predictor is the highest level of math completed by the student. The median high school graduate is between geometry and algebra 2 (Table I column 2).

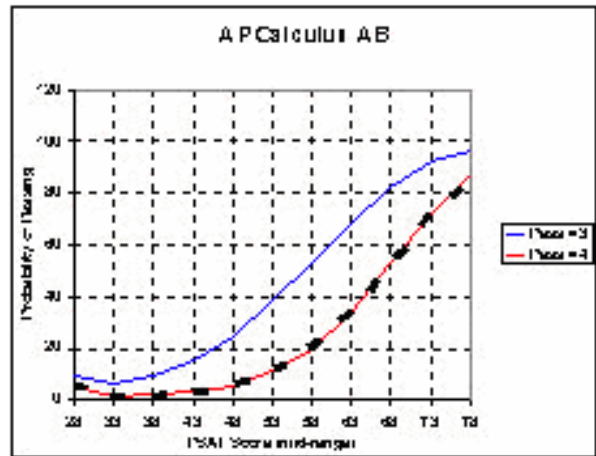


Figure 1 (lower curve is Pass=4)

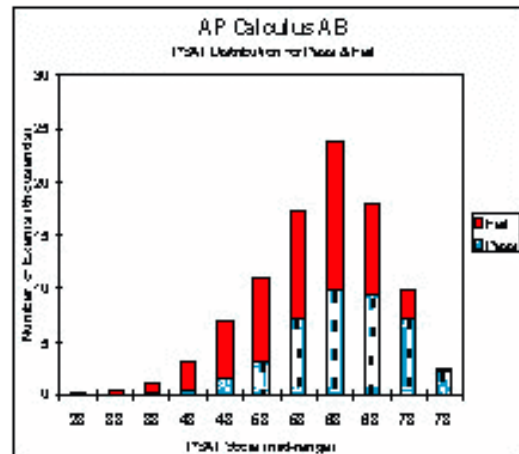


Figure 2 (lower part of bars are “pass”)

Imagine raising the academic level by moving each student up to the next math stage. According to Table I, if students went from the pre-calculus level to calculus, the gain in BA degrees awarded would be 0.3% of the graduates. A move from algebra 2 to Trigonometry would increase graduation by 6.4%, a twenty times larger effect. Less advanced programs than AP are more likely to reach and benefit the bulk of high school students.

Summary, Conclusions, Recommendations

AP is now standard college preparation that works for gifted students. It does not work for average and below average students. AP could better reach these students by introducing new tracks in its program. AP has a faulty scale, and needs quality controls, outside monitoring and policy guidance.

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Text of an invited paper given by W. Lichten, Yale University, New Haven CT 06520-8120, at the April Meeting of the American Physical Society, Washington, DC, April 28-May 1, 2001, in the session entitled **Whither Advanced Placement?**

W. Lichten is at the Institution for Social and Policy Studies, Yale University

Doing Research and Teaching

Jan Tobochnik

How can we best integrate our teaching and research? Does the pursuit of one necessarily detract from the other? Can a physicist be good in one area and not the other? How can we use knowledge from one area to enrich our work in the other? The answers to these questions are becoming increasingly important to physics faculty at all institutions of higher learning.

The current separation between teaching and research is manifested in the existence of two organizations of physicists, APS for research and AAPT for teaching. This separation is not good for our profession. All of us who do research in any setting should be concerned with communicating the knowledge and skills of physics. And all of us who teach to any students should be aware of, if not engaged in, research. Thus, there are many reasons to bring APS and AAPT members closer together, and more physicists should be members of both organizations.

Members of APS have an important role in making their research accessible to students and their instructors. The *American Journal of Physics* provides one outlet for you to do that. As the new editors of *AJP*, Harvey Gould and I are hoping to recruit active researchers to write articles that will help bring contemporary research into the curriculum. Most college physics courses still primarily discuss topics that are between one and three hundred years old. When more contemporary material is included, it is usually very descriptive. We need to make physics research come alive in the classroom so that students can be engaged in a meaningful way beyond the level of

Scientific American. Some students participate in on-campus research with their professors, off-campus research in government and industrial labs, or participate in NSF sponsored REU programs. However, this student research usually comes late in an undergraduate's college experience, and is frequently disconnected from the rest of the physics curriculum.

