InterActions

across physics and education

Premiere Issue | December 2006

Special Focus

Physics Education in the Pacific Northwest

Also:

- workshop physics
- conference for new physics and astronomy faculty
- the news on science education policy

Editor's Desk

Unified-Field Approach

Welcome to the inaugural issue of *Interactions*!

Why *Interactions*? By way of explanation allow me to use as an analogy the "unified theory." Accordingly, the mission of *Interactions* is to unify the known forces that define the science of physics and the practice of teaching. And though these forces differ significantly in strength and behavior, together they explain everything you—our readers—do as both scientists and educators.

Excuse our appearance, for we are still under construction. But the promise of our this work-in-progress is to offer in-depth analysis, relevant news, useful advice, and thoughtful opinion on the ideas, issues, and initiatives shaping physics education around the world. The vision of the magazine is of a vehicle advancing a global discussion on science literacy, curriculum reform, education research, and professional development. The ideal is to inspire advocacy for the practice and teaching of physics.

Interactions is a forum for a variety of perspectives and for showcasing a diversity of institutions and interests. All are welcome to interact, of course.

While developing the concept for the magazine, I asked the publisher, Toufic Hakim, the same question: "Why *Interactions*?" His response helped us define a philosophy of the magazine—its creed, if you will:

> Reaching far beyond one society or one caucus, *Interactions* aims to facilitate interactions across ideas, issues, and practices; across students, teachers and curricula; across schools, colleges and universities; across scientists, policymakers and the public.

I hope you find *Interactions* an invaluable resource. And I invite you to email me your creative criticisms, suggestions or story ideas to Pubs@aapt.org.

Daryl Malloy, Managing Editor

INTERACTIONS
Across Physics and Education

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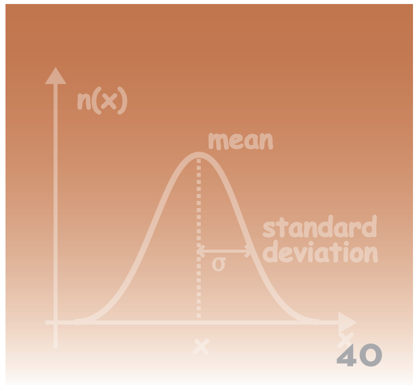


Departments

From the Publisher

Interactions among particles and fields govern the physical world as we have come to know it. It is the study of such interactions that defines the realm of physics.

Similarly, within the vast expanse of the study of physics, individuals and entities with various interests and responsibilities interact:

- Practicing physicists and their apprentices at university and industry settings with a passion for exploration and discovery
- Educators, across K-12 schools, colleges, and universities of all types, with a desire to transfer to others their knowledge of — and love for — physics, and their students who are eager to learn and ready to be fascinated
- Funding agencies of various sizes and missions, and benefactors of many backgrounds, most of whom support knowing for the sake of knowing, and believe that physics enhances our well-being as humans
- Policymakers who make critical decisions that influence research and teaching in physics and science in general
- The larger community whose members benefit directly and indirectly from innovations and advances in physics, and who through the electoral process hold the power to direct local, state, and national policies affecting research and education in physics and the other sciences.

The activities of these individuals and entities are interrelated in a complex web — physics education being the common thread linking them together. All have a stake in it. All have the capability, and hopefully the willingness, to impart momentum to physics education and to help sustain it. Research and education in physics rarely live in separate worlds. The former can only survive in the long term if new generations are attracted to it, energized, and prepared to join the ranks. Similar connections exist among politics, society, and physics education.

It is within this context that we publish *Interactions Across Physics and Education* — a magazine for physics educators and anyone interested in and responsible for physics education. We are pleased to develop it on behalf of AAPT, a national organization dedicated to advancing physics through teaching.

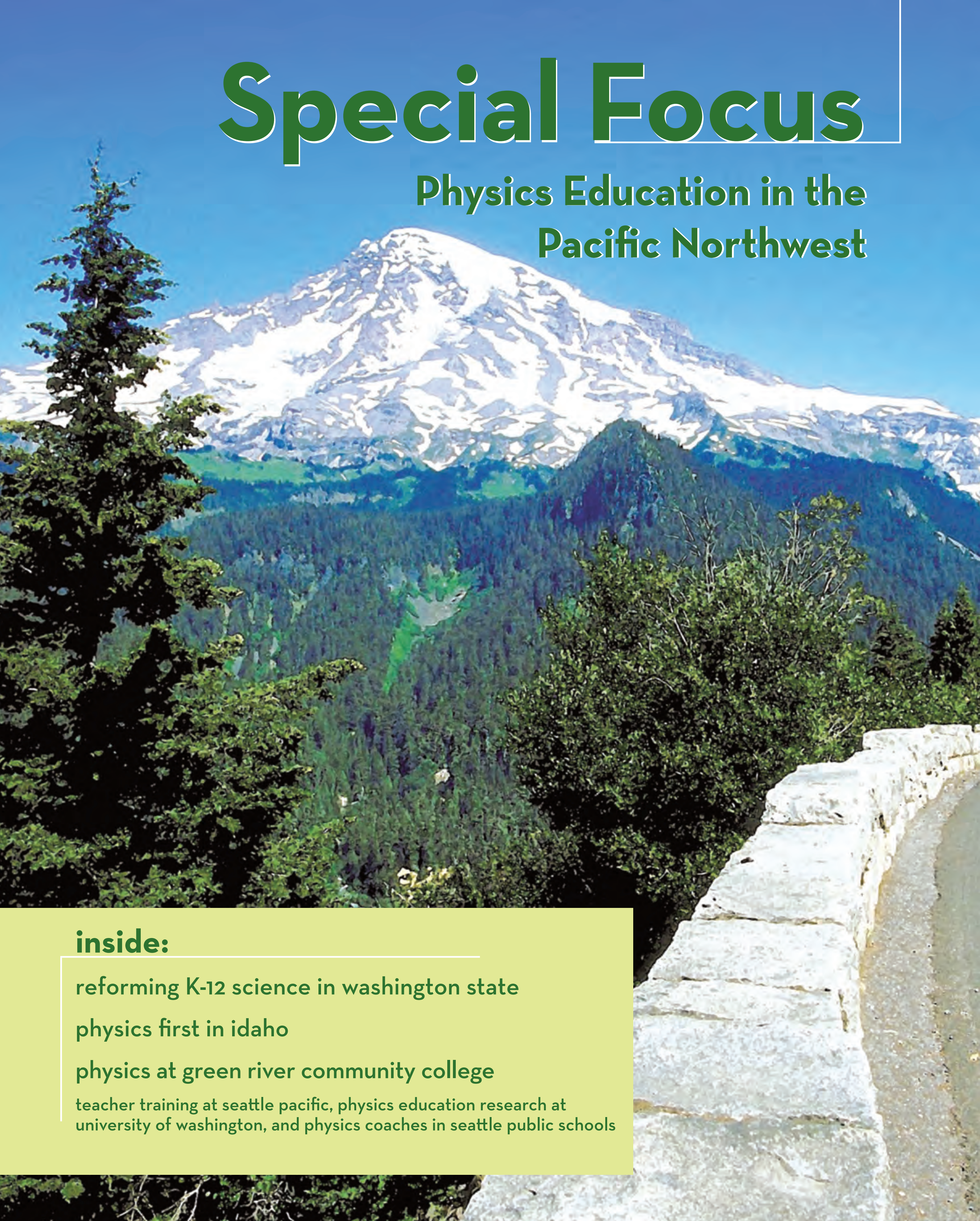
Toufic Maurice Hakim

nota bene

I was quite fortunate to be at the meeting of the Washington section of AAPT in Seattle in early November, and to interact with the physics educators in attendance. It is then that I learned about the many ambitious initiatives under way—and the high interest and energy of those driving them. Their goal seems simple and focused: To make a significant difference in the teaching and learning of physics, from the school elementary level through the undergraduate experience. So it appeared natural and fitting to share with all our readers in this inaugural issue of Interactions the collection of works on Physics Education in the Pacific Northwest, which samples ongoing efforts to advance physics education in that region.

Special Focus

Physics Education in the Pacific Northwest



inside:

reforming K-12 science in washington state

physics first in idaho

physics at green river community college

teacher training at seattle pacific, physics education research at university of washington, and physics coaches in seattle public schools

Mission: Science Education Reform and Beyond

George Nelson, astronaut turned education reformer, leads the North Cascades and Olympic Science Partnership on a quest to remake the K-12 science curriculum.

by Daryl Malloy

On the invitation of the Arkansas-Oklahoma-Kansas Section of the American Association of Physics Teachers, George "Pinky" Nelson is in a classroom standing before a group of physics teachers. On this late October afternoon, they have gathered on the campus of Emporia State University in Emporia, Kansas, to listen to the former NASA astronaut talk about science teachers and teaching.

"The majority of students — I would say about 90% — come out not knowing how to think very well, how to actually solve problems," Nelson observes about the failure of American public schools at producing scientific literate citizens. The reason many students lack a basic understanding of science concepts and methods, according to Nelson, is few teachers, particularly in grades K-5, enter the workforce prepared to teach science effectively. "The current model of producing teachers, in my opinion, does not work," Nelson contends.

"At my institution, we've been doing a long-term, informal study by looking each year at the math exams of students who want to be elementary teachers. We find about 25 percent have solid proportional reasoning skills in the sense that if you give them a story problem that involves adding or multiplying, they know which to use. Their knowledge of math and science is generally at about the middle-school level. But there's nothing wrong with these future teachers, except they've been grossly underserved by the system."

Nelson is a graduate of Harvey Mudd College with a bachelor's degree in physics, and he has a doctorate in astronomy from the University of Washington. In 1978, NASA selected Nelson as an astronaut candidate. During his career at NASA, Nelson served as a crew member aboard three space shuttle missions, including Space Shuttle Columbia in 1986—the last flight before the Challenger disaster—and aboard Discovery in 1988, the first shuttle mission following the tragedy.

Nelson left NASA in 1989, and after a stint conducting astronomical research at facilities in the United States and in Europe, he became vice provost for research and associate professor of astronomy and education at the University of Washington in Seattle. It was his experience in the classroom that led him to conclude that pedagogy, no less than intellect and motivation, influences student achievement.

