APS physics

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Nic Rady, Editor

IN THIS ISSUE

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From the Chair

Chandralekha Singh

First of all, I would like to thank Larry Woolf for doing an excellent job as the FEd chair this past year and to Bruce Mason, who was absolutely fabulous as the FEd Secretary/Treasurer for the past six years. Fortunately, Larry will be on the executive committee for another year as the past-chair and will chair the FEd fellowship committee. I would also like to convey our appreciation to the other outgoing members of the FEd executive committee, the past chair, Peter Collings, and the members-at-large, John Thompson and Stamatis Vokos.

I would also like to welcome the new members on the FEd executive committee. Paul Cottle is the new vice-chair, Scott Franklin is the new Secretary-Treasurer, and the new members-at-large are Greta Zenner Petersen and Angie Little.

Renee Diehl, who is the energetic FEd Chair-elect, is also the chair of the FEd program committee for the APS March and April meetings in 2012. If you have suggestions for possible sessions that could be sponsored or co-sponsored by FEd for either of these meetings, please let Renee know. Paul Cottle is the chair of the FEd nominating committee which is charged with nominating candidates for vice-chair and the two members-at-large (one of whom must also be an AAPT member) for next year. If you have suggestions for candidates for any of these positions, please let Paul know.

In addition to organizing invited sessions at the March and April meetings, FEd sponsors three newsletters in fall, spring and summer. The editors for next fall, spring, and summer are Nic Rady, Paul Dolan and Richard Petersen. Please consider writing an article for any of these upcoming newsletters. Also, please go to the APS FEd website to browse through the past newsletters. In those newsletters, you will find useful articles on a variety of topics related to graduate, undergraduate and K-12 education and also on informal physics education and outreach.

Executive committee members can be contacted form the governance page on the FEd's website at http://www.aps.org/units/fed/governance/officers/index.cfm. I am also looking for suggestions on how to improve the FEd activities. In particular, I would like suggestions on how to further engage the more than 4000 FEd members in FEd activities. Please drop me a line if you have ideas.

I look forward to working with you.

Chandralekha Singh is an Associate Professor in the Department of Physics and Astronomy at the University of Pittsburgh. She is Chair of the APS Forum on Education and is the Chair of the editorial board of the Physical Review Special Topics: Physics Education Research.

Letter to the Editor:

The Stull study (Stull, et. al., published in the Spring 2011 FED newsletter) reported a positive learning result from clicker use in a physics classroom. We see this work as a useful contribution to a larger body of research that has gone beyond anecdotal evidence to quantitatively establish the benefits of in-class interactive engagement through clickers or other classroom response systems. For example:

- Catherine Crouch and Eric Mazur, "Peer Instruction: Ten years of experience and results," *American Journal of Physics* 69, 970-977 (2001).
- M. Smith, W. Wood, W. Adams, C. Wieman, J. Knight, N. Guild, and T. Su, "Why Peer Discussion Improves Student Performance on In-Class Concept Questions," *Science* 323, 122-124 (2009).
- Ralph Preszler, Angus Dawe, Charles Shuster, and Michele Shuster, "Assessment of the effects of student response systems on student learning and attitudes over a broad range of biology courses," *Life Sciences Education* 6, 29–41 (2007).
- Erica Suchman, Kay Uchiyama, Ralph Smith, and Kim Bender, "Evaluating the impact of a classroom response system in a microbiology course," *Microbiology Education* 7, 3–11 (2006).
- N. W. Reay, Pengfei Li, and Lei Bao, "Testing a new voting machine question methodology," *American Journal of Physics* 76(2), 171–178 (2008).
- Adam Fagan, Catherine Crouch, and Eric Mazur, "Peer instruction: results from a range of classrooms," *The Physics Teacher* 40, 206-209 (2002).
- Jennifer Knight and William Wood, "Teaching More by Lecturing Less," *Cell Biology Education* 4, 298-310 (2005).
- David Meltzer and Kandiah Manivannan, "Transforming the lecture-hall environment: The fully interactive physics lecture," *American Journal of Physics* 70, 639 (2002).
- Nathaniel Lasry, Eric Mazur, and Jessica Watkins, "Peer instruction: From Harvard to the two-year college," *American Journal of Physics* 76, 1066 (2008).
- Jane Caldwell, "Clickers in the large classroom: Current research and best-practice tips," *Life Sciences Education* 6, 9–20 (2007).

This list is not meant to be exhaustive, but highlights the extensive quantitative results that have come from multiple instructors and institutions.

The Mazur Group, Harvard University

How and Why Academic Physicists Can Aid Learning on Their Campuses

William L. Goffe

Physicists are likely aware that there have been increasing calls for college and universities to become more accountable for student learning. Some of these calls have occurred in the higher education literature (Carey, 2011) and others have occurred in more public contexts. Perhaps the best recent example is "Academically Adrift" (Arum and Roksa, 2011a), which finds little learning among a significant fraction of college students. These authors made their point even more publicly, during the height of the college graduation season, in "Your So-Called Education" (Arum and Roksa, 2011b). For a time, it was one of the most e-mailed articles from the *New York Times*.

It will probably surprise few that such calls date back some years. What might surprise some is how similar concerns from years ago have come to colleges and universities in very real ways. Further, physicists in higher education are poised to play a unique role in helping improve learning on their campuses.

During the later years of the Bush Administration, the then Secretary of Education, Margaret Spellings, formed a committee that became known as the "Spellings Commission" (formally the "Commission on the Future of Higher Education"). While lauding some accomplishments of the U.S. higher education sector, it also expressed serious concerns. In particular, it stated (Commission, 2006):

> Compounding all of these difficulties is a lack of clear, reliable information about the cost and quality of post-secondary institutions, along with a remarkable absence of accountability mechanisms to ensure that colleges succeed in educating students.

This concern has filtered down to colleges and universities through their accrediting bodies, which in turn are accredited by the U.S. Department of Education. The accrediting bodies wield a major stick–if an institution of higher education is not accredited, their students can no longer use federal education support to pay for that institution's tuition and fees.

As a result of increased accountability pressures, U.S. colleges and universities are now directed to "assess" their students' learning and to take action if that learning is found wanting. It may surprise physicists that assessment experts are not familiar with the role that Physics Education Research (PER) has played in improving student learning. Indeed, Banta and Blaich (2011) lament that they can find virtually no examples of improved learning in higher education after a teaching innovation. Their paper does not mention physics at all! As a non-physicist familiar with some elements of PER, such as the work of Hestenes et al. (1992), Hake (1988), Crouch et al (2007) and Deslauriers et al. (2011) (of course, after Banta and Blaich (2011), but notable nonetheless), this lack of awareness of PER is remarkable.

This situation represents an opportunity for physicists. Assessment mandates are driving a real interest across campuses to improve student learning and most have committees that focus on this issue. Physicists should consider advising if not joining these committees to bring their expertise to bear on both assessing learning and on teaching methods that increase learning. They are likely to find a very receptive audience given assessment pressures. As Banta and Blaich (2011) indirectly suggest, it appears that physicists have a nearly unique set of skills. It would be a loss for non-physicist colleagues and in particular our students if the teaching expertise that physicists have developed stays in physics departments.

1. Carey, Kevin, (2011). 'Trust Us' Won't Cut It Anymore, *Chronicle of Higher Education*, January 18, http://chronicle.com/article/Trust-Us-Wont-Cut-It/125978/, retrieved 6/16/2011.

2. Arum, Richard and Josipa Roksa (2011a). *Academically Adrift: Limited Learning on College Campuses*, University Of Chicago Press.

3. Arum Richard and Josipa Roksa (2011b). Your So-Called Education, *New York Times*, May 14, 2011, http://www.nytimes.com/2011/05/15/opinion/15arum.html, retrieved 6/16/2011.

4. Commission on the Future of Higher Education (2006). *A Test of Leadership*

5. Charting the Future of U.S. Higher Education, http://www2.ed.gov/about/bdscomm/list/hiedfuture/reports/final-report.pdf, retrieved 6/16/2011.

6. Banta, Trudy W. and Charles Blaich (2011). Closing the Assessment Loop, Change–*the Magazine of Higher Education*, January/February,

7. Hestenes, D., M. Wells, M. and G. Swackhamer (1992). Force Concept Inventory, *The Physics Teacher*, 30(3), 141--158.

8. Hake, Richard .R. (1988). Interactive-engagement versus Traditional Methods: A Six-thousand-student Survey of Mechanics Test Data for Introductory Physics Courses, *American Journal of Physics*, 66(1), 64--74.

9. Crouch, C.H. and Watkins, J. and Fagen, A.P. and Mazur, E. (2007). Peer Instruction: Engaging Students One-on-one, All at Once, *Reviews in PER*, 1(1), http://www.compadre.org/

PER/items/detail.cfm?ID=4990
10. Deslauriers, L., E. Schelew and C. Wieman (2011). Improved Learning in a Large-Enrollment Physics Class, *Science*, 332(6031), 862-4.

