FORUM on EDUCATION

of The American Physical Society
Spring 2001

From the Chair

Kenneth J. Heller

Welcome to the first all electronic edition of the Forum on Education Newsletter. This is part of the continuing effort to fashion the Forum on Education into a tool to help you directly affect education in this country. APS members do not necessarily agree on what should be done in education or how it should be done. But we do agree that something needs to be done. Our Society has no unifying educational philosophy except that improved science and mathematics education is essential for all citizens.

The APS is not a large, rich, or politically powerful organization. We will never be able to mobilize a Million Physicist March or rival the lobbying power of AARP or the NRA. Our strength is in the talent and interests of our individual members. Even more than politics, all education is local. There are APS members in every state. Each member of the APS makes an important contribution to education every time they convince a teacher that science is interesting and important, teach a college class that is meaningful to students, show a middle school student that interesting and rewarding jobs exist for those with science and mathematics skills, work with a teacher in an industrial laboratory for the summer, judge a local science fair, talk with a local member of congress, convince a graduate student that teaching is important, or volunteer at a local science museum.

The Forum's job is to help members communicate their accomplishments and challenges in the field of education and to build on the experience and ideas in our community. The Forum also alerts members to national educational issues or new developments and helps them organize efforts for more extensive initiatives at the state or national level.

Electronic communication by email and the web is making this task more possible. With this edition of the Newsletter, the Forum takes the step of going totally electronic. I must admit that we were motivated in this direction by financial considerations. Printing and mailing three issues of the Newsletter was causing the Forum to run a deficit. Rather than cut down on the number of Newsletters, the Executive Committee decided to try the electronic format. From our survey (see page 3), we know a significant fraction of our

Continued on page 2

IN THIS ISSUE

from the Chair, continued from page 1

members prefer the current paper version of the Newsletter. We hope everyone will give the electronic version a try and let us know what you think. Perhaps people will like this format better once they have experienced it, perhaps not. Specific suggestions for improvement are always welcome. We have tried to make it easy to print the entire newsletter or just specific articles.

An electronic format will permit the Newsletter to have longer articles with embedded links to web sites and more graphics. Without a space limitation imposed by paper, the Newsletter can have more contributions from APS members. Over time, we expect that an electronic Newsletter will develop into a more effective mode of communication at a lower cost than paper. Ernest Malamud (malamud@fnal.gov) has edited the first of what will be many issues in this format. Please send him, or any of the Forum officers (list at http://www.aps.org/units/fed/) feedback that can be used to improve future editions. Your contributions of articles are always welcome.

Another example of the Forum's use of electronic communication is our web-based survey described in this Newsletter by Ken Lyons. If you have not yet participated in the survey please take a few minutes to go to the FEd web page and do so. The database from this questionnaire will facilitate better contact among members with similar educational interests. Last year, the Forum also began using the web for voting for its officers, a practice that continues with the upcoming election.

The Forum has not abandoned its more traditional forms of communication. We sponsor sessions at APS meetings that highlight issues of education. These sessions cover a range of issues including communicating physics through community organizations such as museums and newspapers, preparing new and future faculty to teach at the university level, preparing elementary teachers to teach science, improving university physics classes, and communicating with Congress. We hope you will make time in your busy conference schedule to attend some of them. The Program Committee believes that these sessions have information important to all of us. Currently most of these sessions are at the April meeting although we would be happy to schedule education sessions at other APS meetings. Please contact me heller@mnhep.hep.umn.edu or next year's Forum Program Committee Chairman, Ken Krane kranek@physics.orst.edu with suggestions.

I know that everyone is swamped with tasks that needed to by done yesterday. For most of us education is in our long-term interest but is not as urgent as the request for funding that must be in at the end of the week or the analysis that has to be finalized. Convenient communication will make it easier to use your limited time to contribute to improving education in this country. Please take the time to visit the Forum web pages http://www.aps.org/units/fed and send your officers email suggesting improvements, APS meeting sessions, Newsletter articles, or other actions that you think would help.

Kenneth J. Heller is the Chair of the Forum on Education and Morse-Alumni Professor of Physics at the University of Minnesota

Forum on Education Sessions

The Program Committee of the Forum on Education has organized sessions at APS meetings to address educational issues of concern to our members. The following sessions will be held at the March and April APS meetings.