Today, Nelson leads a project called the North Cascades and Olympic Science Partnership (NCOSP), which aims to reform science education for grades 3 through 10 in Washington State, by altering the depth and breadth of what K-12 science teachers know about science topics and how they are trained to teach them. NCOSP is a regional partnership involving 4 community colleges, 26 local school districts, and other education agencies. (Each partner demonstrated its commitment to the program by signing a binding agreement.) Western Washington University, where Nelson is director of the Science, Mathematics, Technology, and Education (SMATE) program, serves as “lead institution.” Through SMATE and its Woodring College of Education, Western Washington provides resources such as experienced researchers and teachers dedicated to science education. “Our goal is to produce confident and competent learners. How you become confident and competent is what you learn on the job. You don’t have to learn everything, but when you come up against something you don’t know, you should know how to learn it,” Nelson said.

In 2003 the partner school districts faced a possible crisis. Consistent with a growing national trend towards greater accountability and standards-based teaching, Washington State would require by 2008 all students to pass a science assessment before graduating from high school. At the time the districts served an ethnically diverse region in northwest Washington, comprising growing populations of Hispanic, Asian, and Eastern European immigrants, as well as students from nine American Indian reservations, according to the NCOSP NSF-grant proposal.

The principles behind the state science assessment are rooted in a vision of science education as defined by the National Science Education Standards, which calls for “dramatic changes throughout school systems” in order to improve science literacy. But the assumptions that underlie all standards-based testing also illustrate the challenges for administrators in meeting state and national expectations at odds with the demographic realities defining their student populations, not to mention the organizational constraints imposed by their teachers’ interests in and knowledge of the curriculum.

For instance, the Washington regional school districts had to consider the following:

Were the science curricula used for grades 3 through 10 appropriately aligned with state and national standards?

Were teachers properly prepared to help students learn the skills and knowledge to be tested, especially to historically underachieving and at-risk students?

What resources would be needed and how should they be allocated throughout the system to ensure effective implementation?

Nelson and his colleagues, Carolyn Landel and Scott Linneman, met with district administrators and teachers to discuss their needs, then worked with the other partners to develop a comprehensive plan to improve the science programs at each participating school and maximize student performance on the state science assessment. The plan called for a systemic reform of teacher preparation, requiring “close collaboration between the partner higher education institutions to closely align content courses, improve the preservice preparation of teachers in both science content and pedagogy, and coordinate efforts to recruit diverse science teachers,” according to the NSF proposal.

Its goals are no less ambitious than its scope. By 2008, NCOSP expects 90 percent, or 64,800 out of the school districts’ approximately 72,000 students will meet or exceed standards on the state science assessment; 1,000 teachers will complete at minimum 86 hours of professional development instruction, and 90 percent, or 1,026 out of approximately 1,140 science teachers will be teaching research-based curricula effectively.

Reform requires changes across all components of the overall system—from the instructional material used in the classroom to the college-level curriculum used to train future teachers to the administrative systems used to support the districts and their schools. Nelson offers this example to explain the challenges and the NCOSP strategy for overcoming them: “You can’t just say, Okay, I’m going to change the way physics is taught in the high school and somehow that’s going to fix K-12 education. But at the same time, improving K-12 education so that all students learn well does involve improving the way we teach high school physics. And so [NCOSP] will focus on improving high school physics in addition to reforming elementary school science instruction.”

“You can’t just say, okay, I’m going to change the way physics is taught in the high school and somehow that’s going to fix K-12 education. But at the same time, improving K-12 education so that all students learn well does involve improving the way we teach high school physics.”

Or, consider the NCOSP strategy for addressing another key area of science education reform: introductory science courses and graduation requirements for preservice students—that is, elementary and secondary education majors at higher education institutions. The aim is to develop and implement a common, standards-based undergraduate course sequence for these future teachers. Western Washington University, for instance, produces on average 500 preservice teachers annually. “We have more secondary science teachers than every other program in the state combined. And we have a large number of elementary teachers,” Nelson says.

Western Washington revised its elementary program to include five science courses taught by scientists. The students take a three-quarter sequence starting with physics, then geology, then biology. Next comes a one-quarter capstone course called Inquiry Science, which focuses on chemistry, then they take a quarter on the nature of science and on science and society. Finally the students take two pedagogy classes: a methods class and a practicum class.

Nelson points out that nearly 50 percent of preservice teachers certified through Western Washington come from and take their science courses at regional community colleges. This means the course sequences at Western must be well-aligned and ideally would be identical with the courses offered by the two-year colleges. Nelson credits the successful design and implementation of a common science sequence in all the partner schools to the flat organizational structure of NCOSP. “The group is not hierarchical. We don’t care who works for a four-year institution and who works at a community college. We’re all professionals. We’re all scientists, and we’re all interested in education.”

In addition to collaborating effectively, building a network for knowledge exchange also played a key role. For example, the year-long science sequence comprising physics, biology, and geology was built around a core set of innovative methods and materials borrowed from other education researchers. This existing knowledge base served as a template for the new curriculum. “First thing we did in developing the courses was say, We need some staff development as a group,” Nelson explains. “So we brought in Iris Weiss [president of Horizon Research, Inc.]. Her staff spent a long weekend with us, going over her research on effective teaching in the classroom.” They also brought in assessment experts to help them develop performance measurements.

The challenge was to devise an undergraduate-level science course adopted on inquiry-based teaching methods that was suitable for preservice elementary teachers. As it turned out, a suitable physics content curriculum for elementary teachers already existed. The NCOSP team adopted the physics content course on *Physics for Everyday Thinking* (formerly Physics for Elementary Teachers) or PET, as it is more popularly known. "The first thing we did was go through the PET text with a member of our physics faculty who had field tested the materials so that we could access its pedagogical aspects," Nelson says.

PET was developed at San Diego State University under the direction of Fred Goldberg, a professor of physics. The program was designed to introduce future elementary teachers to physics ideas and activities consistent with the National Science Education Standards and the Benchmark for Scientific Literacy. Goldberg and Steve Robinson at Tennessee Tech. University and Valerie Otero at the University of Colorado at Boulder, wanted to design a coherent curriculum that would foster a deeper conceptual understanding of basic physics principles.

"We used [PET] as the template for our courses. We looked around the country to see if there was anything out there that we could use, and couldn't find anything, so we had to create biology and geology materials that work very much like the physics materials we used," Nelson explains.

The PET course content is organized around "seven cycles of learning," each focusing on a specific physics principle. The students progress through each cycle—starting with the theme "Interactions and Motion" and ending with "Interactions and Conservation." Through hands-on activities, investigatory experiments, and small-group and whole-class discussions, students play the role of scientists: collecting and interpreting evidence, sharing and defending their judgments with peers, and, ultimately, allowing better alternatives to inform their own ideas.

According to Goldberg, pre-tests with post-test comparisons have consistently demonstrated the learning gains achieved with the PET curriculum. "PET may represent a curriculum that is better suited to reform-based teaching methods," Goldberg said during a telephone conversation.

The reformed-based curriculum developed by NCOSP utilizes small classes — no more than 30 students, working in groups of three. Nelson describes the teaching style in the classroom: "Students develop their ideas individually, then try to gain consensus with their group. If somebody initially says something that's incorrect, we know what they are thinking and can focus on helping them come around to the scientific idea through observation and discussion of phenomena."

He then adds: "For physicists or people like me, who are not necessarily warm and fuzzy, this method doesn't come easy, but it's really important that we work on it."

The faculty spends time in class talking about pedagogy and about the science: Why we think this way? "[The students] gain an appreciation for the reason we're teaching a certain way," Nelson says.

"You cannot produce someone who knows everything about chemistry, physics, geology, biology, and astronomy but it can be someone who is a confident, competent learner who knows some important things and is going to be capable of learning more when necessary." Δ

Putting PHYSICS First

An award-winning Idaho teacher explains why students should start their high school education with physics.

by Denise Jarrett Weeks

BOISE, Idaho—The first place Larry Neznanski ever held class was underneath Lake Superior. In the 1960's, he was in a copper mine, with the lake bed hundreds of feet above, when he found himself sharing a lunch hour with a group of seasoned electricians. They worked for the White Pine Copper Company, a massive mining and smelting operation that included its own power plant.

The industrial compound was beautiful to Neznanski's eyes. He'd just finished the undergraduate program in electrical engineering at Michigan Technological University and would be heading to graduate school at Purdue University at the end of the summer. Until then, White Pine had given him a summer job.

He remembers that a bunch of electricians who stood around eating began asking him questions. They were interested in this budding engineer, a kid really, and they struck up a conversation with him, asking about the science behind the electricity that they worked with every day.

"Guys were always asking about transistors and things, and they'd say, 'Well, we know how to use this stuff, but we don't know how it works.' So I thought, 'Well, I know how it works.' So I took out some of my texts and started putting stuff together. I'd go down there and these guys would be eating sandwiches, and I'd have my little board and I'd start teaching solid-state physics. They loved it. So I did it for a whole summer."

From Briefing Room to Classroom

After that summer, Neznanski went on to earn master's and doctoral degrees in electrical engineering from Purdue and followed that with a high-flying military career in Cold War technology. It was thrilling and demanding, the life of a suitcase jock who researched, designed, built, and monitored satellite and missile systems for the United States Air Force. But 25 years after teaching those electricians in the mine, Neznanski found himself once again using his lunch hour to teach in an unlikely place: the physics lab at Boise's Bishop Kelly High School, Idaho's only Catholic high school.

It was 1990, and it seemed he'd stepped directly from the briefing room to the classroom. Still in his 40s, Neznanski had retired that spring as an Air Force lieutenant colonel, just as the Cold War was ending. By fall, he and his family had moved from Los Angeles to Boise and he was teaching physics and math, and coaching football, at Bishop Kelly — or "BK" as it's known here.

That year, the Idaho legislature had passed a law providing an alternate route to certification for industry professionals who wanted to go into teaching. Neznanski was the first to go through the program and BK snapped up his application, willing to take a risk that this military man would be a good addition to the faculty. Neznanski launched into his second career, calling himself a "retread" and soaking up all that he could from his teaching mentor, Henry Krewer, a much-loved chemistry and physics teacher at BK.

When Krewer retired, Neznanski inherited the physics lab. In short order, his lunchtime lessons began. The room would be empty at that time of day but for a clutch of inquisitive students and "Doc Nez," as the students had dubbed him. They'd be huddled

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at the blackboard or around one of the tables, talking about optics or thermal dynamics, or probing the incongruities of electromagnetism—things not normally covered in such depth in the regular physics course. Neznanski sensed that these kids, many not necessarily academic stars, could go much farther than the basics. So, he issued an open invitation: any student who wanted to plumb the deeper mysteries of how the world works could come to Room 17 at the lunch hour.