*William Goffe is an economist in the Department of Economics at SUNY Oswego. He can be reached at: bill.goffe@oswego.edu. While an economist, he became interested in PER after two other economists (Mark Maier and Scott Simkins) sent him a paper they had written on PER as well as Carl Wieman's "Why Not Try a Scientific Approach to Science Education?" (*Change, *September/October, 2007). He was deeply impressed and feels that PER has much to offer other teachers in higher education. Besides research in economic education, he has also published in computational economics and in how economists can best use the Internet. He is an associate editor of the* Journal of Economic Education.

When Did You Learn About the Weirdness of Quantum Mechanics? The Role of Citizen-Scientists in Society

Hirokazu Miyake and Nabil Iqbal

Quantum mechanics is weird. For example, how is it that we cannot know exactly where an object is and how fast it is moving at the same time? As Richard Feynman, one of the most eminent physicists of the 20th century said, "nobody understands quantum mechanics."[1] Yet despite its weirdness, quantum mechanics forms the basis of the existence of atoms, the properties of magnets and metals, and how the sun shines and provides energy for life forms to flourish on earth, among many other phenomena.

Physicists who have become accustomed to the weirdness of quantum mechanics through extensive course work and research may find these sorts of questions to be mundane and irrelevant to the mainstream of the scientific enterprise. However, despite the relevance of quantum mechanics to numerous aspects of our everyday lives, how many people in the general public realize that such bizarre and fantastic phenomena in fact occur and describe nature? Moreover, how many middle school and high school students know about them? From our experience, not too many. Practicing scientists are well positioned to help remedy the lack of appreciation of modern science in general by participating in outreach activities and conveying the joy and excitement of the cutting edge of research directly to the general public.

Of course, the standard K-12 science education curriculum does not include topics such as quantum mechanics. What are covered are more foundational topics, such as the structure of cells, the properties of the periodic table, and calculations of the trajectories of flying objects. There is no doubt that these topics serve a very good purpose of educating students on the scientific method of hypothesis, experimentation, and testing of a given scientific theory. However from the point of view of getting the public–especially middle and high school students–excited about physics, talking about topics such as quantum mechanics and relativity are a great way to accomplish this. Understanding pendulums and inclined planes is absolutely essential to proceed in an education in physics, but to pique the interest of young students, it is perhaps more effective to go beyond the standard school topics and provide them with a glimpse of where the cutting edge of science is.

One way to complement formal education is for practicing scientists such as graduate students, post-docs and professors to go out into the public and talk about their research and the frontiers of science. We, as graduate students, have been teaching classes for four years now through the Educational Studies Program (ESP) at the Massachusetts Institute of Technology. ESP is a student-run group that provides opportunities for anybody interested in teaching any subject to middle and high school students. So far we have taught topics ranging from the Heisenberg uncertainty principle and Bose-Einstein condensates to the twin paradox and black holes to almost 800 middle and high school students.

We gear our classes towards those students who are interested but have no prior knowledge of the subject since we aim for our classes to be a starting point for students to further explore the topics on their own. This means that we focus on qualitative features of the physics involved and avoid calculations as much as possible. The qualitative aspects are usually the most interesting and ultimately fundamental. We keep the discussions light-hearted and attempt (we feel mostly successfully) to be humorous. We also encourage the students to actively participate throughout the class, thus spending almost half of the time on questions and discussions. We pose questions to the students whenever we can: for example we present the twin paradox as a challenge to the class. The class is always split on which twin ends up younger, leading to an interesting discussion.

We have found this teaching experience to be a very satisfying one, both for the students and for us. The probing questions that the students raise challenge us to understand the physics and explain it in a clear and understandable way. When a particle quantum tunnels through a barrier, is it 'passing through the cracks' in the atoms that make up the wall? Why can't you go faster than the speed of light? Can something quantum tunnel out of a black hole? Questions such as these force us to refine our own understanding of the physics that we are trying to explain. These probing questions and the positive feedback we receive after our classes indicate that the students are tremendously excited to learn something completely new such as quantum mechanics and relativity. The excitement they feel may encourage them to pursue a scientific career. And even if they do not go into science, they will have a much better appreciation of the technologies and scientific issues that permeate our everyday lives. On the other hand, we as teachers have the opportunity to step back from our everyday research work, think about the big picture, truly appreciate the fundamentally interesting aspects of physics and remember why we got excited about it in the first place.

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[1] Richard P. Feynman, *The Character of Physical Law*, Cambridge, MA, MIT Press, 2001.

A State-by-State Science and Engineering Readiness Index (SERI): Grading States on Their K-12 Preparation of Future Scientists and Engineers

Susan White andPaul Cottle

In 2007, the authors of *Rising Above the Gathering Storm* [1, subsequently referred to as "RAGS"] were "deeply concerned that the scientific and technological building blocks critical to our economic leadership are eroding at a time when many other nations are gathering strength." (p. 3) The highest priority actions recommended by this report focused on science, engineering, and math teaching in K-12 programs.

The Bioscience Industry Organization (BIO) released a report in 2009: "Taking the Pulse of Bioscience Education in America: A State-by-State Analysis" [2]. This report referred to RAGS explicitly; it provides a framework to assess bioscience education in the US at the state level. Not surprisingly, the report focused mostly on K-12 biology courses and student achievement in this subject. States were sorted into four categories ("leaders of the pack," "second tier," "middling performance," and "lagging performance") by their ratings on a list of indicators, including the average scale score of 8th graders on the National Assessment of Educational Progress (NAEP), the average scores on the science section of the American College Test (and specifically on the biology items on the test), the pass rate on the Advanced Placement Biology test, and the percentage of biology teachers who had certification in biology. Florida was included in the "lagging performance" group, prompting an official of the state's Department of Education to tell a gathering of school district officials that the state's students are "pretty much last in the nation in science." [3]

The BIO report focused on biology. We propose a Science and Engineering Readiness Index (SERI) as a tool for policy-makers and educators to use to examine progress in K-12 physical science and engineering education. The foundation provided in K-12 schools to better prepare students for careers in science and engineering is crucial.

Economics, Physical Sciences, Math, and Engineering

The authors of RAGS were concerned with the erosion of the scientific and technical building blocks for our economic leadership. Not only is this impact felt at the macroeconomic level, but it also rings true at the microeconomic level, too. The American Institute of Physics recently demonstrated [4] that the very best economic opportunities for new bachelor's degree graduates are in the mathematical and physical sciences and engineering.

Research shows that students' success in the demanding undergraduate programs leading to these degrees depends not only on the work of college faculty in these programs, but also on how well these students are prepared during their K-12 years. The 2007 study by Tyson *et al*. [5] that followed Florida high school graduates through their postsecondary years demonstrated strong correlations between high school preparation and bachelor's degree attainment, particularly in STEM (science, technology, engineering and mathematics) fields. In particular, Tyson *et al*. demonstrated the importance of high school physics and advanced mathematics courses (including calculus) in the preparation of successful STEM students. Sadler and Tai [6] demonstrated that taking a high school physics course is correlated with success in physics at the college level (with the corresponding statements about biology and chemistry being correct as well), while taking calculus in high school is correlated with success in all college science courses.

Given the importance of high school physics and calculus in preparing students for the engineering and physical science fields that offer the best economic prospects for bachelor's degree graduates, it makes sense to offer policy makers and the public a succinctly-stated measurement of how well their states are doing in preparing K-12 students for these fields. Here we propose a Science and Engineering Readiness Index (SERI) that incorporates results from the National Assessment of Educational Progress [7,8] ("NAEP", conducted periodically by the US Department of Education), Advanced Placement Examination results in calculus and physics [9], the physics course-taking results from the American Institute of Physics National Survey of High School Physics Teachers [10] and information on teacher certification requirements in science compiled by the National Council on Teacher Quality (NCTQ) [11]. The information from these sources is gathered into three scores on mathematics performance, science performance and teacher qualifications. The scores are then used to assign each state a single composite score. The formulation of this index provides an opportunity for examining the strengths and weaknesses of each state's K-12 mathematics and science programs.

All of the information used in formulating SERI is available to the public on the Internet. While other indicators would have been desirable–the percentage of graduating high school seniors who have taken a quantitative physics class, for example–we focused on indicators that are readily available.

Math score

Two indicators were used to obtain the SERI math score. The first was the percentage of students who earned achievement levels of proficient or higher on the 2009 8th grade NAEP Math Assessment [6]. NAEP sorts students into four "achievement levels"–advanced, proficient, basic and "below basic." A student below the "proficient" level is not on track for a career in the physical sciences or engineering, so we focus on this achievement level. Nationally, the percentage of students rated "proficient" on the 8th grade NAEP math assessment was 34%. The state with the highest percentage is Massachusetts (52%) and the state with the lowest percentage is Mississippi (15%). The 12th grade NAEP math assessment, which might have been more directly applicable to a readiness index, is not reported on a state-by-state basis.

