'Physics First'
First Conference Held at Cornell

by John L. Roeder

Leon Lederman has long advocated beginning the high school science curriculum with a course in physics, but not until this summer do I know of a three-day conference devoted to what has been called "Physics First". The convener of the conference was not FermiLab, which Lederman once directed, but rather the Laboratory for Elementary-Particle Physics (LEPP) at Cornell University. And the driving force behind it was Cornell Physics Professor Ahren Sadoff. The dates were 30 June-2 July 2003.

Sadoff told us that he saw "Physics First" as a way to promote science literacy. He felt that the present place of physics in the science curriculum places more emphasis on problem solving than on conceptual understanding needed for science literacy. Moreover, he was concerned by reports from high school physics teachers that average high school students are scared from taking today's physics courses by the New York State Regents exam and saw "Physics First" as a way to address this concern.

LEPP's Program Outreach Coordinator Lora Hine brought together about forty educators involved in various phases and stages of implementing Physics First to grapple with some of the basic questions concerning what one participant characterized as "the most revolutionary change in science education in a long time":

- Why Physics First?
- Why physics for all?
- Should a ninth grade physics course be evaluated by a Regents or other standardized exam?
- Should there be different levels of ninth grade physics courses for students with different background?
- What should be the role of math in the ninth grade physics course?
- What is the best approach to teaching a ninth grade physics course?

To address these questions were several leading practitioners of Physics First:

- Len Bugel, physics teacher at Stratton Mountain, VT, who is especially interested in teaching twentieth century physics to freshmen;
- Arthur Eisenkraft, Director of ***Active Physics***, a physics course developed with funding by the National Science Foundation in association with the American Association of Physics Teachers and the American Institute of Physics and now taught or adopted in San Diego, Boston, Prince Georges County (MD), and Miami-Dade County;
- Barry Feierman, physics teacher at The Westtown School (PA), who has taken a special interest in developing laboratories for the "Conceptual Physics" course he teaches ninth graders there and has established a "Physics First" listserv (physicsfirst@yahoogroups.com, with associated website http://groups.yahoo.com/group/physicsfirst);

• Paul Hickman, Director of the Center for the Enhancement of Science And Mathematics Education (CESAME) at Northeastern University, who set up a pilot ninth grade physics course at Cold Spring Harbor (NY) High School in the 1970s;
• Gerald (Gary) Kitzmann, University Faculty Senator and physics professor from the State University of New York at New Paltz;
• Miriam Lazar, math and science coordinator of North Babylon Schools (NY), who has a vision of Physics First for her district;
• Olga Livanis, Associate Principal for Physical Science at Stuyvesant High School, who wrote the first Ph.D. dissertation about Physics First after accepting a challenge to do so from Lederman after attending him lecture about it in 1998 (she also maintains a "Physics First" website at http://members.aol.com/physicsfirst/);
• Doug Mountz, science teacher at Twin Valley High School (PA), which has just completed its first year of "Physics First";
• John Roeder, physics teacher at The Calhoun School (NY), who has taught "Physics First" there since 1990;
• Flo Turkenkopf, physics teacher at Packer Collegiate School (NY), where "Physics First" has been taught since 1993;
• Mark Vanacore, physics teacher at Albion H.S. (NY), where students can elect to take science courses in any order they choose;
• J. R. Wilt, originally trained as an industrial chemist who realized that physics was the logical first course in high school science while substitute teaching a biology class.

Why Physics First?

Leon Lederman had been invited to address the leadoff question, but Hickman pinch-hit for him. After quoting Lederman ("Ninth grade physics is the proper discipline to introduce students to science. Ultimately, the goal . . . is to embed in all high school graduates a 'science is a way of thinking' that will endure forever"), Hickman focused on four categories of argument in favor of "Physics First": pedagogical, developmental, belief based, and outcomes. Among the pedagogical arguments cited by Hickman, physics is the foundation of all science, it is the easiest to observe through experiments, it gives students the opportunity to apply their mathematical skills to real situations, and it deals with phenomena that relate directly to students' worlds. Among the developmental reasons for teaching Physics First, physics provides concrete science experiences, it improves problem-solving skills, and it improves oral and written communication skills. Hickman particularly noted how eager ninth graders are and observed that mathematics they might be lacking can be introduced as it is needed.