Physics First

Today, 15 years later, Neznanski teaches physics from first to last bell. He no longer teaches math or coaches football. Instead, in addition to teaching regular physics, he parlayed that lunchtime class, which he led for four years, into a two-year Advanced Placement physics course. And he persuaded his science colleagues—not to mention the BK administration—that conceptual physics needed to be taught to freshmen before they study chemistry and biology. So, Neznanski—who was named a Micron Outstanding Science Teacher in 2003 and was selected as the American Physical Society Distinguished Physics Teacher from Idaho in 1999—now teaches three levels of high school physics, and the number of physics students has gone from 14 to 125.

> "Taking physics before and concurrently with courses in algebra, precalculus, and calculus creates a wonderful synergy between the science and the math"

Creating the conceptual physics course for ninth-graders was a radical change to the curriculum. (Freshmen are now required to take either conceptual physics or earth science.) Neznanski was midway through the 1993–1994 school year when he got the idea, and by fall he was teaching it. Credit this lightning-speed progress to willing colleagues, a private school's relative freedom to make curricular changes, and to one Paul G. Hewitt, says Neznanski.

Paul G. Hewitt is a retired physics professor whose widely used textbook, *Conceptual Physics,* promotes teaching physics to all students—not just the top achievers—and teaching it earlier. Hewitt's views validated something Neznanski knew to be true from his own experience but that is still under-recognized in education: an understanding of basic physics ideas should form the foundation for studying chemistry and biology. In fact, some say the traditional sequence of teaching first biology, then chemistry, then physics has it backward.

It's long been believed that students need advanced algebra and calculus skills to do physics, but Hewitt, as well as such prominent physicists as Leon M. Lederman—a Nobel laureate who supports the "physics first" movement—believes that the basic laws of nature can be learned with minimal mathematical foundation.

As Hewitt tells students in the opening pages of his textbook, "Physics is about the rules of nature—so beautifully elegant that it can be neatly described mathematically. That's why many physics courses are treated as applied mathematics. But introductory physics that emphasizes computation misses something essential—comprehension—a gut feeling for the concepts."

Neznanski puts it this way: "It makes little sense to teach biology, chemistry, and then physics. Biology is the most complex of the sciences; it's the study of life. And we are chemical-based life forms, so you want students to understand physics and chemistry before studying biology.

"Chemistry is essentially the study of chemical bonding, but the forces and the atomic stuff behind that are pure physics. If you understand forces, it's easier to understand why particular atoms or molecules will bond the way they do.... If you understand vectors then you understand something about forces and that they have directions, and that will help you understand chemistry."

Guy Hudson teaches chemistry at BK. Before going back to college to earn a teaching degree, he worked as a scientist with Micron Technology in Boise. He says, "What I notice is that the kids who have taken Nez's class in conceptual physics, and have done reasonably well in there, are more prepared for my class because they're used to a little more critical

What is Physics >>>FiRST?

Physics First calls for a re-sequencing of high school courses so that students study physics before chemistry and biology. There are many historical events that have led to the current common practice in the United States of teaching physics to students after they have taken biology and chemistry. While the story as to how this sequence developed is interesting, the important point is: with this sequence, only 30% of U.S. high school students take any course in physics.

The wisdom of placing physics last is being reconsidered by educators because 1) in order to understand modern molecular biology and the biochemical processes in cells, students need a solid background in both physics and chemistry, and 2) mastery of the basic physics concept of electrostatic and nuclear forces and the concept of energy storage and transfer are crucial to the understanding of chemical structures, atomic binding, gas laws, and the periodic table of the elements.

The National Science Foundation (NSF) and many other public policy groups have established the goals of promoting a science-literate citizenry and encouraging more students to consider careers in science, engineering, and mathematics. Placing physics first would expose more students (not only the current 30%) to the discipline that provides the foundation for understanding engineering concepts and provides real-world connections to mathematical concepts.

Exposing most students to physics at the appropriate time and at the most appropriate level will allow more students the opportunity to develop interests and make the choice of a profession that relies on science, engineering, or mathematics. Observations of the performance of U.S. students on tests comparing them with non-U.S. students indicate that our competitive edge may be slipping. In his book *The World Is Flat: A Brief History of the 21st Century*, Thomas Friedman adds to the cacophony of voices warning that America is in the midst of a "quiet" crisis. "We are not producing, in this country, in America, enough young people going into science, technology, and engineering—the fields that are going to be essential for entrepreneurship and innovation in the 21st century."

Furthermore, the American Association of Physics Teachers (AAPT) recognizes that the Physics First approach has the potential to provide students with a solid intellectual foundation for the study of chemistry and biology later in their high school education as well as to increase the coherency of the secondary school science curriculum. Advocacy for the change to the Physics First approach has developed out of research in physics education that has identified problems with teaching physics last in the high school science sequence.

One strong voice for changing the science sequence in U.S. high schools has been that of Leon Lederman, Nobel Laureate and former Fermilab director. Similarly, the Project ARISE (American Renaissance in Science Education) advocates a three-year, coordinated science sequence that begins with physics, then chemistry, then biology while integrating earth science and astronomy topics into these areas.

Implementation Suggestions

- Evaluate the overall philosophy of the school about science education. Do your teachers feel that it is more important to teach vocabulary, formula manipulation, and factual information, or to emphasize scientific thinking, reasoning skills, and experimental design? Get consensus among faculty and administration to support the change, especially those who will teach the class. The faculty who teach the course should believe in its merit and agree on the methods of instruction. Trying to force a ninth-grade physics course on teachers who don't believe that students will benefit from this approach will make its success that much more difficult.
- Decide whether to invert and integrate the entire introductory science sequence (biology, chemistry, and physics), require physics for all students, or put physics first and allow students to select their own sequence. Decide if the change will be an abrupt switch or a gradual one done over three or four years.
- Provide training for those who have never taught physics at the ninth-grade level. This should be structured to identify areas of both content knowledge and pedagogical approaches that are needed for the success of this approach. For any new science program to be successful, the teacher must have a positive attitude, must like teaching younger students, must know physics well, and must understand the most appropriate pedagogical approach to meet the needs of these students.
- Make presentations to parents, administration, guidance counselors and faculty to educate as to the reason for change.
- Read as much of the literature on reform initiatives as possible as you plan the curriculum. Subscribe to AAPT's Physics First listserv (www.aapt.org/Membership/listservs.cfm) and check the physics first webpage (http://members.aol.com/physicsfirst) often for updated information and links.
- Work with middle school math and science teachers to help them understand the change and solicit their help in preparing your future students.

Excerpted by permission from Physics First: An Informational Guide for Teachers, School Administrators, Scientists and the Public, *being published in early 2007, by AAPT.*

thinking. They can relate several concepts and put them together, which is really the crux of chemistry. It's a really good prep course for those kids."

Taking physics before and concurrently with courses in algebra, precalculus, and calculus creates a wonderful synergy between the science and the math, [according to] calculus teacher Wendy Dalrymple. As part of her graduate work in mathematics, she took several courses in physics, and she and Neznanski feel particularly in synch, regularly reinforcing the concepts each is teaching in their classrooms.

"The kids that have had conceptual physics and then go on to take further physics and are taking the math that goes with that … seem to have a bigger curiosity about how math works. Not to just find the number answer, but why something occurs," she says. "Especially in calculus, if I can do a physics problem and show them a method to find a number answer, and then show them the math, then we get to meld our disciplines together, and that's what works. Absolutely, it makes you a better math student to practice and have applications."

Physics for All

Not only are the kids taking physics at BK these days more diverse in their academic abilities, but also in gender. There are more girls participating than ever before. Forty-five percent of this year's entire freshman class subject, girls' participation dips as the courses get more advanced. In regular physics, 30 percent of the students are girls, and in AP physics, that number drops to about 20 percent. Neznanski has observed that girls are often more interested in pursuing advanced biology than physics, but he can point to more than a few who have pursued physics and even gone on to study engineering in college. And both boys and girls can be enthusiastic advocates for physics, and they struggle and triumph equally.

"I really don't like math and science usually," says Lilly, a freshman. "It's really not my thing. But physics is not so much a science and a math as a way of understanding … what happens [in everyday life]. So I think it's really interesting because it can be applied to almost anything. I can take this and make it more advanced into chemistry and biology and all those other more complex sciences. Physics is, I think, a really good basic building block."

Roland is also a freshman this year. He doesn't consider himself a "science whiz" like his older brother, so he was surprised to find just how much fun physics could be in Doc Nez's class.

"When I came here I just got the crap kicked out of me. I mean, I did horrible at first, but once Doc kind of started to explain it, it got a lot easier. I like it a lot. I think it's really fun. He makes it so that something you see everyday, he compares it to that. Like we're doing atoms right now [and] he's kind of comparing it to planets and stuff like that. So it makes it a lot easier."

One thing's for sure, these students are beginning to see their world very differently. "Everything else in life used to be simple," says freshman Laura. "Everything's more complicated now because he just makes me think more."

Peter, an upperclassman, agrees, and tells an anecdote that sends him and his classmates into fits of laughter: "Rachel and I went to see the Nutcracker and for the first half of the ballet they were doing their dances, and I was thinking, 'OK, the center of mass is over their footprint. Their dresses are coming up because of differences in pressure—Bernoulli's Principle.' She leans over and says, `Hey Peter, look: rotational inertia.' Yep, I been thinking of that the entire play!' Three years of physics ruins ballet, watch out!"

Science Olympiad

By turning the "regular kid" on to physics, Neznanski has helped to generate a lot of excitement about science in this school of some 600 students. About 45 students compete every year in the Science Olympiad, and five teachers and some steadfast parents devote considerable time to coaching and traveling with them to competitions. Neznanski started the program at BK 11 years ago, and BK students have won the state competition nearly every year. When they make it to the national competition, they are frequent medalists and they were awarded the Spirit Trophy in 2002. Last year, the BK team brought home four national medals.

While some schools that participate in the Science Olympiad recruit only the kids with high SAT scores, he says, "They're missing the kids in the middle, and they're the ones who need it the most. What I was looking for was something that an average kid could do that would turn them on to science. I'm not looking for your top students only. I don't care if a student is a hellion or has D's. I just want someone who's interested. They may not get A's, but they won't quit once they see they belong somewhere."

He continues: "The thing that makes a great scientist is single-minded, total persistence and incredible dedication to work. Being able to do that hard work and do good science over many, many years and stay with it is not necessarily creative. It's creative in a sense but it's just hard scientific work and it pays off."