For each indicator used in SERI (like the percentage proficient on the 8th grade NAEP Math Assessment), we formulate a scaled NAEP sub-score between 1 and 5 so that the lowest state (in the case of the 8th grade NAEP Math Assessment, it is Mississippi) receives a scaled NAEP sub-score of 1 and the highest state (here Massachusetts) receives a scaled NAEP sub-score of 5. We explain the details of the calculation in the appendix. The sub-scores are scaled so that they reflect the actual variation in a given indicator.

The second indicator used in the formulation of the math score reflects the numbers of students passing Advanced Placement Calculus Examinations (Calculus AB and Calculus BC) in 2010. The AP Calculus sub-score is calculated using the combined number of students passing (score of 3 or better) both exams, relative to the number of high school seniors in the state. The numbers of students passing and the numbers of high school seniors are taken from the College Board's "7th Annual AP Report to the Nation" and the subject and state supplements [8]. Nationally, the number of students passing both the Calculus AB and BC exams divided by the number of high school seniors is 6.3%. The highest state is Massachusetts with 11% which yields an AP Calculus sub-score of 5. The lowest is Mississippi with 0.8% which yields an AP Calculus sub-score of 1.

Finally, the score for math is calculated to be the average of the sub-scores for the 8th grade NAEP Math Assessment and AP Calculus. Massachusetts has the highest math score, 5. The lowest score, 1, was earned by Mississippi.

Science score

Three indicators were used to calculate the science scores. Two of them, corresponding to performances on the 2009 8th grade NAEP Science Assessment [7] and the AP Physics examinations, were formulated in ways identical to the corresponding indicators used in the math scores. The third indicator was the course-taking rate for high school physics as determined by the AIP's National Survey of High School Physics Teachers [9].

Nationally, the percentage of 8th graders who earned "proficient" or above on the NAEP Science Assessment was 30%. The highest and lowest states by this measure were Montana (42%) and Mississippi (15%), respectively. Numerical state sub-scores for this indicator were calculated using the same procedure used for the NAEP Math Assessment.

The AP Physics indicator (and the corresponding numerical sub-score) were calculated using the same prescription used for AP Calculus. However, the two exams used in formulating this indicator were the Physics B exam and the Physics C Mechanics exam (Physics C Electricity and Magnetism was not used because the students who passed this exam were almost certainly just a subset of the students who passed the mechanics exam). Nationally, the ratio of passing scores on the two AP Physics exams to the number of high school seniors was 2%, and the states with the highest and lowest ratios were New York (4.3%) and North Dakota (0.3%), respectively. The resulting AP Physics sub-scores were topped by the 5 awarded to New York; North Dakota had the lowest sub-score of 1.

In 2009, the AIP National Survey of High School Physics Teachers [9] sorted states into three categories for physics course-taking –states significantly higher than the national rate of 37% (Massachusetts, Michigan, Minnesota, New Hampshire, Texas and Wyoming), states significantly lower than the 37% national rate (Alabama, Alaska, Arkansas, Idaho, Mississippi, Montana, Nebraska, Nevada, North Carolina, North Dakota, Oklahoma and Tennessee), and states not significantly different from 37% (everybody else). Similarly, in 2005, the national physics-taking rate was 33%. The above-average states were Massachusetts, Maryland, New Jersey, and Pennsylvania, and the below-average states were Alabama, Arkansas, Mississippi, Oklahoma, and Tennessee. Specific details on how we calculated the physics-taking sub-score are described in the appendix.

The numerical score for science is then computed by averaging the numerical sub-scores for the three indicators. There are four states that did not participate in the NAEP Science Assessment (Alaska, Kansas, Nebraska and Vermont). For these states, the numerical score for science is calculated by averaging the numerical sub-scores for AP Physics and the physics-taking rate. The highest score for science was earned by Massachusetts (4.55). The lowest was awarded to Mississippi (1.27).

Teacher qualifications score

In 2010, the NCTQ issued a report [11] on science teacher certification in each state and assigned a grade of "red light", "yellow light" or "green light" depending on whether a state had discipline-specific certifications for each science discipline. Some states have only general science certifications, while a few have a certification for each discipline (biology, chemistry, Earth science and physics). States with discipline-specific certifications earned green lights, while states with general science certifications earned red lights. Yellow lights were awarded to states with certification procedures that were somewhere in the middle of these two limits.

We assign a teacher qualifications numerical score of 5 to those states that earned a green light from the NCTQ, a score of 3 to yellow light states, and a score of 1 to red light states.

Composite SERI score

In calculating a composite SERI score, we weight the scores for math and science to each account for 40% of the total. The teacher qualifications score accounts for the other 20%. While teacher qualifications are very important, the NCTQ report provides a very coarse evaluation that does not account for the difficulty of earning (for example) a physics certification. Under these circumstances, the 20% seemed appropriate.

Only a few good states

Massachusetts easily leads the field with a SERI of 4.82.

Minnesota, New Jersey, New Hampshire, and New York score between 3.94 and 4.06. These scores are well above the national average of 2.82. We rate Massachusetts as "Best in the US" and the call the next four states "Well above average."

A third group of states post above average scores between 3.24 and 3.73. These states are Virginia, Maryland, Indiana, Connecticut, and Maine. We call these states "Above average."

These ten states with SERI scores above the national average accounted for just over 20% of high school graduates in 2009.

"Average" states post average SERIs between 2.53 and 3.13. Nineteen states fall into this group. These states accounted for just over 37% of 2009 high school graduates.

"Below average" states post SERIs that range from 2.14 to 2.47. These twelve states include California. These states accounted for almost one-third of 2009 high school graduates.

"Far below average" states have a SERI between 1.58 and 2.01. These states accounted for about 9% of 2009 high school graduates.

Finally, Mississippi's SERI is 1.11. This lags the other states by almost half a point and results in Mississippi being labeled "Worst in the US."

Table 1 shows the sub-scores, component scores, SERI, and rating for each state. Figure 1 depicts the percentage of seniors graduating from schools by SERI rating, and Figure 2 shows the SERI data by state.

The need for science and engineering readiness

In 2010, the sequel to RAGS, *Rising Above the Gathering Storm, Revisited: Rapidly Approaching Category 5* (2010) examined the status of the recommended actions. [12] The findings with respect to K-12 math and science education are not good: "[I]n spite of sometimes heroic efforts and occasional very bright spots, our

Table I. 2011 Science and Engineering Index indicator scores

	Math			Science				Teachers		
State	NAEP	AP Calculus	SCORE	NAEP	AP Physics	Physics-taking	TOTAL	SCORE	SERI	Rating*
AK	2.95	3.09	3.02	N/A	1.92	2.03	1.97	1.00	2.20	Below average
AL	1.54	1.92	1.73	1.57	1.63	2.11	1.77	1.00	[illegible]	Far below average
AR	2.30	1.74	2.02	2.29	1.35	1.87	1.84	3.00	2.14	Below average
AZ	2.51	1.84	2.18	2.00	1.41	2.88	2.10	1.00	1.91	Far below average
CA	1.86	3.79	2.83	1.71	3.30	2.88	2.63	1.00	2.38	Below average
CO	3.70	3.89	3.80	4.00	3.02	2.88	3.30	1.00	3.04	Average
CT	3.70	4.42	4.06	3.86	4.16	2.88	3.63	1.00	3.28	Above average
DE	2.84	3.74	3.29	2.43	2.79	2.88	2.70	1.00	[illegible]	Average
FL	2.51	2.96	2.74	2.43	2.42	2.88	2.58	5.00	3.13	Average
GA	2.30	3.19	2.74	2.71	3.30	2.88	2.97	3.00	2.88	Average
HI	2.08	3.22	2.65	1.29	3.53	2.88	2.57	1.00	2.29	Below average
IA	3.05	1.70	2.38	3.86	1.49	2.88	2.75	1.00	2.25	Below average
ID	3.49	2.06	2.77	4.14	2.14	2.43	2.90	1.00	2.47	Below average
IL	2.95	3.53	3.24	2.86	3.12	2.88	2.95	3.00	[illegible]	Average
IN	3.27	2.68	2.97	3.43	1.87	2.88	2.73	5.00	3.28	Above average
KS	3.70	2.01	2.86	N/A	1.39	2.88	2.14	5.00	3.00	Average
KY	2.30	2.32	2.31	3.71	1.51	2.88	2.70	5.00	3.00	Average
LA	1.54	1.61	1.58	1.71	1.07	2.88	1.89	1.00	1.59	Far below average
MA	5.00	5.00	5.00	4.71	4.87	4.06	4.55	5.00	4.82	Best in the US
MD	3.70	4.44	4.07	2.86	3.89	3.32	3.35	3.00	3.57	Above average
ME	3.16	3.80	3.48	3.86	2.62	2.88	3.12	3.00	3.24	Above average
MI	2.73	3.01	2.87	3.86	2.19	3.34	3.13	1.00	[illegible]	Average
MN	4.46	3.61	4.04	4.57	2.49	3.80	3.62	5.00	4.06	Well above average
MO	3.27	1.92	2.59	4.00	1.77	2.88	2.88	1.00	2.39	Below average
MS	1.00	1.00	1.00	1.00	1.05	1.77	1.27	1.00	1.11	Worst in the US
MT	4.14	1.64	2.89	5.00	1.19	2.66	2.95	1.00	2.53	Average
NC	3.27	3.29	3.28	2.29	1.89	2.03	2.07	1.00	2.34	Below average
ND	4.03	1.68	2.85	4.86	1.00	2.08	2.65	1.00	2.40	Below average
NE	3.16	1.72	2.44	N/A	1.42	2.54	1.98	1.00	1.97	Far below average
NH	4.03	3.88	3.95	4.43	2.58	3.74	3.58	5.00	4.01	Well above average
NJ	4.14	3.84	3.99	3.71	3.56	3.54	3.60	5.00	4.04	Well above average