The computer may help to bring research activities to students earlier. Undergraduates can learn enough programming to write meaningful research-type simulations or perform numerical analysis. They can use the computer to analyze data from experiments even if they have not done the experiments themselves. As visualization becomes a more prominent feature in contemporary research, it should make more research accessible to students and hopefully motivate students to study physics. Students can already visit the Web sites of numerous research groups to learn more about what is going on in physics. Some of these sites have very good visual aids for explaining research projects. More of this material should be integrated into the curriculum.

However, relying only on computer technology to make the physics curriculum more interesting would be a mistake. I also believe that we need to incorporate more experiments and empirical observations into the curriculum. The physics curriculum has become too theoretical. That needs to change.

Many of us are looking for specific help in teaching. From research on physics education, we now know that students encounter many conceptual difficulties in their physics courses, and there are new materials that have improved student under-

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standing. Most of this work is at the introductory level, but there is a growing interest in student learning beyond introductory physics. In my own experience I find that many student difficulties carry over to higher level physics courses.

In addition to the conceptual difficulties that students face, there are at least two other barriers to learning physics. First, many students are not very proficient mathematically. Even though they can do algebra, few can do it quickly with a low error rate. Perhaps algebra prowess is not as important as it once was, and we should reduce the number of problems that require significant algebraic manipulation. Problems that primarily require students to fill in numbers to evaluate formulas are a waste of time. They might have been somewhat useful when students had to use slide rules that required an independent determination of the location of the decimal point in the answer and limited the precision of the answer to only a few significant figures. In this way students gained a sense of the order of magnitude and the precision of physical quantities. Today it's just an exercise in pressing buttons on a calculator. I can imagine a similar situation for algebra. Already many calculators can do graphing, simple symbolic manipulation, and even some calculus. Why ask students to press buttons to do these operations? Those who are actively involved in research need to help answer the question, "What skills are really necessary for understanding physics and doing scientific research?"

A second barrier is lack of motivation. Fewer undergraduates major in physics, and many of these students are more interested in engineering and other fields. Most of us believe that physics is an excellent major for many career paths, and it doesn't bother me that many of our students are using physics for purposes other than becoming research scientists. However, our teaching becomes less effective if the material is not of interest to students. We are in the midst of many exciting fundamental and practical developments in physics, such as quantum computing, the cosmic microwave background, atomic trapping, and nanotechnology to name a few. In addition, condensed matter physics, biological physics, and physics subfields that border other disciplines are providing a better understanding of complex phenomena. Physicists as always are at the forefront in developing new ways of attacking problems in many fields. Thus, there should be much more interest in studying physics even if students do not major in it. Why isn't there more interest? I believe that part of the problem is that students spend too much time in our courses doing work (such as routine problem solving and cookbook experiments) that is not relevant to anything else that they are doing, and is not especially useful in any conceivable future employment including research in physics.

It is essential that those in research-oriented institutions and those in teaching-oriented institutions talk more to one another. Researchers need to communicate better about contemporary research and the skills students need to develop.

Teachers and researchers in physics education need to communicate better what skills and beliefs students bring into the classroom, and how we all can effectively educate our students.

If there is an AAPT meeting near where you live, I urge you to go to it, at least for a day or two. Volunteer to give a talk about your work. Think about how you can convey your research to a general audience of physicists in such a way that those in the audience can take something of value home to their students. There are many active AAPT members who want to learn about contemporary physics research. I am confident that we can arrange more sessions that focus on contemporary research. Although you may not find many talks in the existing sessions that appear relevant to your teaching needs, you will find some. Your presence in the audience asking probing questions can help provide a different viewpoint than what is usually seen at many AAPT meetings.

More importantly, we need to schedule more joint APS/AAPT meetings. A number of regional chapters already do so. Joint national meetings seem to be dead at the moment. However, it might be possible to organize specialized APS meetings in conjunction with the AAPT national meeting. For example, the winter 2001 AAPT meeting was held jointly with the American Astronomical Society, and I understand that it was a very successful meeting for both associations.