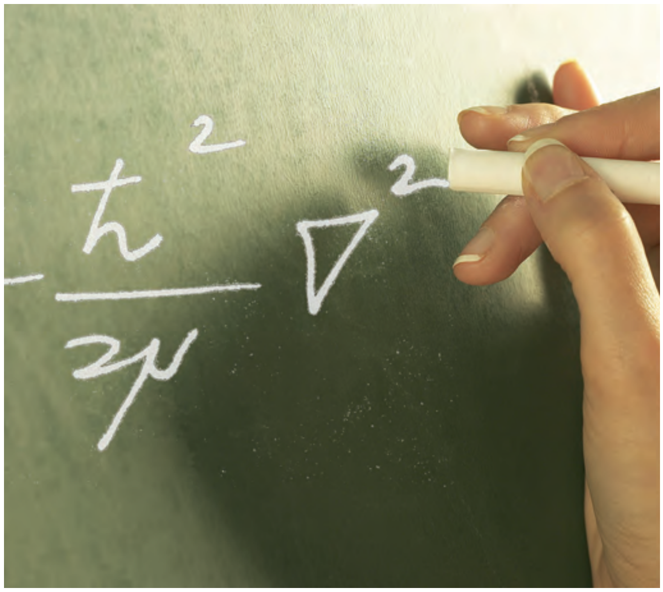
He points to several models of towers and boomilevers made out of balsa wood that sit on a top shelf in his classroom. They are lovely to look at, these designs of simple engineering. The objective in the tower-building competition in Science Olympiad is to build the lightest tower with the most structural efficiency that can support a load of up to 15 kilograms—about 33 pounds. These designs won high marks in the competition last year.

"Being an engineer, I can spot these kids, the kid who will take something like that and focus on it and never quit. Some of the projects have hundreds of hours put into them."

"Retreads"

Moving from a professional science career into teaching isn't a piece of cake, but it does have its advantages. Twenty-five years of experience with military bureaucracy taught Neznanski how to write terrific proposals, and he's turned that knack into successful grant writing. When he set out to find funds to build up the physics lab, "I shot for the sky," he says. His aim was true. The lab now is equipped with $80,000 worth of equipment—computers, software, probes, gauges, calculators, you name it—thanks to the likes of Hewlett-Packard, the Wiegand Foundation, and the BK Booster Club. But the best knack Neznanski brought with him into the classroom was an innate talent for teaching young people, says former mentor Henry Krewer.

"A lot of teachers want to do a job and they want to walk out feeling good, forgetting how the kids walk out: they walk out baffled; they walk out upset. If you feel like, 'Oh, I did a great presentation; that was clever and that was wonderful,' the kids don't know anything about that. Larry was the other way. Larry wanted to know that every kid in the room knew what he was talking about. I think that was the biggest gift he gave to the kids."



And the best way he's found to teach is to relate physics ideas to the real and sometimes exciting world of work, where such things as repositioning a satellite in space are apt to capture the imaginations of young minds.

"That's one of the reasons why I think that 'retreads' are worthwhile," he says. "There is an element that you can bring into the classroom that's important, and that is what's going on outside [school] that students might want to do someday." That interest may play out for a lifetime. "I think that's where a lot of the motivation comes from. If you can get a kid to do something in science that they never thought they could do ... those are life forces that are so valuable that you can't quantify them." Δ

Share Your Opinion

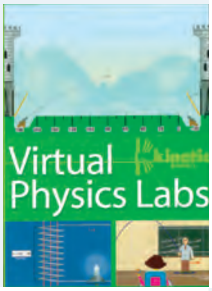
This article does not necessarily represent the views of this magazine. The mission of *Interactions* is to foster an open discussion on any issue of particular interest to the physics education community. That means representing all points of view.

If your observations, insights, and judgements on the Physics First, differ from those reflected here, we welcome your feedback.

Send comments to: interactions@aapt.org.

Products of Interest to Physics Educators

Kinetic Books' *Virtual Physics Labs* (NVT-11).
This DVD contains virtual labs covering topics ranging from one-dimensional motion to special relativity, and will augment any physics teacher's toolkit. Contains 16 virtual labs, each one taking 45 to 60 minutes to complete.
Produced by Kinetic Books.



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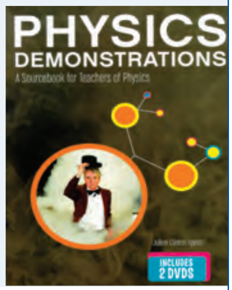
***Physics Demonstrations: A Sourcebook for Teachers of Physics* (NB-47).**
Julien Clinton Sprott shares demonstrations from his popular lecture series, "The Wonders of Physics." Organized to teach the six major areas of classical physics—motion, heat, sound, electricity, magnetism, and light.
Published by Univ. of Wisconsin Press. (290 pp.) hardcover
ISBN: 0-299-21580-6



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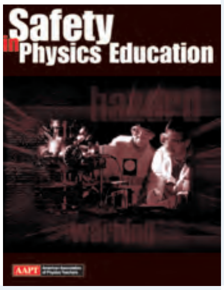
Safety in Physics Education (OP-67)
Edited by the AAPT Committee on Apparatus.
Safety in Physics Education is intended to create an awareness of safety, to encourage safe habits, and to teach respect for potential safety hazards. It can be used across the spectrum of experimental and demonstration activities —from elementary to advanced undergraduate laboratories. (121 pp.)
ISBN 1-931024-01-4



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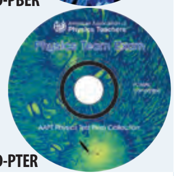
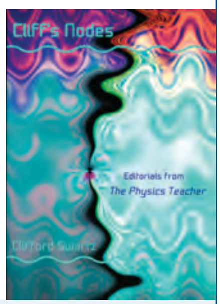


CD-PTER

***Cliff's Nodes: Editorials from The Physics Teacher* (NB-46)**
From the pages of *The Physics Teacher* comes a collection of editorials by its longtime editor, Cliff Swartz, a passionate advocate of better physics teaching, based on a curriculum that is quantitative and includes experiments "with a purpose." Published by Johns Hopkins University Press. (338 pp.)
ISBN: 0-8018-8307-5



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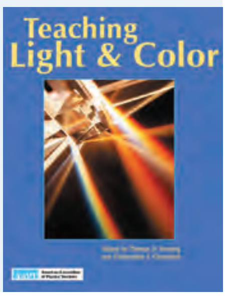
***Teaching Light & Color* (RB-74)**
Edited by Thomas D. Rossing and Christopher J. Chiaverina, this collection of scientific papers, articles, and brief excerpts from books is intended to provide teachers with source material for teaching light and color. It also contains references to some 281 books, papers and websites.
(250 pp.)
ISBN 1-931024-02-2



Members: $15
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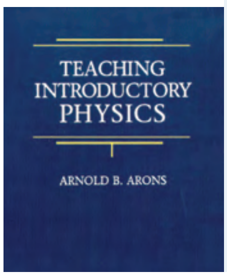
***Teaching Introductory Physics* (NB-23)**
Written by Arnold B. Arons, this guide to teaching introductory physics, from high school to calculus-based college courses, presents systematic observations based upon research into how students learn and reason. Includes many test questions and homework problems. Published by John Wiley & Sons, Inc. (816 pp.) paperback
ISBN 0-471-13707-3



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Cityscape of downtown Seattle

The Emerald City

Dubbed "the Emerald City," Seattle is much more than rain and coffee. Surrounded by lakes, rivers, Puget Sound, and mountains, Seattle is definitely a recreation enthusiast's dream. The greater Seattle area is home to 2.8 million people. Microsoft, Nordstrom and Starbucks are based here. Seattle is also known as the birthplace of the crazes for grunge rock and espresso coffee.

History

Seattle celebrated its 150th anniversary in November of 2001. It was in November of 1851 that the Denny Party landed on the beach at what is now West Seattle and named their new home New York Alki, using an Indian word meaning "by and by." Later, the village became Seattle, which eventually became a regional metropolis.

Leading up to the city's establishment, explorers Lewis and Clark completed their trek across the continent and arrived at the Pacific Ocean on November 15, 1805. About 40 years afterward, the Oregon Territory was created, driving settlement of the Northwest. After a long, grueling trek over the Oregon Trail, the Denny Party sailed to Puget Sound from Portland and landed near Alki Point on a wet and dreary November 13, 1851. Their first winter was harsh, but they survived with assistance from the Duwamish and Suquamish tribes. In the spring, the settlers relocated across Elliott Bay, and built a village.

In 1852, David "Doc " Maynard arrived and is credited with naming the village after his friend Chief Sealth, leader of the Duwamish and Suquamish tribes. In 1853, the Oregon Territory was carved up to create the Washington Territory, which became a state on November 11, 1889.

In January 1856, the settlers and local Indians started the "Battle of Seattle." Indians, upset at efforts to relocate them, attacked and were routed by the settlers.

Following are some key milestones:

December. 2, 1869: Seattle incorporates itself.

June 6, 1889: The Great Seattle Fire leaves more than 25 blocks of downtown Seattle in smoldering ruins. But there were no confirmed deaths.

July 17, 1897: The steamship Portland docks in Seattle loaded with gold, igniting the Klondike Gold Rush. Business generated by supplying prospectors brings great gains in wealth and population to the city.

1901: The Wallin and Nordstrom shoe store, the forerunner of retail giant Nordstrom, opens.

November 15, 1906: A major inundation occurs in South King County when a monsoon — combined with some farmers' amateur river engineering — drowns the region. Annual flooding in the White River Valley leads to the creation both Mud Mountain and Howard A. Hanson dams.

1919: Eddie Bauer begins doing business in Seattle.

April 21, 1942: Japanese Americans are ordered to evacuate Seattle. More than 12,000 U.S. citizens of Japanese ancestry from King County are held in inland "relocation centers" during World War II.

April 21, 1962: The World's Fair opens, leaving as part of its legacy the Space Needle, Monorail and many of Seattle Center's buildings.

April 1971: Starbucks opens its first cafe.

April 4, 1975: Micro-Soft (the hyphen was removed in 1976), the software giant, is founded by Bill Gates and Paul Allen. In 1978, Microsoft moves from Albuquerque to Bellevue, Wash., bringing jobs and wealth to the Seattle area.

Sept. 15, 1983: The first Costco discount warehouse opens on Fourth Avenue South.