Table 1 Continued

State	Math NAEP	Math AP Calculus	Math SCORE	Science NAEP	Science AP Physics	Science Physics-taking	Science TOTAL	Teachers SCORE	SERI	Rating*
NM	**1.54**	**1.91**	**1.73**	**1.86**	**1.51**	**2.88**	**2.08**	**1.00**	**1.72**	**Far below average**
NV	2.08	2.48	2.28	1.71	1.74	2.71	2.05	1.00	1.93	Far below average
NY	**3.05**	**4.21**	**3.63**	**3.29**	**5.00**	**2.88**	**3.72**	**5.00**	**3.94**	**Well above average**
OH	3.27	2.71	2.99	4.14	2.29	2.88	3.11	1.00	2.64	Average
OK	**1.97**	**1.76**	**1.87**	**2.43**	**1.58**	**1.00**	**1.67**	**3.00**	**2.01**	**Far below average**
OR	3.38	2.70	3.04	3.86	2.03	2.88	2.92	1.00	2.58	Average
PA	**3.70**	**2.94**	**3.32**	**3.86**	**2.38**	**3.32**	**3.19**	**1.00**	**2.80**	**Average**
RI	2.41	3.08	2.74	2.57	2.69	2.88	2.72	1.00	2.38	Below average
SC	**2.62**	**2.88**	**2.75**	**2.14**	**1.74**	**2.88**	**2.25**	**1.00**	**2.20**	**Below average**
SD	3.92	2.39	3.16	4.57	1.69	2.88	3.05	3.00	3.08	Average
TN	**2.08**	**2.19**	**2.14**	**2.86**	**2.01**	**1.28**	**2.05**	**5.00**	**2.67**	**Average**
TX	3.27	2.49	2.88	3.00	2.27	3.00	2.76	1.00	2.45	Below average
UT	**3.16**	**3.74**	**3.45**	**4.43**	**2.18**	**2.88**	**3.17**	**1.00**	**2.85**	**Average**
VA	3.27	3.93	3.60	4.00	2.78	2.88	3.22	5.00	3.73	Above average
VT	**4.03**	**3.82**	**3.92**	**N/A**	**2.93**	**2.88**	**2.91**	**1.00**	**2.93**	**Average**
WA	3.59	3.44	3.52	3.71	2.80	2.88	3.13	1.00	2.86	Average
WI	**3.59**	**4.39**	**3.99**	**4.29**	**2.29**	**2.88**	**3.15**	**1.00**	**3.06**	**Average**
WV	1.43	1.46	1.44	2.00	1.12	2.88	2.00	1.00	1.58	Far below average
WY	**3.16**	**1.96**	**2.56**	**4.00**	**1.14**	**5.00**	**3.38**	**1.00**	**2.58**	**Average**
US average	2.95	3.14	3.04	3.00	2.65	2.89	2.86	2.31	2.82	

*Best in the US (SERI = 4.82)
Well above average (3.94 < SERI < 4.06)
Above average (3.24 < SERI < 3.73)
Average (2.53 < SERI < 3.13)
Below average (2.14 < SERI < 2.47)
Far below average (1.58 < SERI < 2.01)
Worst in the US (SERI = 1.11)

overall public school system–or more accurately 14,000 systems–has shown little sign of improvement, particularly in mathematics and science." (p. 4)

Science and engineering readiness are building blocks for scientific and technical achievements which contribute to a better society. Not only do the tools, techniques, and tangible goods developed by scientists and engineers provide for more comfortable living conditions, but the economic viability of new discoveries is vital to the sustaining our place in the global marketplace. The call to improve science and engineering education has been sounded repeatedly. Our goal has been to provide a tool to enable policy makers and others to assess progress in that direction.

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Appendix: Calculating the Sub-scores

We calculated the sub-score for each indicator, $S_{(indicator,\ state)}$, in two steps.

In the first step, we calculated a ratio for the indicator for each state relative to the highest indicator:

$$R_{(indicator,\ state)} = I_{(indicator,\ state)} / I_{(indicator,\ max)}$$

For example,

$$R_{(NAEP\text{-}Math,\ MS)} = 15 / 52 = 0.288$$

where 15 is the Math NAEP Indicator for Mississippi and 52 is the maximum Math NAEP Indicator over all states.

The resulting ratios ranged from a minimum of less than 1 to a maximum of 1. We then converted these ratios, $R_{(indicator,\ state)}$, into sub-scores where were scaled to range from 1 (for the lowest state) to 5 (for the highest state) for each indicator as follows:

$$S_{(indicator,\ state)} = 1 + (R_{(indicator,\ state)} - R_{(indicator,\ min)}) / R_{(indicator,\ range)} * 4)$$

Where

$R_{(indicator,\ min)}$ is the minimum ratio for a particular indicator over all states

and

$$R_{(indicator,\ range)} = R_{(indicator,\ max)} - R_{(indicator,\ min)}$$

For the physics-taking indicator ($I_{(physics\text{-}taking,\ state)}$), we used the national average physics-taking rate for states in which the rate did not differ significantly from the national average. For states in which the physics-taking rate was significantly higher than the national average, we used the lower bound of the 95% confidence interval for physics-taking in the state. For states in which the physics-taking rate was significantly lower than the national average, we used the upper bound of the 95% confidence interval for physics-taking in the state. We used the average of two ratios ($R_{(physics\text{-}taking,\ state,\ 2005)}$ and $R_{(physics\text{-}taking,\ state,\ 2009)}$) using data from both the 2005 and 2009 surveys. We chose to use the average to account for year-to-year fluctuations in these data.

Figure 1: Percentage of Seniors Graduating from Schools by SERI Rating, 2009

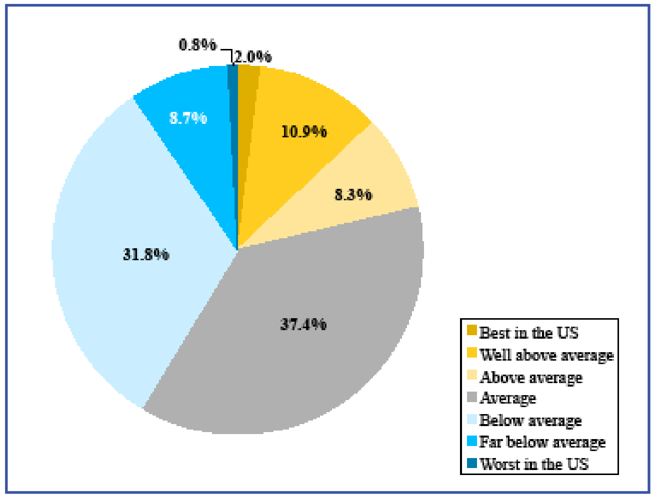
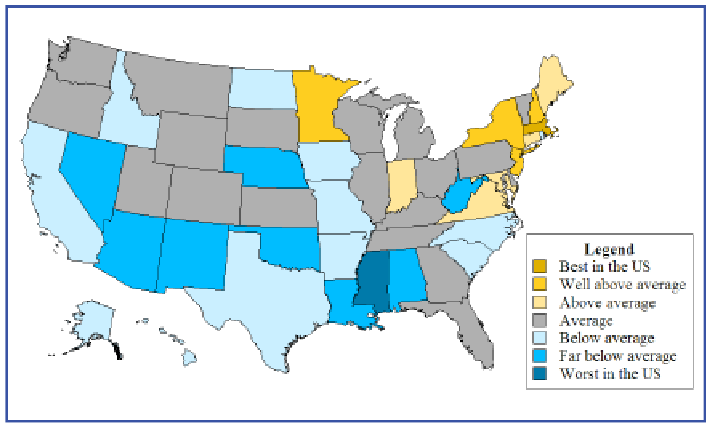


Figure 2: SERI Scores by State



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Section on Teacher Preparation

Teacher Preparation Section

John Stewart, University of Arkansas

In this issue, we focus on two of the newer collections in the ComPADRE digital library that might be of interest to working teachers and to the advisers of future teachers. ComPADRE is the National Science Digital Library (NSDL) portal for physics and astronomy education. ComPADRE has previously been featured in the *Fall 2007 Forum on Education Newsletter*. Crystal Bailey will introduce the Careers site, a site containing physics career information. As a physics adviser, one of the questions that I am most often asked is, “What kind of job can I get with a physics degree?” Wolfgang Christian, Doug Brown, and Francisco Esquembre will discuss Open Source Physics (OSP) a ComPADRE collection containing a wealth of classroom ready computer simulations and supporting materials. ComPADRE will reach the end of its current funding in August 2012. If the physics community wishes this valuable resource to continue, alternate sources of funding must be found.