Among the belief bases cited by Hickman, Physics First fosters conceptual understanding, cooperative and collaborative learning, and writing to make thinking visible. Among the outcomes arguing for Physics First are enrollment by students in more science courses, greater success in chemistry and biology, more females taking physics, and parental perception that the physics-chemistry-biology sequence is more rigorous. But Hickman cautioned that the evidence for these last two categories thus far is strictly only anecdotal.

Next Livanis related how her persuasion to get Stuyvesant Principal Stanley Teitel to teach one section of freshman physics three years ago led to such good results -- their percentage achieving mastery level on the Regents test exceeded that of Stuyvesant juniors -- that he wants to change over all 13 sections in the school. Like Hickman, she also noted the eagerness of freshmen, and attributed this as one factor in their success. She also felt that freshmen take their first high school science course more seriously and are therefore more hardworking -- and that they have fewer misconceptions.

Physics for All

Addressing "Physics for All," Eisenkraft said he was addressing the 99% of students who don't go to Stuyvesant. Some of them have weak math skills, some were socially promoted, but the "all" in "Physics for All," he said, means the same as it does in the Pledge of Allegiance. To those who would claim that "Physics for All" is not "real" physics, he responded that according to that line of reasoning, Little Leaguers are not playing really playing baseball and only artists like Yo Yo Ma are really playing the cello.

Eisenkraft also offered a schema for selecting physics topics in terms of benefit (frequency of use) and cost (amount of time to learn). As an example of a low-cost, low-benefit item, he offered the value of the specific heat of aluminum -- easy to teach but of limited use. His example of a high-cost, low-benefit topic was blackbody radiation. At the other end of the spectrum -- high-benefit, low-cost -- he suggested the reflection of light. His choice of a high-benefit, high-cost topic was the most fundamental of all science -- the First Law of Thermodynamics.

The approach Eisenkraft advocated to teach "Physics for All" included maximum intellectual engagement of students, respect for the cultural diversity of students, and respect for the disabilities of students (after all, we let those with vision problems wear glasses). He also shared his expansion of the 5E Learning Cycle (Engage, Explore, Explain, Elaborate, Evaluate) by prefacing "Engage" by "Elicit" and adding "Extend" at the end.

Barriers and Steps to Implementation

The remainder of the first day of the conference was devoted to barriers to implementing Physics First and steps that could be taken to overcome them. The barriers were discussed in breakout sessions chaired by Wilt (intellectual and instructional), Lazar (teacher training and shortage), and Roeder (assessment and scheduling). Among the intellectual and instructional barriers reported back by Wilt were modifying the approach to accommodate differences in intellectual maturity and social skills and to spend more time on fewer topics in shifting from teaching 12th to 9th graders; the failure to teach the math needed for physics, even though it is in the middle school curriculum; the lack of physics curriculum materials readable for ninth graders; the breeding of doubt in ninth graders by laboratory work leading to poor results; and the teacher-centered way physics is presently taught to 11th and 12th graders.

Teacher training and shortage barriers reported out by Lazar included lack of focus by colleges on physics teacher training, greater attractiveness of physics than physics teaching for a career, excessive science phobia in elementary teachers, and difficulty attracting and keeping good physics teachers and persuading them to teach ninth graders. Lazar's group also came up with some suggestions to overcome these barriers: for physics departments to take over the training of physics teachers and modeling the teaching of physics by the way it should be taught, making physics teaching a more attractive career, and development of a solid ninth grade physics course not based on a Regents exam.

Among the scheduling and assessment barriers reported by Roeder were unwillingness of administrators to schedule ninth grade physics courses or seek exemptions from standardized tests for them; the perception that Regents tests in biology and earth science are more "passable"; having to schedule a teacher to teach a course for only one year as part of a transition; college perception of the naming of ninth grade physics courses; persuading administrators and parents that ninth grade physics should be taught as the third science credit (which doesn't require a Regents exam); and having to schedule enough sections of ninth grade physics in existing facilities with existing laboratory equipment. Some members of Roeder's breakout session felt that "Physics First" sounded variously more threatening or easier than "Freshman Physics," a basic course that everybody takes.