You can also become more involved with AAPT and AJP. AJP publishes articles about contemporary research as well as articles specifically designed to improve teaching. However, it is not an archival journal of physics research nor are most of its articles directly focused on the classroom. As I stated, I would like to see more articles that discuss contemporary research and present something that could be used directly with students such as homework problems, mini-research projects, or access to experimental data to evaluate. In this way you could communicate your research to a much broader audience than you'll reach by publishing only in archival research journals. Also, read AJP regularly by subscribing to AJP through a membership in AAPT. Currently, there is a half price first year membership for APS members. Also, let me know what your needs and interests are. What kinds of articles would be helpful to you? I also encourage you to review manuscripts for AJP. If you are willing to do so, please complete the reviewer questionnaire at <http://www.kzoo.edu/ajp/referees.html>.

Another avenue for building bridges between research and teaching is the new Gordon Conference series on Physics Research and Education that was started in June 2000 and meets biannually. The focus topic of the first conference was statistical and thermal physics, and the focus of the next conference at Mount Holyoke College, June 9-14, 2002, is quantum mechanics. The goal of the conference is to bring together physicists doing research related to the topic, researchers in physics education, and faculty who are teaching courses in the topic.

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For more information on the next conference visit <http://www.grc.2002/programs/2002/physres.htm>. The conference focuses on a different topic each time and your suggestions for the focus in 2004 would be welcome.

I began this article with a few questions. Now let me summarize my answers. Research and teaching should be integrated as much as possible. Every time we write an article for PRL or AJP, we should keep in mind how that article can contribute not just to the knowledge base of physics, but also to the enlightenment of our students. In the classroom we should be constantly searching for ways of introducing research methods and ideas, and communicating these ways to a broader audience through talks and articles in AJP and other publications. In our research we need to involve students at all levels.

Physics is a dynamic field, constantly changing as new ideas and tools are developed. These changes must be present in the classroom, and thus the best teachers will generally have some involvement in research. Many of us find that our teaching enhances our understanding of physics which in turn is useful in our research, and that our research provides excellent applications of the physics we are teaching. Separation of teaching and research is artificial and damaging. Let us all look for ways of reducing that separation.

Jan Tobochnik is the Editor of the American Journal of Physics and a Divisional Associate Editor for Physical Review Letters. His current research includes studies of the glass transition and granular material. In collaboration with Harvey Gould, he has written textbooks, edited a column, and developed software for the educational and research use of computer simulations in physics.

Browsing the Journals

Thomas D. Rossing

- Alarmed by declining student interest in science and the superior test scores of some of its neighbors in East Asia, Japan is planning to reform the way science is taught in its schools, according to a news note in the 6 September issue of *Nature*. The plan will start next year with the establishment of 20 “super-science high schools,” each of which will receive special funding to buy equipment and teaching assistance from university researchers. In addition, the plan will provide equipment grants to 1500 other schools.

- George Soros is giving \$250 million to endow Central European University, a graduate institution in Budapest and Warsaw that he helped to found in 1991, according to a story in the October 14 issue of the *New York Times*. His gift will be the largest single gift to a European university. The endowment is part of Soros’s commitment to give away his fortune while he is alive. Last year his network of foundations gave out nearly \$500 million for education, public health, and the development of open societies in Central and Eastern Europe, the former Soviet Union, the United States and elsewhere. Founded in Prague, the main campus of the university is now in Budapest, where it offers graduate instruction, mostly in humanities and the social sciences to 858 students from 40 countries.

- “Lessons Learned from Arnold Arons” is the title of a column in the November issue of *The Physics Teacher* intended for new teachers. The authors identifies 5 lessons: 1. Pay attention to underpinnings (gaps in students’ backgrounds); 2. Pay careful attention to how you say things (the “linguistic



elements”); 3. Develop the idea first and give it a name afterwards; 4. Provide multiple representations; 5. Establish a classroom climate of active engagement. Cookbook labs provide activity but rarely do they require active engagement. Likewise, working problems by plugging numbers into prescribed equations doesn’t force learners to identify why the equation fits the situation.

- Telescopes in Education, a project that makes a 24-inch research-quality robotic telescope at the Mt. Wilson observatory in California available to students all over the world, is described in an article in the May issue of *Physics Education*. Observing sessions generally last an hour or two and are booked in advance. Two telephone lines are kept open during a run: a voice line to communicate with the dome and a data line for the telescope. The telescope is equipped with a CCD camera, and by taking photographs through red, green and blue filters, separate black-and-white photographs can be combined into color images.