The 2011 PhysTEC Conference, focusing on Building Sustainable Programs, was held May 23-24, 2011 in Austin, TX. The PhysTEC conference, formerly the PTEC conference, featured presentations by members of many of the most successful institutions in physics teacher preparation. The UTeach Conference was held immediately afterward. The PhysTEC conference features about 125 participants passionate about improving the training of physics teachers. As always, it was a wonderful affair and I strongly encourage all to attend next year’s conference. Each year it is my favorite. Materials from the conference and previous conferences will be made available at the ComPADRE collection on physics teacher preparation, ptec.org.

Physics Careers Resources

Dr. Crystal Bailey, American Physical Society

One of the biggest challenges physics educators face, given today's ever-evolving technological environment, is helping their students understand the career paths available to physics graduates. The training one receives with a physics bachelor's degree goes far beyond one particular skill set. Physics underlies all other physical sciences, and in learning how to do physics, students learn how to solve problems, design solutions, and understand the fundamental nature of the universe–in short, they learn "how to think."

It should therefore come as no surprise that physics bachelors are highly sought after in the workforce. According to the American Institute of Physics (AIP) Statistical Research Center, around 40% of graduating physics bachelors enter the workforce directly after graduation. Of these, the majority work in science-and technology-related fields in the private sector (such as engineering or computer science); a sizable portion also go into non-science fields.

Not only are physics bachelors highly employable, they are also likely to be highly paid. In 2009, AIP published data on initial starting salaries of physics bachelors, which shows graduating physics bachelors can now expect to earn higher salaries than civil and mechanical engineering , chemistry, and biology majors.

However, the range of opportunities for physics bachelors does come as a surprise to students, and also to those who advise and mentor them. In spite of the fact that only a tiny fraction of physics bachelors can reasonably expect to become physics faculty, students consistently name this career path as the "typical" track for physicists. Therefore a reliable, accurate source of information about physics careers is essential, in order to give students a clear picture of what's possible after graduation, and beyond.

The Physics Careers Resource website (http://www.careersinphysics.org) provides information about physics careers to students and those who advise and mentor students. While some resources for teachers and professors are new, much of the information has been collected from professional society and gov-

The comPADRE Careers Resource Website Home

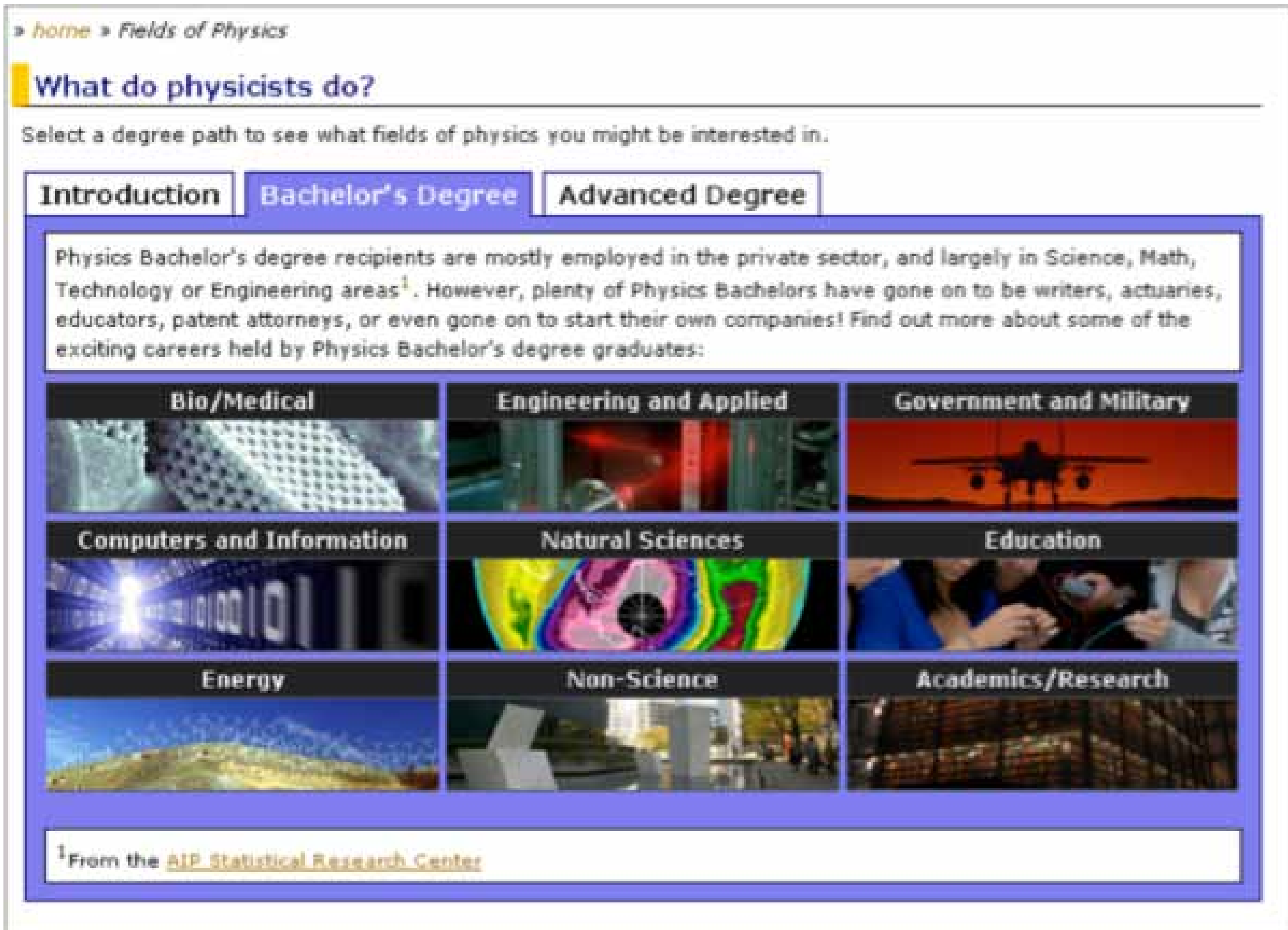
ernment resources into a single location. Wherever possible, the links to original sources are included, to enable the user to find more detailed information. The Physics Careers Resource is part of the comPADRE Digital Library, which is a partnership between APS, the American Association of Physics Teachers (AAPT), AIP, and the American Astronomical Society, and a member of the National Science Digital Library.

The website is organized in two main sections: one for audience-based information, and one for general facts and resources. The audience-based sections provide information relevant for student, educator, and parent audiences. For example, the college student section links to career resources on the APS website, APS webinars, the Society of Physics Students' comPADRE publication The Nucleus, the Graduate School Shopper, guides for marketing skills to potential employers, links to the APS Job Center, and more. Each of these sections contains information specifically tailored to each of these groups at the middle school, high school, and college levels.

In addition to the audience-based sections, there are five general information sections: Employment Facts, Physicist Profiles, Physicist Employers, Physics Institutions, and Fields of Physics. The Employment Facts section contains the latest reports and statistics on the careers of physics bachelor's degree recipients (including starting salaries, employment rates, and common employment sectors). The Physicist Employer and Physics Institution sections include interactive maps showing locations

Example of a Physicist Profile

Fields of Physics Page



that physics bachelors found employment in recent years, and also names and locations of physics degree-granting institutions within the United States.

However, the heart of the collection is the library of Physicist Profiles. The profiles represent working physicists from a variety of degree and career paths, and give information not only on the physicist's current job description, but also on how their physics training informs what they do today. In conjunction with the profile collection, the website contains a special section on the Fields of Physics, which gives a brief description of the primary employment bases for careers in physics, and describes how job descriptions change in those areas as one moves from a bachelors to an advanced degree.

The Physics Careers Resource website is one of many APS programs designed to excite and inform students about careers in physics. Physics InSight is a free, downloadable slide show which is generated bi-monthly, highlighting specific physics careers, statistical information, and current research topics. The slideshows are designed to be displayed on monitors in common areas in university science buildings, physics departments, and in high school classrooms. The slide shows are colorful and eye-catching, and always contain fresh, up-to-date content. You can find more information on Physics InSight–and download the latest slideshow–at our Physics InSight webpage.