Roeder was also given the assignment of addressing the positive side of the barrier question: steps which could be taken to implement Physics First. Drawing from his experiences in implementing Physics First at The Calhoun School, visiting the meeting of the School Board of Montgomery Township, NJ, when the application was made to adopt Physics First there, hosting visits by delegations headed by Lazar from North Babylon to see ninth grade physics taught at The Calhoun School, and learning of the importance of professional development in the successful adoption of *Active Physics* in San Diego (reported in our Spring 2003 issue), Roeder emphasized the importance of obtaining the support of all relevant stakeholders and providing professional development to teachers who would have to teach "out of field." In addition to having enough teachers, he stressed the importance of having the required facilities and equipment as well, since physics is best learned by freshmen when they discover physics concepts and relationships experimentally rather than by sitting in seats looking at a blackboard. In fact, he noted that a change to a Physics First curriculum is often marked by a change in pedagogy and that this change in pedagogy, by following the *National Science Education Standards*, could be used as a selling point for the change.

Roeder then led the participants through two possible models of changing over to Physics First: one reversing a biology-chemistry-physics sequence (which requires extra physics sections for two years, and no biology sections for the same time), the other replacing a physical science course in ninth grade by physics and reversing biology and chemistry in the following two years (which requires extra chemistry sections and no biology sections for one year). He closed his presentation by listing some consequences of implementing Physics First: 1) a physics course for all students; 2) a physics course that involves more learning by experimental discovery and verbalizing than number crunching of formulas; and 3) a three-year science sequence taken by all students, with biology taught at a more sophisticated level. Roeder noted parenthetically that the increase in science requirements for graduation in most states to three science courses was especially conducive to Physics First. He also noted that Physics First also meant a chemistry course for all students and left open the question of whether it should place less emphasis on traditional calculational aspects and more emphasis on organic chemistry (relevant to the ensuing course in biology).

the role of Math in "Physics First"

Vanacore began the second day of the conference by speaking on "Math and Physics Integration," which he subtitled "Getting the Most out of Freshman Physics." Since his school allows students to enroll in any science class in any of their high school years, he has taught mixed groups of students, including both freshmen and seniors, and he has found the students from different grades in these mixed groups to be remarkably similar. They all must pass the New York State Regents exam at the end of his course, and he has found that freshmen can do this.

Vanacore expressed the feeling that physics cannot be taught at any level without mathematics -- physics is "where the mathematics meets the road." He therefore feels that his role as a physics teacher is to create a mathematical framework for his students to understand the world. Because of the mixed groups of students he teaches, he realizes that he can rely only on the mathematics they learned in middle school. But according to the New York State Mathematics, Science, and Technology Learning Standards, this includes familiarization with the trigonometric functions (though this may have been minimal), and the state eighth grade exam will ensure that these topics are covered.

Still Vanacore finds that many freshmen behave in solving physics problems as if they learned nothing since the fourth grade, when they were supposed to learn fractions; and he discourages algorithms, because they are helpful only to solve problems phrased in the way to which the algorithm specifically applies. But while ninth graders may need more help setting up and solving problems, he finds that they can do it and that the seniors in his classes benefit from it as well.

Computational or Conceptual?

In continuing with "Computational vs. Conceptual: The Best Approach to Teaching Ninth Grade Physics," Turkenkopf -- who arrived at Packer Collegiate five years after Physics First had begun -- reported frustration with mixed groups of what she called "mathematically-minded" and "conceptually-minded" students. The former were frustrated by the omission of math from the conceptual approach, and the latter were frustrated when math was included. In 2002 she received authorization to begin a computational physics course for the "mathematically-minded" ninth graders in addition to the conceptual course.