Earthquakes
April 13, 1949: A 7.1-magnitude earthquake kills seven in Seattle. The quake only lasts 20 seconds, but repairs go on for years.

April 29, 1965: An earthquake, which registers between 6.5 and 7 on the Richter scale, kills eight people from falling debris or heart attacks.

Source: http://seattletimes.nwsource.com/news/local/seattle_history/articles/timeline.html

Washington State Convention and Trade Center

Attractions

Seattle Center
The 1962 World's Fair, also known as the "Century 21 Exposition," brought in nearly 10 million visitors from around the world for a glimpse of tomorrow, Seattle-style. What remains of the exhibition halls, arenas, and public spaces is now called the Seattle Center. It includes the famous Space Needle, which is a must-see. Journey skyward for amazing views, fine dining and an experience you'll never forget. At a height of 605', the Space Needle boasts fabulous 360-degree views that include Mt. Rainier, Puget Sound, the Olympic and Cascade Mountains, the beautiful city of Seattle, and beyond.

Pacific Science Center
Located in Seattle Center, the center is hosting a special exhibit on the Dead Sea Scrolls until Jan. 7, 2007. Also, find dinosaurs, local water exhibits, and Imax movies.

Pioneer Square
The cultural heartbeat of the Pacific Northwest, Pioneer Square features more than 20 city blocks of Victorian Romanesque architecture, fine art galleries, shops, and is the entertainment epicenter of Seattle's nightlife. Hungry? Your tastebuds will thank you for exploring the rich flavors of the district's many restaurants and coffee houses.

Whether you're searching for Seattle's history, a neighborhood business directory, a map of the Square, or information about our special events. You'll find it all on PioneerSquare.org.

Myrtle Edwards Park
Located in downtown Seattle, this park has a 1.25-mile winding bike and pedestrian path along Elliott Bay, fantastic views of the Olympics Mountains, Mount Rainier, and Puget Sound, easy access from downtown and easy connection to bike paths to Magnolia.

Seattle Aquarium
Located at Pier 59 on the waterfront, the aquarium offers special exhibits specific to Puget Sound and the waters around Seattle.

Arrive at the aquarium for feeding times—to find a list of the different times go to http://www.seattleaquarium.org/exhibits/feeding/

Tour the city
Ducks of Seattle: Amphibious World War II vehicles will show you Seattle from both land and water.

Double-decker Buses: Tour Seattle at your own pace with Hop-On/Hop-Off Double-decker buses.

Dining

You can find an abundance of culinary styles, including seafood and sushi, of course :
http://www.seattleweekly.com/food/restaurants/

Weather

In the winter, temperatures rarely fall below freezing near sea level in the city of Seattle -- the city may see two or three light snow days per year. The best way to prepare for visiting Seattle is to layer -- the climate, with the hilly terrain's "convergence zones," is unpredictable. Seattle has a milder climate than many other parts of the world, with fewer extremes in temperature, and a higher number of cloudy days with misty and damp weather.

Transportation

Many Seattle visitors arrive by plane at the Seattle-Tacoma International Airport (SeaTac). The municipal corporation that runs SeaTac Airport is called the Port of Seattle. There are many shuttle buses that can take you to Seattle and elsewhere in the region, or you can rent a car.

SYMPOSIUM on Physics Education

overcoming gravity

The Critical Force of Physics Education in Boosting National Competitiveness

At the AAPT-AAS Joint Meeting • January 10, 2007

Leaders in business, government, physics, and science education at the school and college levels will address a number of pertinent questions at the symposium:

- **Why do we need a strong workforce in science and engineering?**
- **What should be the role of physics education in developing this workforce?**
- **Are recent increases in the numbers of students in physics a supportive trend?**
- **What sorts of local action and new thinking are needed to sustain this trend?**

A brighter economic future depends on an energized workforce in science and engineering. The National Academies' 2005 report, *Rising Above the Gathering Storm*, and the 2006 workforce benchmarks developed by the Task Force on the Future of American Innovation support this observation and make recommendations for attracting the best talent from America and around the world into the sciences and engineering. These reports are influencing major public discussions and decisions on national competitiveness, and are calling the physics community to coordinated action.

Invited Speakers

Governor Chris Gregoire, Washington
Jeanne Narum, Director, Project Kaleidoscope; Moderator
Shirley Ann Jackson, President of Rensselaer Polytechnic Institute
Rick Rashid, Vice President for Research, Microsoft
Michael Neuschatz, Senior Research Associate, American Institute of Physics
Kenneth Krane, Professor of Physics, Oregon State University
Arthur Bienenstock, Professor of Materials Science, Engineering and Applied Physics, Stanford University
Michael Bennett, Executive Director, Astronomical Society of the Pacific

For more information about the program and speakers, and for passes to the Symposium, please visit (http://www.aapt.org/Events/symposium.cfm)
Overcoming Gravity is sponsored in part by the M.J. Murdock Charitable Trust (http://www.murdock-trust.org/).
The symposium is organized by the American Association of Physics Teachers (AAPT).

FEATURED SPEAKERS

Award Lecturers


Alex Filippenko

Richtmyer Memorial Lecture
Evidence from Type Ia Supernovae for an Accelerating Universe and Dark Matter

Alex Filippenko, University of California, Berkeley, CA

Melba Newell Phillips Memorial Award Presentation

Clifford Swartz, Stony Brook University, Stony Brook, NY


Clifford Swartz


Carl Wieman

Oersted Award Lecture
Interactive Simulations for Teaching Physics: What Works, What Doesn't, and Why

Carl Wieman, University of Colorado, Boulder, CO
Nobel Laureate – 2001

Plenary Speakers


Kathryn Thornton

Plenary Session I
Space Flight: A HumanPerspective

Kathryn Thornton, Former Astronaut

Plenary Session II
The Coming Revolutions in Particle Physics

Chris Quigg, Fermi National Accelerator Laboratory


Chris Quigg

q&A

... with Professor Clay

Keith Clay reveals Green River Community College's recipe for first-rate physics teaching at a two-year college

Interview by Daryl Malloy

Keith Clay
Green River Community College

Tell us about Green River's Physics Department.

The full-time faculty now consists of Ajay Narayanan, Chitra Solomonson, and me. We typically have three or four adjuncts faculty on staff as well as a full time laboratory technician name Brett Carroll. A major development, made possible through Ajay Narayanan's enthusiasm, is the spectacular growth of our Society of Physics Students chapter over the past four years. The group meets every other week to share food, camaraderie, and physics experiments. While most of the membership comes from the ranks of our calculus-based physics class, the current president is an extremely enthusiastic student from our liberal arts physics class. The SPS chapter has been honored for excellence by the national SPS society as well as Green River's student programs office.

Another development is the continuing evolution of Project TEACH, our math-and-science-learning teacher preparation program. What started as an idea of Marv Nelson [Long-time GRCC faculty member, now retired. In 1999, named Outstanding Undergraduate Physics Instructor in the United States.] and Stephen Kinholt [presently, an instuctor in GRCC's Math Division], grew into an National Science Foundation [NSF] funded project with statewide responsibilities called the Center of Excellence for Careers in Education. Let me put this in perspective. When we applied for our first NSF grant for Project TEACH, we were told that we must have misunderstood. Two-year colleges do not train teachers. We feigned deafness and reapplied, prompting the NSF to give us a much smaller grant, less rope lest we hang ourselves. When that grant was evaluated the conclusion was that we had accomplished more with our small grant than some universities had done with much more money. [Additional] grants followed, from NSF, FIPSE, Boeing, Washington State, and elsewhere. Recently, Project TEACH geologist Bob Filson was awarded an NSF research grant to study whether completing Project TEACH courses influences the style of teaching of [preservice students] when they get their own classroom. This research

Matt Payne

is ongoing, but, in about eight years we have moved from "two-year colleges don't train teachers" to "two-year colleges get grants to do research on the training of teachers."

What have been some of the key factors in building a successful physics program?

A key factor has been the emphasis on teaching by inquiry. At a small college we have the flexibility to teach how we want and to modify our teaching with every class if need be. Should a given class have exceptional trouble with conservation of energy, we can spend more time on that topic. Part of that flexibility comes from eliminating the distinction between lecture and lab sessions. All classes meet in the laboratories and all classes are ninety minutes long. If in the course of working through an example the students seem particularly unwilling to believe Newton's third law, the equipment required for them to test their ideas are only minutes away. "Labs" can be created and carried out in the middle of a class session. This environment helps to break down the idea that all knowledge comes from the instructor in front of the room.

One aspect that has been both a challenge and a key to our success is the support we have received from our administration. Whether amused or bemused by our odd way of doing things, our administrators have recognized that something good was going on in our classrooms and they have honored it and they deserve the credit for that. We are pretty lucky to have administrators who appreciate what we do. Another challenge has been the body of work involved with keeping quality high. Teaching by inquiry is more work than teaching by lecture. Fortunately the same innovation that creates additional work also keeps us fresh and involved with our classes. Teaching the way we do will never be easy, but I don't think any of us would be satisfied if it was.

Green River is acclaimed for developing future K-12 science teachers. Why is teacher training important?

The short answer is that I have two kids in public school. I've seen the difficulties faced by teachers struggling to teach subjects for which they are poorly trained. My own work in local school districts agrees with studies done by local universities estimating that roughly two out of three elementary school teachers are unable to do simple proportional reasoning. Nevertheless, the new Washington State standards appropriately require our elementary students to learn about density, pressure, heat, temperature, and Newton's laws. At some point we have to quit blaming the quality of our students on the teachers that came before us. If we could each give our local districts a handful of elementary teachers that are trained in these subjects every year then maybe someday we could see the quality of our incoming students improve as well.

Why do you prefer the inquiry method over traditional lecture?

My first year of full time college teaching was at Pacific Lutheran University. At the end of the year two students came to my office to thank me for the class. They were pretty good A-minus students but as we chatted I heard more and more errors and misconceptions in their thinking. Instead, what I saw was that these students had constructed superb mental highways that allowed them to move through the problems in the back of the text, but there were gaping chasms beneath the pavement. These highways were going to crumble at the first sign of a storm and I had done very little to prepare these students for that. Then I came to Green River, where I met Marv Nelson and learned that one could do inquiry exercises every day.

We had accomplished more with our small grant than some universities had done with much more money.

Many students object at first since inquiry requires work on their part as well, but most come to enjoy it in time. My experience has been that all students benefit. The weaker students are able to fill in holes at their own rate, rather than getting left behind in a lecture designed for somebody else.