March meeting in Seattle:
http://www.aps.org/meet/MAR01/

Educational and Societal Issues, **A8**, Monday AM, March 12.
Physics Education for Non-Physics Majors, **C10**, Monday AM, March 12.
Revitalizing Undergraduate Physics Education, **G1**, Tues AM, March 13

April meeting at Washington, DC:
http://www.aps.org/meet/APR01/

The Physics Teacher Education Coalition: Physicists "Shaping the Future," **B5**, Sat. AM, Apr. 28.
Whither Advanced Placement?, **J5**, Sun. PM, Apr. 29
Recruiting and Retaining Undergraduate Physics Majors, **Q6**, Monday PM, April 30.
Recruiting and Retaining Women, **V5**, Tues. AM, May 1.

Plan to attend these interesting sessions!!

Results of the Member Survey

Ken Lyons, Web Page Administrator

A member survey was initiated in October on our website. The survey is intended to be an ongoing effort. Members can still access it, and the response records can be modified at any time. Now is a good time to review the results received to date.

At this writing, we have 697 responses, 530 from members. The survey drew nearly as large a web response as our election did last year. The respondents come from 26 countries, and 48 of the 50 states. In this article, I will give numbers from the total responses with the member response in parenthesis, unless otherwise stated.

One of the issues of immediate interest is delivery of the Newsletter. Of the respondents, 413 (404) said that they "always" or "frequently" read the Newsletter. Overall 45% (56%) of the respondents stated a preference for a paper copy. Of the ones stating a preference, the ones who read the Newsletter more frequently tend to prefer paper copies.

Frequency of reading the Newsletter	Always	Frequently	Rarely	Never
% preferring paper copy	76%	66%	41%	38%

The significance of the last column is unclear, but there appears to be a strong case for providing both modes of access. Those who pay close attention to FEd matters tend to prefer having the paper copy. But the roughly 15% of the members who "rarely" look at it, might pay more attention when it's available on the web. Presuming that this preference carries over to other members who have yet to fill out the survey (about 85% of our membership), this could mean that the web presence is quite important for these less-involved members. Yet, at the same time, the members who strongly support our activities favor the paper copy quite heavily, so doing away with it entirely may not be the best idea. Our current experiment along those lines is proceeding, so we shall see what future member feedback tells us.

It is interesting to note that among our 45 responding foreign members, fully 80% said that they always or frequently read the Newsletter, and, of those, 72% said that they prefer paper. So even our foreign members, who presumably have a harder time receiving the paper copy, prefer it to web access.

Another area of interest in the survey results has to do with the interests and concerns of our members. I've been able to look over the results and organize them according to the "votes" that various items received. I should hasten to add that this isn't really a voting procedure! If a small group is interested in an item, they can still have an impact, when they get involved. But the survey provides us with some idea of what is important to the members, as well as information as to whom to contact when opportunities for involvement arise. For example, only 27% of our members indicated an interest in political action, but that group could make a big difference if they act in a concerted manner.

In the tables below I'll report only member responses. What are members interested in or concerned about? The ones receiving the highest responses follow:

Member concerns and interests – top 7	
Undergraduate curriculum	427
High school curriculum	273
Professional development of current teachers	255
Graduate level physics education	220
Science content standards	204
Local alliances between teachers and physicists	202
Science teaching standards	183

Among the activities in which our members are involved either as volunteers or professionally, the following areas drew the heaviest responses:

continued on page 4

survey - continued from page 3

Member Involvement – top 10	
Undergraduate curriculum	397
Mentoring undergraduate research	382
Education of K-12 teachers	276
Science Fairs	260
Local high schools	239
Develop demo equipment	221
Weekend or summer science programs	205
APS/AAPT committees	182
Education research	182
Development of funding for student research	168

It appears that a good fraction of the respondents combined the volunteer and professional activities in that section of the questionnaire, so I don't think we can separate the two categories very easily.

The good news, I think, is that we have a large number of members who are interested and involved in important issues regarding education. The challenge is to find ways to tap into that pool.

There is a wealth of information in this survey, and as we go forward it should enable the Executive Committee to target approaches to members based on their interests in various areas. This capability will be important in fulfilling our charter goal of facilitating the involvement of our members in activities that benefit physics education at all levels.