APS has also recently launched a series of free webinars, designed to connect viewers to the expertise of individuals offering insight into physics careers, educational programs, and professional development for students, working physicists, and educators. Topics have included careers in patent law, maintaining a work/life balance as a physicist with a family, and how to become a physics teacher, among others. The webinars are currently broadcast monthly, and are archived so that registrants can view the broadcast at a later time. For a listing of upcoming webinars, or to view a previously recorded webinar, you can visit the APS Webinar homepage.[4]

Providing students with the necessary tools to solve tomorrow's problems with their physics training is an important goal for the physics community, and a crucial first step is connecting them with stimulating, relevant, and rewarding careers. Through the Physics Career Resource and other programs, APS is committed to helping achieve this goal. We invite and encourage your participation as well, by using these resources and sending us your ideas for ways to improve these important services.

Dr. Crystal Bailey is the Education and Careers Program Manager at the American Physical Society in College Park, MD. Some of her principle projects include the physics InSight slideshow, ComPADRE Physics Careers Resource website, Future of Physics Days events at annual meetings, and APS Career Fairs and job boards. She received her PhD in nuclear physics from Indiana University in 2009, and her Bachelor's degree from the University of Arkansas in 1999. While at the University of Arkansas, Crystal was a student of Gay Stewart, to whom she attributes her inspiration to become a physics major.

(Endnotes)

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3. http://careers.aps.org
4. http://www.aps.org/careers/webinars

OSP Tools and the ComPADRE OSP COLLECTION

Wolfgang Christian, Doug Brown, and Francisco Esquembre

1. Introduction

Current technologies allow physics educators the ability to combine traditional instruction with computational modeling. However, the implementation of a computational modeling pedagogy often requires a programming effort for teachers and students who want to use this approach. This paper describes a pedagogy that limits the amount of programming when designing, implementing, distributing, and using computational models. It is based on the integration of the Easy Java Simulations and the Tracker tools with the ComPADRE National Science Digital Library. Easy Java Simulations (EJS) is designed to create interactive simulations in Java (applications and applets) without the necessity of prior programming knowledge. Tracker is a video modeling tool that allows users to combine dynamical models with traditional video analysis.
Over the past dozen years the Open Source Physics (OSP) project has produced some of the most widely used interactive computer-based curricular materials for the teaching of introductory and advanced physics courses. These materials are based on Java applets called Physlets [Christian 2001] and on new OSP programs and authoring tools [Christian 2007, Gould 2007, Brown 2009].

This paper outlines the pedagogical and technical features of the OSP project and how we use OSP-based tools and resources to introduce modeling into the curriculum. We describe our current effort to create and distribute new material using the Easy Java Simulations and Tracker tools and how we distribute this curricular material with ComPADRE National Science Digital Library [OSP 2009]. The paper is organized as follows. Section II introduces the Modeling Cycle that is the basis for our pedagogy. Section III describes basic Easy Java Simulations concepts and section IV describes Tracker. The main features of ComPADRE are presented in section V and section VI presents the pedagogical benefits of this connection. Finally, section VII summarizes the improvements obtained by the use of our approach.

2. Modeling Cycle

Physics education has become an important research topic in the last few decades [Redish 2003]. The increasing interest in exploring new teaching methods in physics has its roots in: 1) the realization that interactive engagement teaching pedagogies improve learning, and 2) the desire to incorporate current technologies and current professional practice into curricula. Computational physics education has much to gain from the synthesis of these new learning pedagogies and tools [Christian 2008].

The modeling approach to teaching is a research-proven pedagogy that predates computers. It attempts to enhance student achievement through a process called the Modeling Cycle. The Modeling Cycle was pioneered by Robert Karplus [Fuller 2001] and the SCIS Project in the 1960s and 70s and later extended by the Modeling Instruction Program led by Jane Jackson and David Hestenes at Arizona State University [Jackson 2008].

The goal of modeling is to teach in a student-centered environment where students do not solve problems in a formula-centered way. The start of the modeling cycle is the development of the model by:

- Qualitative description
- Identification of variables
- Planning an experiment
- Performing the experiment
- Analysis of the experiment
- Presentation of results
- Generalization

After development, the model is employed to study a variety of new physical situations in a variety of ways to test, expand, and enrich the student-created model.

Although the Modeling Cycle can be used without computers, it is well suited for computer modeling if we replace the word “experiment” with “simulation” in the development phase. The analysis of a computer simulation is, in fact, similar to that of a laboratory and often provides the student with a novel perspective on the behavior of a system. Furthermore, the use of computers allows students to study problems that are very difficult and time consuming to study experimentally, to visualize their results, and to communicate their results with others.

The Modeling Cycle approach has been shown to correct weaknesses of traditional instruction by actively engaging students in the design of physical models that describe, explain, and predict phenomena. It is believed that the combination of computer modeling, theory, and experiment can achieve insight and understanding that cannot be achieved with only one approach.

3. Easy Java Simulations

Easy Java Simulations (EJS) is a Java-based authoring tool. EJS offers a range of possibilities that allow teachers to pick their level of student engagement. Teachers may: use/modify existing simulations for their teaching; distribute ready-to-run JAVA simu-

[1] Partial funding for this work was obtained through NSF grant DUE-0442581.
[2] Partial funding for this work was obtained through Spanish Ministry of Science projects DPI 2007-61068 and MTM2008-03679.

lations to students for visualization purposes; distribute partially constructed or flawed models that students must edit and return; or construct broad assignments for students to create models from scratch.

The architecture of EJS shown in Figure 1 is based on the model-view-control (MVC) design pattern with documentation, where a simulation is composed of:

- The computational model which implements the phenomena under study in terms of
  - ◊ Variables and parameters that describe the state of the system.
  - ◊ Algorithms, such as ODE solvers, that advance the state of the model.
  - ◊ Relations among variables, such as the conservation laws in physics.
- The *control* which defines actions that a user can perform on the simulation.
- The *view* which shows a graphical representation (either realistic or schematic) of the model and its data.
- The *description* which provides an opportunity for the author to document the model's theory, assumptions, and range of validity.

A user interface is constructed by dragging and dropping control and visualization components from a palette onto the model. While some programming knowledge is assumed, users are encouraged to focus on the computational implementation using either ODE notation within a differential equation editor or explicit Java code. For example, an Euler-Cromer time evolution of the simple pendulum can be implemented as follows:

```
double a=-g*Math.sin(theta)/L;   // compute acceleration
omega = omega + a*dt;            // advance omega
theta = theta + omega*dt;        // advance angle
t += dt;                         // advance time
```

The global dynamical variables theta, omega, and t and the global constants g, L, and dt are defined in a variables table. (See the EJS tutorial available online [Easy Java Simulations 2009] for how to use the symbolic ODE editor rather than an explicit algorithm to solve differential equations and arrays of differential equations.)

After a model is built, documented, and tested within EJS, the model (including its non-Java resources such as graphics and html description pages) is packaged for distribution into either a jar file or a zip file by clicking on a button within EJS. The resulting jar file, about 1 Mbyte for the pendulum model above, is a stand-alone Java application that does not require EJS and can run on any computer with a Java VM. The model's html documentation appears within a viewing frame and links to PDF documents within the jar