Would you agree that the typical two-year college lacks the resources to effectively teach inquiry-based physics?

I disagree completely. Most two-year colleges are small enough and flexible enough that they can quickly change curricula and adapt to their students. GRCC would not have the program it has today if we had to get a hundred or even a dozen physics faculty to agree to every change we have made. Class sizes are also usually smaller at community colleges than at local universities. Even the private liberal arts colleges in our area have seen the sizes of their introductory classes creep up in recent years. Because we "don't have the resources" to do that, it simply isn't a problem for us. We can add new sections if we can find available time slots during the day, but we keep our individual classes small, so any class session can feature inquiry exercises with individual attention from the instructor.

How would you explain your success in attracting women and minorities to physics?

Although we have been mystified by this ourselves at times, two things have come up over the years. One is the popularity of Physics 101 and Interdisciplinary Science class. Both classes are entirely inquiry-based. There is no textbook. Students work in groups to perform physics experiments and learn from the results. They discuss their results with each other first, smoothing out the roughest edges before they ever consult an instructor. I think this environment is much more comfortable and less threatening for students who may have grown up thinking they aren't very good at science. As for the other classes I can only point to the use of inquiry and group work in those classes as well. Although our other classes do involve lecture and are not entirely derived from inquiry, the use of group discussion and inquiry probably still eases the transition for some "non-traditional" students.

... this environment is much more comfortable and less threatening for students who may have grown up thinking they aren't very good at science.

What inspired you to become a teacher of physics?

Long story ... my wife and I were pre-meds. I took my first physics course in college because I wanted to be a physician. When the woman that was then my girlfriend expressed an interest in the Peace Corps, we got married and went to Kenya where we taught math and science. As expatriates in another culture, we hungered for stuff that reminded us of home. As a couple of science geeks, that meant the kind of intellectual stimulation that we were used to in college. Fortunately, there are merchants in Nairobi that grab magazines abandoned on airplanes and sell them on the streets. Whenever we went to Nairobi we bought every issue of Science and Scientific American we could find.

One night back at our school I lamented that I read the articles about medicine because I thought I should, but I read the articles about physics because I wanted to. My wife said, "You could be a physicist, you know." The thought had never occurred to me before.

About eight years later I was finishing up my dissertation at the UW. I was offered a pretty attractive post-doc position and a temporary teaching job at Pacific Lutheran University [PLU]. I followed my heart. The job at GRCC came along a year later and although some faculty at PLU looked scornful at the idea of working at a community college, they quickly changed their tune when they heard it was Green River and that I would be working with some guy named Marv Nelson. Δ

action reaction

Texas Requires More Math and Science to Graduate

On November 17, 2006, the Texas State Board of Education approved a science education reform measure by increasing the number of math and science courses required for graduation. Students entering the ninth grade in 2007 must take four math and science courses to earn a diploma under two college readiness graduation plans.

Currently, the graduation plans known as the Recommended High School Graduation Program and the Distinguished Achievement Program requires four credits of English and social studies, but only three math and science credits. The State Board of Education, however, chose not to change the Minimum Graduation Program, which requires students to earn at least three credits of math and two of science.

The state board implemented the new math and science standards in response to House Bill 1 (HB1), the education finance and reform law passed by the 79th Texas Legislature and signed by the governor in May 2006. HB1 includes provisions that focus on science and technology instruction, in general, and requires the State Board of Education to "implement programs that give students the opportunity for academically rigorous course work in math and science at the high school level," in particular.

Under the current plan, students must earn at least one credit of biology , with two credits coming from chemistry or physics or from a course called Integrated Physics and Chemistry. Hence, it is possible to avoid physics by earning the required three science credits in biology, chemistry, and advanced (AP) biology. (Starting in 2012, Integrated Physics and Chemistry will no longer be a course option for students graduating under the Recommended or Distinguished Achievement programs.) Under the new graduation plan, known as "four-by-four," students can still avoid physics by taking, for instance, biology, chemistry, "Principles of Technology," and Environmental Systems. The board voted to adopt a proposal to add Principles of Technology as a course option for which students can earn physics credit. ∆

Task Force Urges More Federal Support for Math and Science Education

America's future scientists and engineers may be today's math and science students, but they are not getting the support and preparation they need to become the global leaders of tomorrow, according to a report released in November 2006.

The 40-page report by the Task Force on the Future of American Innovation looks at the latest key indicators and concludes the United States invests too little in basic science research and education and risks losing its technological advantage global competitors. "The benchmarks help us see how inadequate investment has helped set in motion an erosion of American leadership in science, in turn jeopardizing the foundation upon which our future economic and national security will be built," the report states.

According to "Measuring the Moment: Innovation, National Security, and Economic Competitiveness," total federal spending on research and development was $130 billion in fiscal year 2005, of which merely seven percent, or $9.5 billion represented investment in university-based research in physics, chemistry, astronomy, as well as the NSF-defined categories such as environmental sciences, mathematics, and computer science. "As a share of GDP, the U.S. federal investment in both physical sciences and engineering research has dropped by half since 1970," the report notes.

Moreover, the proportion of students obtaining an undergraduate degree in one of the science, technology, engineering, and mathematics field fell from 32 percent to 27 percent between 1995 and 2004, even though college enrollment increased during the same period. The United States lag most developed countries in math and science literacy among 15-year-old students.

The report is the second of two "Benchmarks of Our Innovation Future," white papers produced by the task force. The first report, entitled "The Knowledge Economy: Is the United States Losing Its Competitive Edge?" was issued in 2005. The Task Force on the Future of American Innovation is a coalition of businesses, scientific institutions, and universities. ∆

THE "GATHERING STORM" AGENDA

**Under consideration in the United States House of Representatives and Senate is a series of legislative bills that have been inspired by the need for a better prepared science and engineering workforce and will have an impact on education in physics and the sciences, and on science teacher preparation.
Among them:**

BILL	SUMMARY
S.2198 Protecting America's Competitive Edge	To ensure the United States successfully competes in the 21st century global economy.
S.2109 National Innovation Act 2005	To promote a national innovation initiative.
H.R.4334 10 Thousand Teachers, 10 Million Minds: Science and Math Scholarship Act	To authorize science scholarships for education, mathematics, and science teachers.
H.R.4596 Sowing the Seeds Through Science and Engineering Research Act	To authorize science scholarships for education mathematics and science teachers.
H.R.5141 Accelerating the Creation of Teachers of Influence for Our Nation Act	To increase by up to 10,000 per year the number of elementary and secondary science and mathematics teachers through scholarship programs.
H.R.5358 Science and Mathematics Education and Competitiveness Act	To authorize programs relating to science, mathematics, engineering, and technology education at the National Science Foundation and the Department of Energy Office of Science.

Some of these bills have been inspired, and adopted almost verbatim, the recommendation of the 2005 National Academies' report, *Rising Above the Gathering Storm*, which calls for the increase of America's talent pool by vastly improving K-12 science and mathematics education, the strengthening and sustainability of long-term basic research, and the development of an environment in the U.S. that is attractive to scientists and engineering and conducive to innovation.

The debate that accompanies the consideration of these bills gives the physics community a significant opportunity for taking coordinated action in the areas of undergraduate and teacher education.

Compiled with contribution from Jennifer Greenamoyer, American Institute of Physics.

Cause Effect

A Physics Department, Redefined

Seattle Pacific University shows how a small liberal arts college can have a big impact on expanding physics teaching and improving student achievement.

By Stamatis Vokos

Founded in 1891 by the Free Methodist Church of North America, Seattle Pacific University (SPU) is a Christian institution of the liberal arts, sciences, and professional studies, offering 53 bachelor's, 11 master's, and three doctoral degree programs. Total student enrollment, as of autumn 2006, was 3,830 (2,979 undergraduates).

In 2002 the physics department had three tenure-track faculty; today it has seven. We attribute this remarkable growth to four factors: a department-wide focus on student assessment; collaboration with other academic departments and educational institutions, most notably the education department and local school districts; substantial administrative support within a culture that celebrates the scholarship of teaching and learning; as well as a strategic pursuit of external funding.

Student Assessment and Learning Gains. In 2003, the physics department embarked on the project called "Adaptation and Implementation of Research-Based Curricula in Introductory Physics Courses at Seattle Pacific University," which is funded under the National Science Foundation's Course, Curriculum, and Laboratory Improvement program (CLLI). Calculus-based and algebra-based course sequences were drastically altered through the adaptation and utilization of active learning physics curricula such as tutorials in Introductory Physics, Activity-Based Physics tutorials, and RealTime Physics. Students' conceptual understanding skyrocketed. On several nationally available concept inventories, learning gains doubled. On the Force Concepts Inventory, for instance, one measure of learning gains (g-value) increased from around 30% to about 60%.

The most important outcome of the NSF-CCLI project, however, is the SPU Learning Assistant (LA) program currently led by assistant professor of physics Lane Seeley. The LA program utilizes well-trained undergraduate students as tutors in the teaching of introductory physics courses. This year, the department offered a specially designed course that allows the LAs to concentrate on more general issues of teaching and learning. The development of this course benefited greatly from the input of colleagues in physics and education from the University of Colorado, Boulder, and the University of Arkansas.

The LA program extends beyond physics majors and minors to encompass talented undergraduates from other sciences and engineering programs. In this way, it also serves as a natural recruiting setting for future science teachers.

Increasingly confident about its emerging ability to navigate the shoals of curricular reform, the department has piloted research-based laboratory materials for the introductory course being developed by Michael Loverude (California State University-Fullerton), Luanna Ortiz (Arizona State University), and Stephen Kanim (New Mexico State University).

Collaboration Across and Beyond SPU. There are many forces that influence the professional trajectory of a pre-college teacher. At both the pre-service and in-service levels, the dominant ones are the School of Education, the College of Arts and Sciences, and the school district. According to the national norm, these three institutions play integral roles but with little coordination. In contrast, the SPU approach is one in which all three institutional players have an ongoing collaboration.

The collaborative model being developed at SPU is based on the recognition that blending expertise in tackling teacher preparation issues is crucial. Furthermore, this collaboration includes and impacts the entire physics department faculty, students, and the curriculum.

The Resident Master Teacher (RMT) in the physics department is the nexus of the partnership among education, physics, and local school districts, and plays an indispensable role in all aspects of the department's teacher preparation program.