Ken Lyons, a long-time contributor to the Forum, is a physicist at AT&T Research in Florham Park, New Jersey

Change in Web Page Administration

The arrangement for the FEd website has recently been modified. For the last five years, Ken Lyons has done a great job in implementing all aspects of the page, including static content and various interactive scripts, such as the elections, the summer jobs database, and the recent member survey. In the future, Jim Wynne has taken over the administration of the "static" content (that is, the information that is not generated in response to a query, but simply resides on the server), while Ken will continue to provide the services associated with active scripts. To the users, the change should be transparent, unless you look carefully at the URLs being displayed on your browser. Jim has set up the new pages on the APS server, and the web alias was switched to the new site in early January.

Letter to the Editor

Motivation and Improvement of Student Performance

Jeffrey A. Appel, Fermilab

It has become routine to call for improvement in teaching as the road to improved science and mathematics performance by American students. While there is certainly room for improved teacher preparation and familiarity with content, we also need to place some focus on student motivation outside the classroom. Since there is no single way to improve motivation across the full range of K-12 and higher education levels, we should be exploring options and solutions at all levels.

The largest increase in interest in science and mathematics probably occurred in the Sputnik era. At that time, science and mathematics were widely viewed as demonstrably necessary for the national self-interest. We were in a "space race" with the Soviet Union. It was a matter of national defense. Yet, much of what caught the attention of young students must have been seeing that Sputnik beacon of light crossing the clear night sky. And, not just students. Who did not look to see it at least once? America also poured money into a variety of science and mathematics projects - perhaps as quickly as research projects could be devised. There was no issue of whether one could hope to make a career of science. It was a national calling. The future would take care of itself.

Today, many have said that science and mathematics are necessary for our nation's economic security. We are in an economic race with the rest of the world.

continued on page 5

Letter to the Editor, continued from page 4

Yet, we do not have an equivalent of the Sputnik beacon for all to see. And we do not have American programs, which excite the young people—to judge by the declining enrollments of American students in science and mathematics curricula at the higher education levels. We do have science projects, which jockey for position with limited funding, even in a time of Federal budget surplus. We do have limited employment opportunities in some of the most attractive basic research fields.

Can we learn something about motivation from the Sputnik era which is relevant to today? Certainly, the situation is different in important ways. There was an environment which fostered interest in science and mathematics then. Some of that broader societal interest must be recaptured if teachers are to succeed in interesting a broader range of students to science and mathematics. Should we not be more aggressive in the support of basic science projects which will capture the interest of all?

AIP State Department Science Fellowship Program

This newly established program represents an opportunity for scientists to make a unique and substantial contribution to the nation's foreign policy. Under this new program, AIP will sponsor one fellow annually to spend a year working in a bureau or office of the State Department, providing scientific and technical expertise to the Department while becoming actively and directly involved in the foreign policy process. Fellows are required to be US citizens and members of one or more of the 10 AIP Member Societies at the time of application.

Qualifications include a Ph.D. in physics or closely related field. In exceptional cases, the PhD requirement may be waived for applicants with equivalent research experience. Applicants should possess familiarity with, or experience in, scientific or technical aspects of foreign policy. There is a stipend of $49,000 per year plus allowances toward relocation, in-service travel, and health insurance premiums. Applications should consist of a cover letter, indicating names of references, Ph.D. status, society memberships, and where you learned of fellowship; letter of intent providing reason for applying, scientific training and professional experience, foreign policy interest; resume; and three letters of reference sent directly. All application materials must be postmarked by April 15, 2001 and sent to: AIP State Department Science Fellowship, American Institute of Physics, ATTN: Audrey Leath, One Physics Ellipse, College Park, MD 20740-3843. For additional information, please contact Audrey Leath at aleath@aip.org or 301-209-3094.

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Physics First

Leon M. Lederman

For the past five years I have been campaigning to change the way science is taught in U.S. high schools [1]. In the vast majority of high schools, students' introduction to disciplinary science starts in ninth grade with biology. About 50% of students go on to a year of chemistry and one in four will take a third year of science—the dreaded physics. The sequence goes back about 100 years and is based upon the notion that physics is the most abstract and mathematical of subjects and should wait for some intellectual maturity and mathematical experience.

With the advent of science standards as promulgated by NSES [2] and AAAS [3], there is a strong move towards installing a three-year science and three-year mathematics requirement.