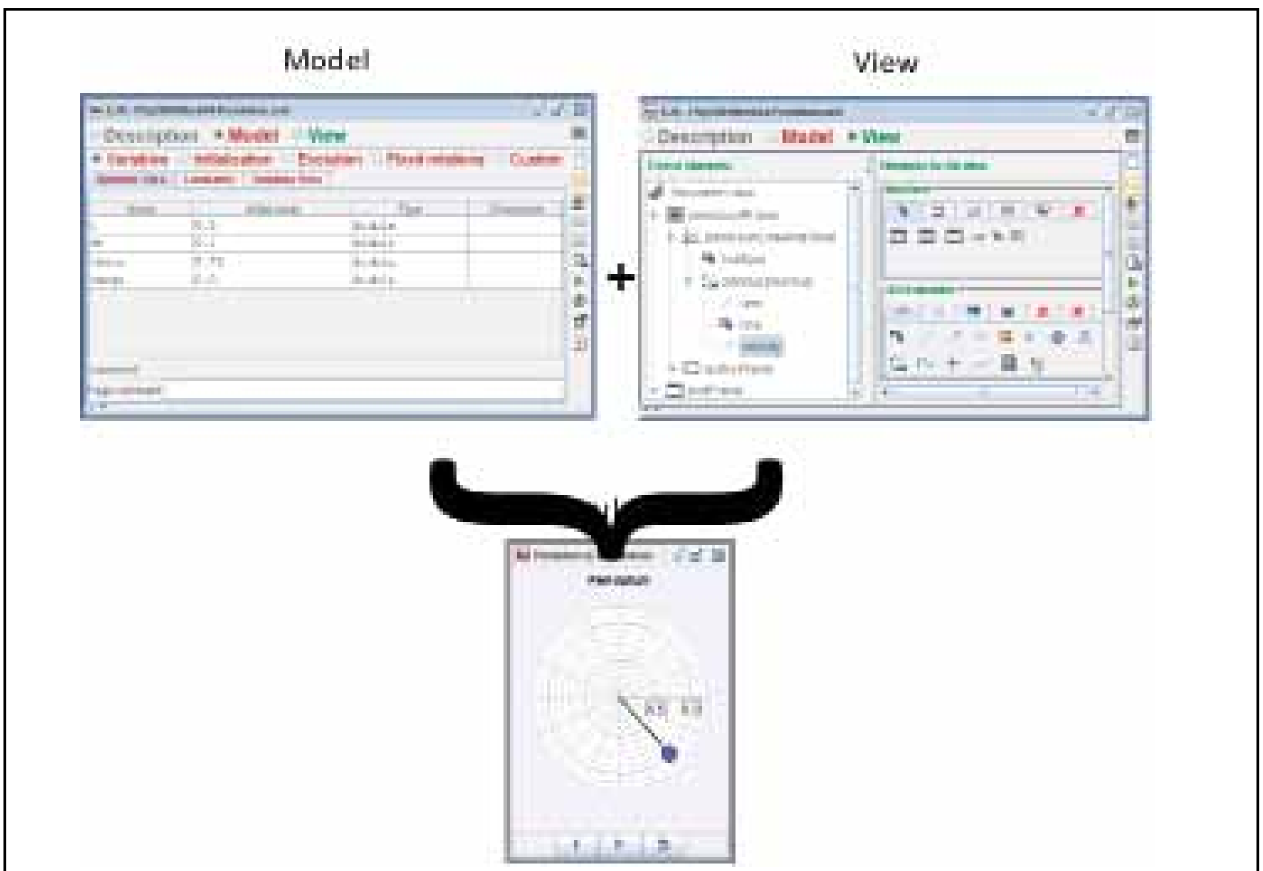

Figure 1: Steps to create a simulation in EJS

open in a native viewer. If a zip package is selected, the resulting 10 Kbyte archive contains the XML source code and other resources but must be unzipped on a computer with EJS to run.

Because an EJS XML source code file is small, the stand-alone jar file also contains this resource. The immediate availability of the code provides one of the most powerful and exciting aspects of EJS models. Unlike most compiled programs, users can examine, modify, and redistribute the model with minimal effort. Right-clicking within a running simulation displays a pop-up menu with the option to extract the XML file from the jar and to copy it into the local computer's EJS workspace. This packaging trick allows a teacher to ask students to modify a compiled model and repackage it, thereby creating a teacher-student feedback loop that supports the Modeling Cycle.

4. Tracker

The Tracker video analysis and modeling tool enables students to create dynamical models that are drawn directly on videos of real-world phenomena (Figure 2). Because the simulations and videos share the same time base and coordinate system, students can test their models experimentally by direct visual inspection, a process that is both intuitive and discerning. In effect, the videos make

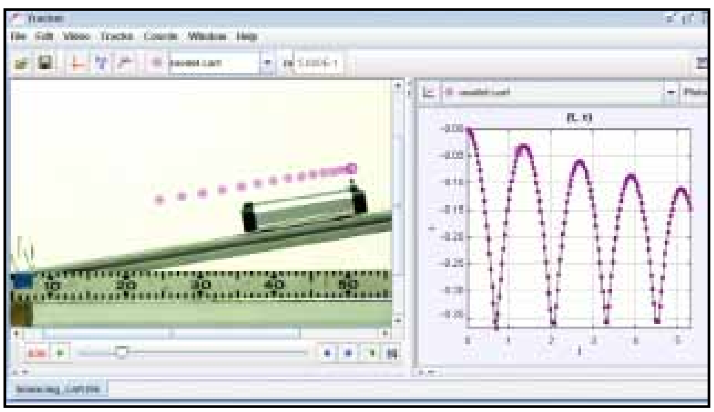

Figure 2: Tracker model of a bouncing cart overlayed on a video.

the models more "real" while the models make the videos more understandable. Additional views of model-generated data such as plots and tables are also available for analysis, and a tabbed page view enables authors to include html documentation, instructions, exercises, etc.

Tracker's "Model Builder" workpanel (Figure 3) provides a gentle introduction to dynamical modeling by making it easy to simulate a particle that obeys Newton's laws. Students define and modify the force expressions, parameter values and initial conditions, and the model particle is automatically drawn on the video. The expression parser accepts all common mathematical functions. The motion is computed with an ODE solver using a Runge-Kutta algorithm but the numerical details are hidden from students so their learning focus is on the forces and resulting behavior. Unlimited

Figure 3: Model Builder with a dynamical model of a simple projectile.

undo/redo and instant visual feedback encourage interactive exploration of models, and even small visual discrepancies can illustrate the limitations of overly simplified models or video distortions.

The process of identifying pertinent forces, defining appropriate expressions and comparing models visually by overlaying videos supports the modeling cycle paradigm in a way that is both rigorous and accessible even to students with no prior computational modeling experience and/or limited data analysis skills. But since Tracker also provides traditional video analysis functionality, more advanced students can compare models with data obtained from manual or automatic tracking of objects within videos.

If the video and html files reside on remote servers, Tracker can open a trk file locally or from the web and load all needed resources. Another packaging option is to compress the trk, video and html files into a single zip file with the same name as the trk–Tracker will open the zip file and extract all resources automatically. In this way teachers and students can create video modeling experiments from scratch or open a trk file to start with a video, instructions and potentially partial (or incorrect!) models. Completed student models can of course be saved in new trk files.

Combining the model-building power of EJS with Tracker's ability to synchronize, scale and overlay models on videos is an exciting extension of OSP computer modeling currently under development. Because the video format is so familiar to students yet contains such a wealth of spatial and temporal data, direct comparison of raw or enhanced videos with model animations is possible in many areas of physics. Such a combination supports both model development and model testing in the Modeling Cycle.

5. ComPADRE Digital Library

The ComPADRE National Science Digital Library Pathway [ComPADRE 2009] is a growing network of online collections containing educational resources supporting teachers and students in Physics and Astronomy. Each ComPADRE collection is focused on a particular community (e.g., high school teachers, physics majors, physics education researcher) or topic (e.g., quantum physics, astronomy).

Figure 4: EJS models in the OSP Collection in ComPADRE are accessible from within EJS.

The Open Source Physics (OSP) Collection within ComPADRE contains Java-based computational resources for teaching and the supporting documentation to help teachers and students take advantage of these materials. The goal of the collection is to provide curriculum resources that engage users in physics, computation, and computer modeling. The collection is built on a repository of source code, executable simulations, and curriculum resources. As with any good library, these items are annotated and cataloged so that users can find materials using standard search criteria such as subject, author, and keyword. Other library and web tools are available to the OSP Collection as a part of ComPADRE. These include personal user collections (both private and shared), comments on resources, connections between resources, and the easy incorporation of OSP and EJS pedagogical materials into all other ComPADRE collections.

The collaboration between the OSP and ComPADRE projects has resulted in a new way of sharing EJS models over the web. The EJS modeling environment can act as a client that directly accesses and downloads models in the ComPADRE library. Clicking on the web libraries icon in EJS connects to online repositories and displays a catalog of models in a table of contents as shown in Figure 4. Clicking a catalog entry shows a brief description of that model. Double-clicking either the catalog entry or the download button copies the model's XML source code and resources from the library into the local EJS workspace where it can be examined and modified.

Although the OSP Library on ComPADRE is a large central repository of resources, EJS developers have the option of sharing their materials through this same web-client interface. This will give teachers and students access to more resources and also different organizational structures for EJS models. For example, the ComPADRE models are arranged by subject while the Davidson College EJS digital library shows models arranged by course syllabus.

6. Pedagogical Benefits

EJS and Tracker models in the ComPADRE digital library with associated curricular materials have the following pedagogical benefits:

- **They help students visualize abstract concepts**. The most obvious benefit of simulations in instruction is that they help students visualize systems. In traditional instruction, students learn the concepts of physical science and physics via static pictures and words. Students construct an understanding through internal visualization, which is usually faulty for new topics and will hamper their progress toward understanding the concepts of physics.

- **They are interactive and require student control.** Students often learn to use a "plug-n-chug" approach to problem solving. When faced with end-of-the-chapter textbook problems, students quickly determine that through a process of elimination, they can find the appropriate equation to use to solve these problems without relying on the physics concepts [Maloney 1994]. In well-designed model-based simulations, physical quantities are not given and must be determined from the simulation. Since determining what information is relevant must be done early in the problem-solving process, students must conceptualize the problem before starting algebraic manipulation.