The RMT at SPU is Lezlie Salvatore DeWater, a veteran teacher, science specialist, and professional development provider for Seattle Public Schools. Lezlie DeWater and Eleanor Close, assistant professor of Physics and Science Education, co-teach SPU's special content and science methods courses for prospective teachers. Pre-service teachers, therefore, get immersed in the inextricable blending of subject matter and pedagogical content knowledge. In addition, the RMT teaches a special course on the nature of science for non-science majors.

Long-term, authentic collaboration with school districts is an essential part of the department's effort. Science coordinators from several school districts and educational service districts consider the department an invaluable partner for numerous local, state, and national initiatives. The department, on the other hand, benefits tremendously from keeping a hand in the realities and mandates of the pre-college classroom to finding "laboratories" for the delivery of research-based professional development.

Administration Support Is Key. Strong support of departmental initiatives by all levels of the university administration has been crucial. The president, provost, deans of the College of Arts and Sciences and the School of Education, and the associate dean of Teacher Education understand the issues and work closely with physics department chair John Lindberg as well as the entire physics faculty to find ways to institutionalize gains and develop new programs.

One substantive example of this institutional support is the fact that the deans decided to move the science education tenure-track faculty position (vacated because of retirement) out of the School of Education and into the physics department. Another example is the funding provided by the university for a postdoctoral associate, who will be immersed in all aspects of the department's program so as to eventually have a positive impact on Christian higher education in physics and teacher preparation.

Sources of External Funding. Seattle Pacific University, with extensive support from the SPU Science Initiative, NSF, the Boeing Co., Lilly Endowment, and the PhysTEC joint project of the American Physical Society, American Association of Physics Teachers, and American Institute of Physics, has embarked on a long-term course to prepare and support teachers of science in ways that are guided by education research.

NSF has funded several departmental projects in the last three years. In addition to the CCLI project, the department has received a major grant to support the project "Improving the Effectiveness of Teacher Diagnostic Skills and Tools."

In partnership with Jim Minstrell and Pam Kraus of FACET Innovations, and the public schools in three of the largest cities in Washington, the project is developing Web-based formative assessments to help teachers in grades five through 10 map out their students' modes of reasoning in foundational areas of physical science.

Most recently, the department (in collaboration with other sciences, mathematics, and education programs) received a Noyce Scholarship grant to attract prospective teachers. Finally, the department leveraged consistent support from Boeing to meet the stringent conditions required for funding to become the latest PhysTEC Primary Program Institution.

Not Only for a Chosen Few. Improving student understanding in the gateway courses, combined with targeted student recruitment, has increased interest in SPU's physics degree program. SPU now graduates five to eight physics majors each year—twice as many as a few years ago. Moreover, the number of female students who choose physics as a major or minor has increased significantly.

Guided by a common theological commitment that all students can and deserve to succeed in physics, and armed with the tools of physics education research, SPU faculty members have focused their attention on other aspects of the curriculum. The department is experimenting with research-based materials in modern physics, quantum mechanics, and classical mechanics, as well as courses for non-science majors. Δ

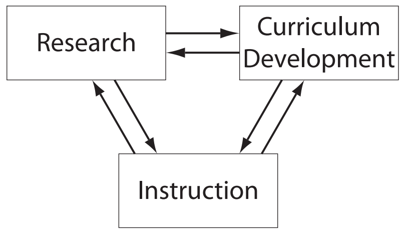
Stamatis Vokos is an associate professor of physics at Seattle Pacific University.

Editor's Note

Seattle Pacific University recently became a member of the Physics Teacher Education Coalition (PhysTEC). Funded by the National Science Foundation, PhysTEC is led by the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics. Its goal is to improve the science preparation of future K-12 teachers by bringing together faculty from physics and education to work on ideas and curricular reform that emphasize interactive engagement and student-centered approaches to learning science.

Improving K–20+ Physics Education

How physicists at the University of Washington started a program that transformed physics education research into an important field of scholarly inquiry.



Iterative cycle that characterizes the work of the Physics Education Group

The Physics Education Group (PEG) in the Physics Department at the University of Washington (UW) conducts a coordinated program of research, curriculum development, and instruction to improve student learning in physics and physical science (K-20). Led by Lillian C. McDermott, together with Paula R.L. Heron and Peter S. Shaffer, the group includes research associates, graduate students, K-12 teachers, and a small administrative staff. Graduate students in the group earn a Ph.D. in physics for research on the learning and teaching of physics. Thus far, the UW has awarded about 20 doctoral degrees in this field.

A major goal of the PEG is to contribute to an expanding research base on student understanding, which can be used as a resource by anyone who teaches physics. Through in-depth investigations, the group seeks to identify and analyze the conceptual and reasoning difficulties that students encounter in learning physics. The findings guide the development of instructional strategies to help students develop a functional understanding of specific concepts.

Ongoing assessments, which include individual demonstration interviews and written questions administered to large numbers of student before and after instruction, provide detailed information that guides subsequent modifications to the curriculum. This interactive process, which takes place first at UW and then at pilot sites, has resulted in the publication of two research-based curricula: *Physics by Inquiry* and *Tutorials in Introductory Physics*.

Physics by Inquiry (volume one and two published by John Wiley & Sons in 1996) is a self-contained, laboratory-based curriculum primarily designed to prepare K-12 teachers, but it is also suitable for other students. Through their experiments and observations, students construct physical concepts and develop analytical reasoning skills. The topics chosen provide the background for teaching K-12 science competently and confidently. Depth rather than breadth is stressed. *Physics by Inquiry* has been translated into Polish and Greek.

Tutorials in Introductory Physics (published by Prentice Hall in 1998) is intended to supplement the lectures and textbooks of a traditional course. The tutorials are suitable for both calculus-based and algebra-based courses where there is an opportunity for students to work together in small groups. Carefully sequenced experiments, exercises, and questions engage students in the type of active intellectual involvement that is necessary for developing a functional understanding of physics. It has been translated into Spanish and Greek and a German edition is forthcoming.

The PEG's origins can be traced to the teacher education program begun in 1968 after Arnold Arons came to UW to create a one-year physical science course for future elementary school teachers. Lillian McDermott joined him shortly thereafter and developed a physics course for prospective high school teachers. These preservice courses led to the creation of intensive summer institutes for inservice K-12 teachers that have been funded by the National Science Foundation. The preservice courses have become an integral part of the physics department's instructional program. A major goal of all of these courses is to prepare preservice and inservice teachers to teach physics and physical science by inquiry.

The PEG began conducting research to guide instruction in the 1970s. At the time, McDermott was developing a course to help under-prepared students succeed in physics. The UW awarded its first Ph.D. in physics for research in physics education in 1979. The dissertation presented results from a series of individual demonstration interviews in which students were asked to observe and compare the motions of two balls rolling on level and inclined tracks. Analysis of the responses revealed serious difficulties with the concepts of velocity and acceleration. Written tests administered on a larger scale confirmed these results and demonstrated that university students with a wide range in preparation often lack a proper understanding of basic kinematical concepts. The resulting articles in the *American Journal of Physics* that were based on this research [48 (12) 1029 and 49 (3) 242 (1981)] were the first of their kind. The findings, along with those from other studies, guided the design of the original Kinematics module in PbI.

The next stage in the history of the PEG began in 1991 when the UW physics department decided to modify the structure of the introductory calculus-based physics course by making laboratory compulsory and converting one of the four lectures per week into small group instruction. The PEG volunteered to produce tutorials for these sessions, which were required for all students. Development of the tutorials has involved a great deal of pretesting and post-testing. The data have shown that, both before and after standard lecture-based instruction, many students have similar conceptual and reasoning difficulties in a wide variety of topics. Moreover, results from post-tests have demonstrated that methods of addressing specific difficulties that are effective with one student population often work well with others. These findings have been highly reproducible and have proved to be generalizable.

Both curriculum development projects have been strengthened by the active involvement of the PEG in the professional development of teaching assistants and new university faculty. The group conducts a required weekly teaching seminar for all new graduate and undergraduate teaching assistants. During the past 10 years, more than 70 faculty, post-doctoral research associates, and graduate students have visited the group to learn about discipline-based education research and associated curriculum development. Some have come for extended visits to develop the expertise needed to start similar programs.

The work of the Physics Education Group is driven by a strong commitment to the improvement of student learning of physics from the early grades through graduate school. The perspective of our group is that teaching is a science, as well as an art. Discipline-based education research, as distinct from traditional education research, has opened new possibilities for cumulative progress in improving the effectiveness of instruction. Δ

Interactions *thanks Lillian C. McDermott (professor) and Paula Heron and Peter Shaffer (associate professors) at the University of Washington for their contributions to this article.*

Personal Trainers

Coaching K-12 Science Teachers to Improve Student Achievement in Seattle Public Schools

Seattle Public Schools wants to be a leader in standards- and inquiry-based science education. To achieve its objective, the school system launched the PreK-12 Inquiry-Based Science Program, which is a collaborative project involving philanthropic organizations, local business leaders, regional colleges and universities, and concerned parents. Initial funding for the project was provided by the National Science Foundation's Local Systemic Change program. The mission of PreK-12 program is "to ensure that all students are able to investigate scientifically in order to acquire conceptual understanding of their world, develop positive scientific attitudes, and become scientifically literate."

The Seattle public school system is the largest in Washington State and the 44th largest in the United States. It comprises 97 schools, more than 2,619 teachers, and approximately 45,800 students. During the mid-1990s, Seattle, arguably like most U.S. public school systems, did a poor job teaching science, particularly in grades K-5. Instructional materials were outdated, and few teachers devoted significant class time to science instruction. Where reading, writing, and math were core subject areas, science was not.

Starting about 1993, Washington State began developing academic standards in science and other key subjects as a way to improve student achievement. The emphasis on science teaching and accountability at the state level spurred curriculum reform and professional development in Seattle and in other districts throughout the state. Seattle's science reform strategy focused not on student achievement directly, but on teacher training.

Because elementary and middle-school teachers typically are ill-prepared to use an inquiry-based curriculum, professional development is a key component of the NSF "systemic change" project. Therefore, a key component of Seattle's science reform effort is extensive, ongoing teacher training, and a notable aspect of Seattle's approach to teacher development is the use of Curriculum Consultants, or "school coaches."

School coaches provide support, training, and guidance to fellow teachers inside and outside the classroom. The science coaches, in particular, help teachers with implementing a new curriculum, work one-on-one with students, lead workshops, and develop or revise instructional materials. According to Elaine Woo, PreK-12 Science program manager, the objective is for coaches to build relationships with the teachers and promote the importance inquiry teaching.