Now it is my firm conviction that the existing situation is pedagogically dumb; the subjects are not connected, ninth grade biology is a turn-off with a huge number of new words to memorize, very descriptive with very little if any of the syntheses that characterize the way science works. If there is any doubt, please see the article by Professor Uri Haber-Schaim that analyzes a variety of high school textbooks [4].

With the existence of standards, we have the opportunity of rethinking this sequence and crafting a core science curriculum of three or four years, suitably blended with mathematics. The current political recognition of the importance of education and in particular of science education offers the opportunity of achieving substantial reforms in how we teach science.

There is no reason why ninth grade physics cannot be made into an exciting and influential gateway to the study of science—all of science.

continued on page 6

Physics First, continued from page 5

If we truly love and feel passionate about physics, we should be proud to consider changing our style and accepting this obligation to introduce our subject to all high school students. Perhaps it would help to imagine that, in our freshman classes, there are future chemists, biologists, neurosurgeons, congressmen, journalists, TV anchors, voters . . . as well as future AP physics students who may be turned off from science by ninth grade biology.

I have been told by good high school physics teachers that, "we don't do freshmen!" Yet, physics teachers know that physics supplies the underpinning of much of chemistry and of molecular biology. Harold Varmus, Nobel Laureate, eminent biologist, former head of NIH, has continuously emphasized the need of modern biology for a strong physics [5].

We have organized ARISE [7] (American Renaissance In Science Education) to address the problem of a new curriculum. ARISE would suggest that the core sequence be arranged so that ninth grade is Conceptual Physics, using only the algebra that is being learned in eighth and ninth grade. Physics, largely mechanics, electricity and magnetism, is concrete, practical, dealing with issues and examples which may be drawn from real life just outside the classroom. As is well known, Conceptual Physics [6] is not easy to teach, but the degree of mathematics included is clearly adjustable and would depend on local circumstances.

However, the last month or so of physics would introduce atoms, their qualitative electrical structure, the relevant forces, and some introduction to the quantum nature of atomic structure. Molecules are studied as stable combinations of atoms, perhaps with reference to potential energy curves. The transition to tenth grade chemistry should be seamless with the productive repetition of atomic structure and binding from the chemistry point of view.

Chemistry is "the science of change," the study of the properties of substances and of the reactions that create new substances from old. Chemical change occurs constantly in the ordinary, visible world of daily life and has overwhelming practical importance. It is, however, best understood by reference to a rarely seen microscopic world of atoms and molecules. The two levels (macroscopic and microscopic) interact constantly in the modern practice of chemistry. The curriculum presents chemistry as a discipline that discovers, on the microscopic level, an underlying unity in the wildly diverse macroscopic changes that condition our lives [7].

Simple chemical bonding theory, electronegativity, electrons and electron dot structures lead to molecular geometries in three dimensions and the introduction to molecular biology. We are now in eleventh grade biology. In this physics-first approach, students are well grounded in the basics of atomic structure and molecular interactions. This enables the teacher to emphasize how structure naturally supports function. For example, many molecules form polymers: What differentiates one type of polymer from another? How are these fundamental components used in various combinations leading to the diversity of life? The appreciation of simple principles derived in physics and chemistry enables the students to understand the natural rise of complexity.

This course begins with the molecule and progresses to the cell, on to the organism and finally to the ecosystem. Everything in the course is connected to survival (natural selection). Reproduction is explored at a genetic level, and then content moves to the environmental level.

Understanding the structure and function of the cell—the basic building block of life—is the optimal way for students to understand life at and beyond the level of an organism. Treating cells as the fundamental unit, the curriculum asks: Why are cells useful? How do they respond to changes? What do they need to function properly? What consequences arise from improper functioning? Similar questions can be applied to the organism and the ecosystem. A high school biology course should also include enough human biology to equip students for making informed decisions about their lives.

Overall, this approach aims at enabling students to become decision-makers in an ever-changing world, a world where the tools of molecular biology are so powerful that humans have the unprecedented ability to alter both themselves and the environment that sustains them.

Issues connecting the disciplines are many, e.g. conservation of energy and energy states, vibrations from simple harmonic motion to microwave spectroscopy, photoelectric effect to photosynthesis, and, most importantly, the nature of science thinking. I believe this new, coherent curriculum can be made to blend in components of science process: how does it work, why is science different from other fields of learning, how do we know these things, some history and the need for skepticism, openness, the need for verification.