- **They are more like real-world problems**. Textbook problems are very different from real-world problems. Solving a real-world problem entails distinguishing between relevant and irrelevant information. In a model-based simulation, just as in a laboratory, students must take data that introduces and reinforces the idea that there is uncertainty in measurements and therefore results. This means that two students when faced with the same model-based simulation will end up with slightly different (correct) answers. Using simulations can therefore bridge the gap between theory and the real world [Ronen 2000].

- **They use multiple representations to depict information.** The idea that students learn best when they see the same ideas presented in different ways is not new. Traditional instruction relies on the written and spoken word and other static depictions. Simulations can not only depict motion, but they can also simultaneously depict the information in a different way via graphs and tables that change with time [Van Heuvelen 2001]. In addition, simulations can provide the opportunity to investigate numerous alternate scenarios [Zacharia 2003].

- **They are simple with limited distracting features.** Educational materials are too often developed based on technology with pedagogy as an afterthought. Only graphics, animations, or sounds that contribute to the learning process should be included in a simulation. This allows students to focus in the task without being distracted by unnecessary or overly flashy additions.

- **They can improve assessment of student understanding**. Researchers have shown that simulation-based resources can provide a superior assessment vehicle as compared to traditional paper-based questions. Dancy compared student responses to traditional conceptual exercises with responses to nearly identical simulation-based exercises. She found that, in general, the simulation-based version of the exercise was more valid for understanding whether students understood a given concept [Dancy 2002].

7. Summary

The combination of a computational physics friendly modeling and authoring tools with Internet technologies allows teachers to easily incorporate computer-based modeling into their curriculum by providing an open and extensible solution for the creation and distribution of educational software. EJS and Tracker are free because they are collaboratively built and released under the GNU GPL software license. ComPADRE has no registration costs because it is part of the National Science Digital Library project and endorsed and supported by the professional societies. Our curriculum modules are extensible, adaptable, and easily modifiable. If a model is uploaded into ComPADRE, its authorship, modifications, and use are documented and intellectually traceable.

The advantage of EJS and Tracker for physics teaching is that it forces students to separate the model into logical parts and to separate the mathematics from the visualization. Students learn the logic of modeling using loops and control structures and study algorithms used in professional practice. Students are introduced to programming concepts but user-interface coding is not required.

The Open Source Physics combination of computational physics tools and computer modeling pedagogy with a digital library provides students and teachers with new ways to understand, describe, explain, and predict physical phenomena. Despite its current focus on upper-level physics, the OSP Collection serves thousands each month. During March 2011 we served 10,000+ visitors over 5,000 simulations–an increase of 32% over March 2010 traffic. We find user loyalty is increasing as well–over 2,500 different users visited at least 8 times between January-March 2011, an 80% increase from January-March 2010 and an indication of the project's increasing visibility to educators.

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Wolfgang Christian, Francisco Esquembre, and Doug Brown have been collaborating since 2000 on the development and distribution of interactive computer based material. Wolfgang Christian is the Brown Professor of Physics and Chair of the Physics Department at Davidson College. He is a Fellow of the APS, past chair of the APS Forum on Education, and president elect of the NC Section of the AAPT. Francisco Esquembre is Associate Professor of Mathematical Analysis at the University of Murcia, Spain, and Dean of its Faculty of Mathematics. He teaches mathematical analysis and implementations numerical algorithms for the simulation of continuous and hybrid systems and he is the author of Easy Java Simulations. Doug Brown retired from Cabrillo College in 2008 where he was Instructor of Physics for 31 years and Chair of the Physics Department for 18 years. He has been an invited speaker at AAPT and APS meetings and is the developer of Tracker.

Browsing the Journals

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- Elisha Huggins has a three-part article on Special Relativity in the March, April, and May 2011 issues of *The Physics Teacher* (http://scitation.aip.org/tpt/). Also be sure to read Michael Grams's two-part discussion of whether students should be provided solutions to homework problems (and if so, from Cramster www.cramster.com or from the textbook publisher?) to help them learn physics in the April and May issues.

- I found Swendsen's article about the meaning of entropy in the April 2011 issue of the *American Journal of Physics* (http://scitation.aip.org/ajp/) to be thought provoking. I also appreciated Lewis's Letter to the Editor in the same issue that we should start reporting the range of visible light in terms of hundreds of THz rather than only in terms of hundreds of nm.

- There has been some controversy about the relative roles of gravity and of atmospheric pressure in the operation of a siphon. The May 2011 issue of *Physics Education* has some useful ideas and demonstrations related to this matter, such as what happens when there is a large air bubble in the siphon line or if the siphon tube runs into another wider diameter tube which runs into the reservoir. I also was intrigued by the demonstration on page 290 of the same issue about constructing a Faraday cage by enclosing a cell phone in a tin can sealed off with foil and punching a hole of increasing diameter in the foil until the phone rings. The journal can be accessed at http://iopscience.iop.org/journals.

- The 1 March 2011 issue of the *Latin-American Journal of Physics Education* (http://www.lajpe.org/) has a paper discussing the motion of a ball rolling on a spinning turntable. The trajectories are conic sections and are analogous to motions of charged particles in crossed electric and magnetic fields.

- The 1 May 2011 issue of the *Journal of Chemical Education* (http://pubs.acs.org/toc/jceda8/88/5) has a nice discussion of using the Metropolis algorithm in an undergraduate thermodynamics course on page 574. Successive pages in the same issue have five articles that consider phase diagrams and entropy that should also be of interest to the same audience.

- The online version of *Physics World* at http://physicsworld.com/cws/article/news/45048 has an interesting discussion of the measurement of the thermal Casimir force (due to thermal fluctuations in the electromagnetic field between two objects).

- The February 2011 issue of *Science* online has a surprising demonstration that under certain circumstances it can be easier to push a can whose top end is closed into a sand pile than an otherwise identical can open at both ends: http://news.sciencemag.org/sciencenow/2011/02/convince-your-friends-youre-a-ge.html?ref=hp&sms_ss=email&at_xt=4d59d1d02a6fc1fe%2C0.

Web Watch

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- The useful EndNote biliographic software now has a web version of its service at https://www.my-endnoteweb.com/EndNoteWeb.html.

- A successful Navy proof-of-concept demonstration of high-power lasers over a distance of miles at sea was recently reported at http://www.katu.com/news/national/119781989.html.

- A series of humorous but educational clips of physics concepts from the animated televison show “The Simpsons” are at http://www.lghs.net/ourpages/users/dburns/scienceonsimpsons/clips.html.

- Spectacular footage of optical projections onto the side of a public building in Portugal can be accessed at http://sorisomail.com/email/74120/mais-uma-projecao-3d-sensacional.html.

- A repository of photographs of the damaged Fukushima nuclear reactors is online at http://www.houseoffoust.com/fukushima/fukushima.html.

- The Annenberg Foundation has a set of 11 videos on modern physics produced at Harvard entitled “Physics for the 21st Century” that can be viewed at http://www.learner.org/resources/series213.html.

- Leo Takahashi has a useful tutorial on how to use PowerPoint to make physics animations, along with a number of examples, at http://www.personal.psu.edu/lht1/.

- Teaching about the elements? Consider amusing your students with Tom Lehrer singing the famous anthem of the periodic table at http://www.periodicvideos.com/videos/feature_elements_song.htm.

- No I don’t get any commission, but I personally found the following commercial service for transferring videotape to DVD useful: http://www.imemories.com/kodakstore/momsb/.

- The physics department at Berkeley has put up webcasts of their colloquia from the past 5 years at http://www.physics.berkeley.edu/index.php?Itemid=223&id=37&option=com_content&task=view.

- Still using the Eudora email client (as I am)? Check out its open source development in Thunderbird at https://wiki.mozilla.org/Eudora_OSE.

Physics Education Award

The Forum on Education Executive Committee would like to make FEd members aware of 2 important issues regarding the Excellence in Physics Education Award.

Excellence in Physics Education Award Funding
The Excellence in Physics Education Award needs your support! Due to financial conditions over the past few years, the award fund is generating less revenue than in the past, requiring that an additional $16K be raised to again make the fund financially stable. If you would like to make a contribution, please visit the Excellence in Physics Education Award web site:
<http://www.aps.org/units/fed/awards/education.cfm>

A contribution to the award fund is a great way to honor a teacher or mentor who has been influential in your professional training. Contributions of $100 or more to the fund will result in the APS writing a letter of recognition to your designated teacher/mentor.

Excellence in Physics Education Award Submission Deadline
The deadline to submit an application for the Excellence in Physics Education Award is Friday July 1, 2011. This award recognizes and honors a team or group of individuals (such as a collaboration), or exceptionally a single individual, who have exhibited a sustained commitment to excellence in physics education. The Excellence in Physics Education Award consists of a $5,000 monetary award, a certificate citing the achievements of the group or individual, and an allowance for travel expenses to the meeting where the award is presented. (Registration fees are waived). The awardees are invited to present a talk at that meeting. The award is given annually.

Application details are at:
<http://www.aps.org/programs/honors/awards/education.cfm>

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