This generated the liveliest discussion of the conference, because those who saw this as "tracking" expressed concern that it would "mark" students' futures in terms of math and science. Other participants felt that both types of students should be exposed to each other. Turkenkopf noted that there indeed *was* objection to this separation into two courses at Packer, but that at the end of the year students in both courses left happy. She said that the conceptual students left feeling empowered and that the computational students left feeling challenged. Moreover, the freshman will move on to one of two levels of chemistry course in their sophomore year, and the junior year biology course may eventually become differentiated as well. But

Turkenkopfemphasized that students are not "marked" by the level of courses they took. Admission to AP science courses in the senior year is determined by students' grades in their first three years of science courses, regardless of level.

Ninth Grade Physics Programs

One of the steps brainstormed in a breakout session on "The Road Towards Implementing Physics First in New York" chaired by Livanis the final afternoon of the conference was to look at available Physics First programs, and conference participants were next cycled through small group presentations on three programs. Mountz recounted how he had become turned on by seeing the Modeling approach to physics teaching in Rex Rice's classroom in Clayton, MO -- an experience he earlier said had given a "second wind" to his teaching career -- and he shared this with us (and gave us the experience of a Modeling "paradigm lab"). Eisenkraft reviewed what is valued and *not* valued in *Active Physics* and gave us the experience of doing some: he invited us to pick a sport, identify physics concepts and principles in the way it is played, and put together a short play-by-play incorporating reference to those concepts and principles in describing the action. Leading the small group discussions on the conceptual ninth grade physics course, Hickman saw a variety of goals for this course: preparing students for later science courses, enabling them to understand what's happening in the world around them, fostering a positive attitude toward science, and developing skills for learning about the world. Although he likes Paul Hewitt's *Conceptual Physics* for its readability, he feels it needs the math supplement authored by his wife, Jennifer Bond Hickman. But he opined that the text is not important if the teacher's content knowledge is strong.

Labs for Ninth Grade Physics

Feierman elicited a wide variety of responses when he asked the participants, "What makes a good lab?" Several of these responses -- produces unambiguous data leading to a conclusion of an important principle, simplicity, and low cost -- figured into the labs he presented in "Designing and Implementing Labs for Ninth Grade Physics Students." In one experiment he charged a capacitor with a battery, then allowed the capacitor to discharge through a circuit element. With his computer-interfaced software, he could display both voltage across and current through the circuit element as a function of time, and voltage as a function of current as well. When the circuit element was a carbon resistor, the familiar straight line of voltage vs. current typical of Ohm's Law was displayed. But when the circuit element was a light bulb, the graph of voltage vs. current displayed a curvature that reflected the higher temperature (and higher resistance) of the bulb at higher currents.

Under the heading of "inexpensive" was a balance made from a straw, with a straight pin stuck through near the middle, a "counterweight" of masking tape on one end, and a slot to insert objects to be weighed on the other. Our unknown was a small piece of fishing line, and our standard masses were little squares of graph paper, cut from a whole sheet we had massed to the nearest 0.01 gram on a standard laboratory balance. The resulting precision was to the nearest tenth of a milligram.

Twentieth Century Physics Topics for Ninth Graders

The morning of the last day of the conference was devoted to twentieth century physics, which Bugel observed used to be called "modern physics." Calling it "twentieth century physics" could not only recognize that we are now in the twenty-first century but also move these topics from being crammed into a single chapter at the back of the book to their more rightful place in claiming a larger share of the curriculum. In his presentation on "Twentieth Century Physics in the Ninth Grade" he showed how easy it was to derive time dilation in the Special Theory of Relativity by using the model of a "light clock." When it came to quantum mechanics, though, he recognized that he could provide no mathematical derivations, but he liked to impart the idea that "electrons, photons, and even forces are particles, but particle behavior is governed by an equation that looks like a wave equation and determines the probability for the location of the particle." To illustrate the probabilistic approach of quantum mechanics, he likes his students to model radioactive decay by the throwing of 120 six-sided dice. He also finds unification of quantum mechanics and special relativity in observing the decay at ground level of muons produced by cosmic ray collisions in the upper atmosphere. He has his students do this by mounting Geiger tubes at the bottom of vertically-mounted iron pipes -- and he finds them eager to do this both at school and on the mountaintops when they are skiing. That they find about the same muon flux at both locations is an indication of the time dilation that allows the muons to reach the ground before they decay.