- Teachers in the United States earn less relative to national income than their counterparts in other industrial countries, yet they spend far more hours in front of the classroom, according to a new international study summarized in the *NYTimes* of June 13. The salary differentials are part of a pattern of relatively low public investment in education in the United States according to the report compiled by the Organization for Economic Cooperation and Development in Paris. Total government spending on educational institutions in the United States slipped to 4.8 percent of gross domestic product, falling under the international average of 5 percent for the first. In addition to the teacher pay gap, the report shows the other countries have begun to catch up with the United States in higher education. For the first time, the college graduation rate in the U.S., now 33%, is not the world’s highest. Finland, the Netherlands, New Zealand and Britain now surpass it. The U.S. is also producing fewer mathematics and science graduates than most

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other member states. The average salary for a high school teacher with 15 years of experience is less than 60 percent of the average in Switzerland, and teachers in the U.S. have a heavier classroom load, teaching almost a third more hours than their counterpart abroad.

- The claim that Copernicus “dethroned” earth from its “privileged” central position in the universe is a cliché that is unwarranted and should be discarded, according to a paper in the October issue of *American J. Physics*. The great Copernican cliché is premised upon an uncritical equation of geocentrism with anthropocentrism, the author argues.

- There is growing evidence that one of the difficulties that students have in understanding and applying physics concepts is a lack of appreciation of the purposes and structure of physics knowledge, according to a paper in the March issue of *Physics World* entitled “Making physics common sense.” Teaching students about the true purpose of models, laws, and theories can help them understand the subject.

- MIT, along with its principal partner Stanford University, has launched THE Open Knowledge Initiative (OKI), an ambitious project to develop a modular Web-based teaching environment for assembling, delivering, and accessing educational resources and activities, according to an article in the June issue of *Syllabus*. Information about OKI, which is based on an open source-licensing model, is available at <http://web.mit.edu/oki>. Another recently announced MIT project, the Open Course Ware Initiative, which will make content from MIT courses available on the Web for free, is described at <http://web.mit.edu/newsoffice/nr/2001/ocw-facts.html>.

- A new “general” physics major at Rutgers University, with a less demanding curriculum for students who do not intend to pursue a research career in physics, is described in a guest editorial by Peter Lindenfeld in the October issue of *J. College Science Teaching*. Two new full-year courses to follow the introductory physics course have been added. One is Advanced General Physics, which includes parts of the normal junior and senior courses, but at a reduced level of intensity and mathematical sophistication. The other is a laboratory course with a substantial amount of computer use. The new major, which compliments the “professional” physics major, also requires two further semesters in physics, which can be chosen from the regular advanced courses or can also be special courses (Physics of Sound, Physics of Modern Devices), which are less rigorous and problem-oriented.

- An article by columnist Alfie Kohn in the Aug. 22 issue of *USA Today* attacks the standardized reading and math tests proposed by President Bush. “Given that time and energy are limited, what is being sacrificed when schools are forced to focus on test results? The answers are increasingly clear—and disturbing—as evidence accumulates from across the USA: Science and social studies have been severely trimmed in states that do not include those subjects on standardized tests.” Many science teachers in schools with poor and minority children are required by their principals to suspend the teaching of science for weeks or months in order to devote science class time to drill and practice.

- A Phoenix astrology school was recently given accredited status, and its students can now pursue federal education grants and loans, according to a news bulletin in the October/November *NSTA Reports*. The Accrediting Commission of Career Schools and Colleges of Technology accredited The Astrology Institute of Scottsdale, largely because the school demonstrated its teachers are qualified and that students find paying jobs, according to the head of ACCSCT. Graduates of the school set up private practice or work in health spas or on board cruise ships.

- In a letter to the editor in the May issue of *The Physics Teacher*, teachers were asked to comment on their experiences teaching algebra-based physics courses online. Three such letters appeared in the November issue of that journal, and no doubt more will appear in succeeding issues. Most of the experiences were positive (see “Teaching on the Web” in this newsletter issue).

- “What do the athlete Jonathan Edwards, the rock star Brian May, and the film director Paul Verhoeven have in common?” begins an article on career options for physicists in the October issue of *Physics World*. The answer is that they all have degrees in physics, as do many other famous businessmen, entertainers, and government leaders, including Mike Judge (creator of “Beavis and Butt-head”), Lindsay Nicholson (editor of *Good Housekeeping*), and many others. Perhaps a catalogue of famous persons who have physics degrees would help to improve the fading image of physics among young people, the article suggests.