The typical science coach is an experienced teacher with strong interpersonal skills who is well-trained in inquiry-based teaching methods. Kathryn Show is a coach for physical, earth, and life sciences. She worked in the Maryland school system before moving to Seattle. Show's duties include planning professional development classes, developing curriculum and lessons that align with state standards, and connecting with teachers to address their needs and concerns. Show notes that elementary teachers on average are uncomfortable with science. Teachers are not required, but encouraged to participate in the program. "It is difficult to change a teachers belief system about what is the best way to teach," Show says. Δ

Interactions *thanks Elaine Woo, Kathryn Show, and Hunter Close of Seattle Public Schools for their contributions to this article.*

Learning by Doing

Workshop Physics is another innovative approach to teaching introductory physics by replacing lectures and labs with collaborative, hands-on activities.

At Dickinson College, a small liberal arts institution in Carlisle, Pennsylvania, the chairman of the Physics Department observed that its traditional teaching approach for introductory physics – comprising lectures and laboratories – did not seem to result in the desired level of learning. "Each day I walked past the physics lecturer for the introductory course – who by the way was a very engaging speaker – and noticed students reading newspapers and doodling," said Priscilla Laws, who is now a research professor at the college. She also found a disconnect between lecture material and lab activities – typically, the lecture topics lagged behind the lab. Professor Laws began mulling over the idea of eliminating the traditional distinction between lectures and labs.

However, the final, galvanizing event was a day-long AAPT workshop she attended in which participants worked with different electronic components – ultimately creating a digital stopwatch. "This hands-on approach was so effective, I believed a similar methodology for teaching physics could lead to greater student learning."

The result was Workshop Physics, a methodology based on the assumption that acquiring transferable skills of scientific inquiry based on real experience is more valuable than traditional learning approaches. There were two reasons for this assumption:

1. Most students who enroll in introductory physics courses lack the concrete experience with everyday phenomena needed to understand mathematical representations of these phenomena. When students are given the opportunity to observe, analyze data and develop models to explain their observations, they can tie personal experience to abstract concepts.
2. Equally important, when students are faced with a massive body of knowledge, they can best succeed by learning selected concepts and acquiring the skills needed for independent investigation of additional concepts.

As a result, the guiding principle for Workshop Physics is to present topics that lend themselves to direct observation by students.

What does this mean in practical terms? No lectures or labs. Hands-on investigation and observation of physical phenomena. Instructor-led discussion. And heavy use of computer technology, particularly computer-assisted data acquisition, video analysis and capture, and spreadsheets.

A curriculum developed by Professor Laws and her colleagues includes ***Classical Mechanics, Heat, Temperature and Nuclear Physics, and Electricity & Magnetism.*** Overall, a typical Workshop Physics course comprising three two-hour sessions per week does not cover as much material as a traditional lecture-based course.

"We do not require additional class time compared to the lecture/lab format, but time is used differently. Students are more engaged and must expend more energy and brainpower," says Laws.

One of the benefits of Workshop Physics is that it's fun for the students. Who wouldn't enjoy "Karate Day" when students calculate conservation of energy and momentum by first observing how many bricks can be placed on a pine board before it gives way, then attempting to break a similar board with their bare hands?

Currently, about 60 high schools and colleges are using Workshop Physics. The methodology is especially well-suited to liberal arts colleges with small classes.

"We like to say that this approach replaces the 'sage on the stage' with a 'guide on the side,' she said. "Although students who are used to memorization may find Workshop Physics too unconventional, for most students, the course allows them to really understand the principles through their own experimentation, reasoning and discussion – and we believe those lessons are the ones that will make a lasting impression." Δ

Continuing Education for New Faculty

FROM OCTOBER 26–29, 2006, the Eleventh Annual New Physics and Faculty Workshop brought together 77 new faculty members representing 61 colleges and universities at the American Center for Physics in College Park, Maryland, for an intensive three-day orientation on physics pedagogy and innovations in teaching physics and astronomy.

The activities began with a three-hour session on National Science Foundation grant programs. Three NSF program officers, Wendy Fuller-Mora, Beverly Berger, and Dana Lehr, explained grant procedures, the variety of NSF programs available, and the review process.

The American Association of Physics Teachers, the American Astronomical Society, and the American Physical Society sponsored the program, which is funded in part by NSF. It included a mix of plenary sessions and small group meetings designed to highlight a variety of physics education and professional development topics. Since its inception, more than 800 new physics and astronomy faculty members have participated in the program.

One session, called "Making a Difference: Teaching for Retention," addressed issues of equity and diversity in physics education and engaged the participants in a lively session discussing several case histories of classroom situations involving equitable treatment of students. Jim Stith, vice president of the Physics Resource Center at the American Institute of Physics, who led the diversity workshop, said later,

> "The data show that even though women and underrepresented minorities aspire to attain science graduate degrees in much the same proportions as white males, they clearly fall short of that goal."

Ultimately, Stith hopes faculty come away from his session able to facilitate discussions on race and gender equity that allow all to see various situations from different perspectives with respect.

Another session, called "Are You Really Teaching if No One Is Learning? Gauging the Success of Instruction Through Research" and led by Ed Prather from the University of Arizona, asked and attempted to answer that question.

Prather outlined a vision of teaching as a scholarly activity with its own research literature and knowledge base. He then showed how that view of teaching informed enhancements of the teaching of astronomy, most of which are also applicable to the teaching of physics. "Lecture has often been described as the process of taking the information contained in the teacher's notes and transferring it into the student's notes without passing through the brains of either," says Prather. "Research on the difficulties students have with learning physics and astronomy have been used to create intellectually engaging materials and instructional strategies that are shown to improve student learning far beyond traditional lecture. So the question remains. Why are so many college instructors still predominantly lecturing?"

Eric Mazur is the Gordon McKay Professor of Applied Physics at Harvard University, who thought he was a good teacher; that is, "until I discovered my students were just memorizing information rather than learning to understand the material."

"Who was to blame?" he asked. "The students? The material?" Mazur came to the agonizing conclusion that the culprit was neither. "It was my teaching," concedes Mazur. "I have since adjusted my approach to teaching by moving away from teaching by telling to teaching by questioning, and found that it has improved my students' performance significantly."

In the workshop "Active Learning and Interactive Lectures" Mazur told the participants how he "discovered" peer instruction as a way to actively engage students more effectively in large lecture classes and about the gains in conceptual understanding that result from the use of carefully crafted conceptual questions and student-to-student interaction during the class.

Examples of smaller group sessions included topics on problem solving, led by Ken Heller from the University of Minnesota, and on digital libraries, by Bruce Mason from the University of Oklahoma. Other sessions focused on professional development issues such as tenure and promotion procedures, supervising undergraduate research, and supervising graduate students.

Peter Shaffer and MacKenzie Stetzer from the University of Washington's Physics Education Research Group (PER) led the final session of the program, entitled "Research as a Guide to Improving Student Learning." The participants used several materials developed by PER to experience first-hand how a research-based physics curriculum can enhance student understanding.

At the end of the program, many participants expressed their newfound appreciation for their roles as physics educators and for the integral part physics education plays in their overall professional development. Δ

Data Points

Physics by the Numbers in Washington State

The number of bachelor's awarded in Washington State over the three year period, 2003 – 05, rose 27%, compared to 1997 – 99, slightly below the national average increase of 28%.

University of Washington and Whitworth College represent the largest numeric increase and percentage gain. Physics bachelor's awarded at the University of Washington increased by 82% during 2003–05 (accounting for 1.5% of all reported physics bachelors degrees awarded in the U.S. during the 3 years). The number of physics degrees awarded by Whitworth College increased by 120% during the period.

Both increases are well above the national average. Between them, they account for 42% of the increase in the state of Washington.

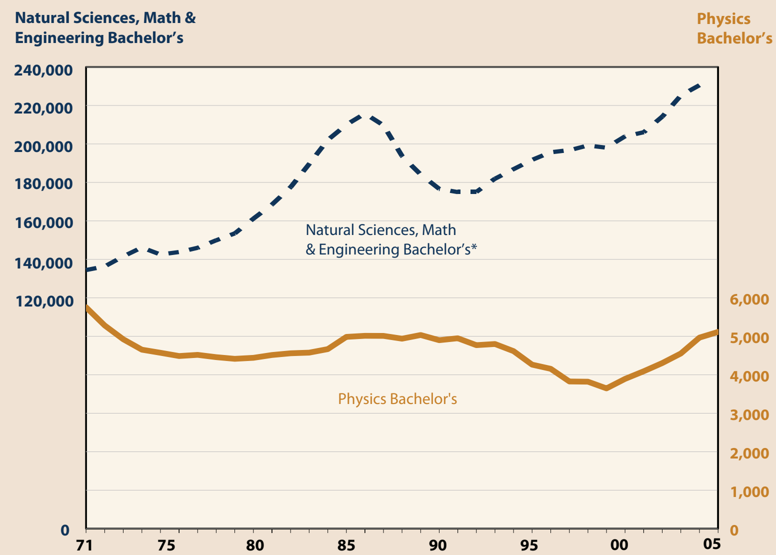
Patrick Mulvey, American Institute of Physics, contributed to this analysis.

WASHINGTON STATE ROSTER OF PHYSICS DEPARTMENTS WITH ENROLLMENT AND DEGREE DATA, 2005.

	2004-05 FIRST-TERM INTRODUCTORY COURSE ENROLLMENTS		FALL 2005 UNDERGRADUATE MAJORS	2004-05 PHYSICS DEGREES
	Physics	Physical Science & Astronomy	Includes Juniors and Seniors	Bachelors
Central Washington U	DATA NOT PROVIDED			
Eastern Washington U	641	242	11	2
Gonzaga U	230	40	5	4
Pacific Lutheran U	73	56	10	2
Puget Sound-U of	160	72	25	8
Seattle Pacific U	220	238	15	8
Seattle U	159	136	11	3
Walla Walla Coll	125	60	8	2
Washington State U	549	135	28	6
Washington-U of	2202	770	86	78
Western Washington U	1914	417	34	4
Whitman Coll	95	10	24	10
Whitworth Coll	85	60	19	10

Data compiled from the "Roster of Physics Departments, 2005"
American Institute of Physics, Statistical Research Center

Physics bachelor's and Natural Sciences, Math & Engineering bachelor's produced in the US, 1971 to 2005.



AIP Statistical Research Center, Enrollments and Degrees Survey and
* NCES Digest of Education Statistics