Bugel's presentation was a perfect lead-in to a tour of the Wilson Laboratory where LEPP is located. There positrons are created, selected, and accelerated to energies of 5 billion electron volts in a half-mile circumference synchrotron, then shunted off onto a neighboring storage ring. They can be stored for up to an hour there, but it takes only 10 minutes to accelerate a batch of electrons to the same energy, going in the opposite direction, and shunt them into the same storage ring to collide with the positrons. Since the facility was shut down for maintenance, we were able to walk around almost everywhere -- to see both the synchrotron ring and the storage ring side-by-side, and the many experiments set up to take advantage of X-ray beams from the synchrotron, which guide Steve Gray likened to the headlight beam of a locomotive traveling around a circular track.

The Next Steps

It was soon time to go, but not until we charted some next steps. Some participants, under Livanis' facilitation, brainstormed and ordered a sequence of ten steps to implement Physics First in New York. Others, under the facilitation of Feierman, discussed ways to publicize the results of the conference and Physics First in general – and the need to change the present view of earth science and biology as the “two initial science courses” in New York State. Barriers to this include the perception that Physics First is not seen as leading to success for all students in terms of passing Regents exams, and that Physics First as the “third science” does not allow fulfillment of graduation requirements early in the high school years. It was also noted that Physics First also threatened to displace a lot of earth science teachers.

Both Livanis and Feierman also articulated to the entire conference some further steps they would like to see. Livanis sought to initiate a "Physics First" journal, and Feierman offered the less ambitious alternative of a "Physics First" column in *The Physics Teacher*. But, as was pointed out, the success of either option would depend on the willingness of Physics First teachers and educators to provide a steady stream of articles.

Kitzmann gave a concluding presentation on "University and School District Partnerships: How Can SUNY Help?" He argued that the economy of New York State depends strongly on a science-trained work force. As a physics professor, he feels that Physics First is a good way to achieve this. He articulated a plan that draws not only on his physics expertise but also his political standing to persuade the New York State Legislature to fund SUNY programs to train Physics First teachers and thereby persuade the State Education Department of Physics First's viability.

As he had introduced the conference, Sadoff concluded it by returning to the basic questions the conference was intended to raise. Sadoff reported that he had sensed consensus among the three days on three basic things: 1) physics for all, 2) physics in the ninth grade, and 3) a physics-chemistry-biology sequence. But he felt that there was not a consensus on the questions of 4) whether the "physics for all" course should be evaluated by a Regents exam or some other assessment, 5) whether there should be one level of physics course or two, 6) the role that mathematics should play in a "physics for all" course, and 7) the approach to use in teaching "physics for all" (conceptual, active, or modeling). Indeed, in his breakout session the preceding day, Hickman polled participants on two of these questions and found a virtual 50-50 split on the questions of whether the Regents exam should be the "exit exam" for a ninth grade physics course and whether there should be one or two levels of ninth grade physics courses.

Sadoff went on to list the types of problems he had sensed in implementing Physics First:

• logistic: agreement of administration, teacher shortage, and lab and equipment shortage.

• cultural: agreement of administration, whether ninth grade physics is "real" or watered down, whether ninth graders can do it, whether 12th grade teachers want to teach it, whether other science teachers support it, and general inertia, fear, and hatred.

• pedagogic: disagreements among proponents.

Yet he found that he couldn't argue with the success that Physics First has already experienced: ninth graders have shown that they can do it, more females are enrolled, and a number of school districts have adopted it. And he closed with the four reasons he learned for doing Physics First: 1) to put the science sequence in a rational order; 2) to include scientific methodology in the curriculum, 3) to replace problem-solving emphasis with conceptual emphasis, and 4) to make physics interesting, exciting, and even fun.

At the end of the conference Feierman presented conference organizer Lora Hine a card we had all signed and a basket of flowers as an expression of thanks for bringing us all together. It seemed very clear that it had been a successful first time to grapple with the issues related to "Physics First," that our agreements outweighed our differences, and that LEPP would play an important continuing role on behalf of the implementation of Physics First.