Thomas D. Rossing is Professor of Physics at Northern Illinois University, DeKalb, IL. He has been an editor of the Forum Newsletter for six years.

The Newsletter Editors invite you to write a letter to the editor or propose an article for the next issue

Spring issue Deadline for Contributions February 1	Summer issue Deadline for Contributions June 1	Fall issue Deadline for Contributions October 1
Ernest I. Malamud Fermilab 16914 Pasquale Road Nevada City, CA 95959 (530) 470-8303 malamud@fnal.gov	Stanley T. Jones College of Arts and Sciences University of Alabama, Box 870268 Tuscaloosa, AL 35487-0268 (205) 348-5050 stjones@bama.ua.edu	Thomas Rossing Department of Physics Northern Illinois University De DeKalb, IL 60115-2854 (815) 753-6493 rossing@phys.niu.edu

FEd Executive Committee

<p>Jack M. Wilson, Chair CEO, UMassOnline One Beacon St. 26th Floor Boston, MA 02108 (617) 287 7160 JackMWilson@JackMWilson.com</p>	<p>Kenneth S. Krane, Chair-Elect (also Chair of Program Committee) Department of Physics Oregon State University Corvallis, OR 97331-6507 (541) 737-1692 kranek@physics.orst.edu</p>	<p>Wolfgang Christian, Vice-Chair (also Chair of Nominating Committee) Physics Dept., Dana Bldg. Davidson College, PO Box 1719 Davidson, NC 28036 (704) 892-2322 wochristian@davidson.edu</p>
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<p>Ernest I. Malamud, Gen. Mem.-At-Large Fermilab 16914 Pasquale Road Nevada City, CA 95959 (530) 470-8303 malamud@fnal.gov</p>	<p>Ramon E. Lopez, Gen. Mem.-At-Large Univ. of Texas, El Paso El Paso, TX 79968 (915) 747-7528 relopez@utep.edu</p>	<p>Richard W. Robinett, Gen. Mem.-At Large Dept. of Physics Penn.State University 104 Davey Lab University Park, PA 16802 (814) 863-0965 rick@phys.psu.edu</p>
<p>Gay B. Stewart, APS/AAPT Member-At-Large Department of Physics University of Arkansas Fayetteville, AR 72701 (501) 575-2408 gstewart@comp.uark.edu</p>	<p>Dean A. Zollman, APS/AAPT Member-At-Large Department of Physics Kansas State University, Cardwell Hall Manhattan, KS 66506-2601 (785) 532-1619 dzollman@phys.ksu.edu</p>	<p>Paula R. L. Heron, APS/AAPT Member-At-Large Dept. of Physics, Univ. of Washington PO Box 351560 Seattle, WA 98195-1560 (206) 543-3894 pheron@phys.washington.edu</p>

Non-voting members of the FEd Executive Committee

<p>James J. Wynne, WebPage Administrator IBM/T.J. Watson Research Center Yorktown Heights, NY 10598-0218 (914) 945-1575 jjwynne@us.ibm.com</p>	<p>Fredrick Stein, APS Director, Education and Outreach Programs One Physics Ellipse College Park, MD 20740-3844 (301) 209-3263 stein@aps.org</p>	<p>John L. Hubisz, AAPT Representative 1604 S. Salem St Apex, NC 27502-7251 (919) 362-5782 john_hubisz@ncsu.edu</p>
<p>Richard A. Saenz, Chair, Cmt. On Education Cal Poly State University Dept. of Physics San Luis Obispo, CA 93407 (805) 756-2447 rsaenz@calpoly.edu</p>	<p>Newsletter Editors:</p> <p>Tom Rossing Stan Jones Ernie Malamud</p>	

Other Key Personnel

<p>Judy R. Franz, APS Executive Officer APSOne Physics Ellipse College Park, MD 20740-3844 (301) 209-3270 franz@aps.org</p>	<p>George H. Trilling, APS President Lawrence Berkeley National Lab, MS 50B-6208 One Cyclotron Rd., Berkeley, CA 94720 (510) 486-6801 ght@lbl.gov</p>	<p>John L. Hubisz, AAPT President 1604 S. Salem St Apex, NC 27502-7251 (919) 362-5782 john_hubisz@ncsu.edu</p>
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