Societal issues should also be dispersed through the curriculum. Hands-on, experimental components, inquiry, the lessons of cognition science must also be blended in. Clearly fewer topics will be covered and subjects which link the sciences should receive priority.

The net result will be high school seniors with a respect and enthusiasm for science, equipped for lifetime with a science way of thinking. Senior year can have a rich offering of the applications of their core knowledge, especially to earth and space science, but also to environmental science, to science, technology and society (STS), or to the array of AP courses in each of the core disciplines.

continued on page 7

Physics First, continued from page 6

In general, the senior year should be a year in which the three years of high school work are integrated and applied in interdisciplinary projects. In a more ideal world, college admissions, usually done in December, would be conditional to the successful completion of the senior year program.

The new sequence has large requirements for new resources: new teaching materials, extensive and continuous professional development, regular meetings of the teachers of sciences to coordinate their course work, enrich examples, seek connections and, perhaps most visionary, include in these conferences the teachers of the arts, humanities and social sciences to present the future citizen with a sense of the unity of knowledge.

Implementing this program faces very impressive obstacles. However, we have located over 100 high schools around the nation that have installed various versions of "physics first". Many of these schools have very positive experiences with this "kinder, gentler (and more logical)" introduction to science. The crucial issue is: Can we get schools to change? It is fortunate that physicists suffer the genetic defect of optimism.

What can physics teachers do? I believe they should join this campaign for a rational science sequence as part of a science core curriculum. There are clearly all kinds of variations on the scheme I outlined. The act of fixing this glaring defect in our schools may well permit even more dramatic reforms in our schools. It should propagate change down into middle schools and up to college science courses. In this 21st century, we need a seamless science education, internally coherent and in harmony with the social sciences and the humanities, stretching from pre-K to grade 16.

Suggestions and advice from the physics community would be very welcome.

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Leon M. Lederman is the Director Emeritus of Fermilab, and holds an appointment as Pritzker Professor of Science at the Illinois Institute of Technology. The Nobel Prize-winning physicist is a founder and resident scholar at the Illinois Mathematics and Science Academy in Aurora, Ill., a public residential high school for the gifted. He is also a founder and the Chairman of the Teachers Academy for Mathematics and Science in Chicago.

Science Centers for the 21st Century

David A. Ucko

Science museums and science centers have undergone great change over the past century. With few exceptions, there has been a pronounced shift during this period from collections and research towards education. Key milestones included the opening of the Museum of Science and Industry in Chicago in 1933 and the Exploratorium in San Francisco in 1969. Each exemplified a different approach: the former focused on large exhibits communicating information about fields of science and technology; the latter emphasized smaller-scale exhibits allowing direct manipulation of scientific phenomena. Today, science centers are beginning to explore new approaches as their external environment changes and as we gain knowledge about the nature of informal learning.

The number of science centers has grown more than tenfold since the founding in 1973 of ASTC, the Association of Science-Technology Centers (www.astc.org). Other types of institutions, including children's museums, zoos, natural history museums, planetaria and botanical gardens, have become members of ASTC as well, indicating the influence of the hands-on educational approach stressed by science centers. The popularity is also seen in the adoption of science center exhibits by commercial enterprises, such as theme parks, retail stores, fast food restaurants, and even cruise ship lines. This imitation is rarely seen as flattery by those in the field, although one can argue that the public benefits from the increased exposure to science, albeit less "pure." The marketplace has become more competitive for science centers as a result of the growth of the field, the increased adoption of the techniques these institutions pioneered, and the expanding numbers of ways in which families can choose to spend together their limited leisure time.

continued on page 8

Science Centers, continued from page 7

Over the same period, knowledge about learning in general has increased nearly as dramatically (see www.nap.edu/books/0309070368/html for a recent overview). When I entered the field from academia more than two decades ago, a question still being asked was how to demonstrate that visitors to science centers were actually learning. It was obvious to those in the field that education was taking place, but in a form very different from the classroom, making school-based measurement tools inappropriate. Today, one need only peruse Falk and Dierking's "Learning in Museums: Visitor Experiences and the Making of Meaning" (AltaMira Press, 2000) to find the growing body of research that clearly shows how informal learning in particular occurs. Their contextual model of "free-choice" learning identifies the importance of the personal, sociocultural and physical contexts of the museum visit. The nature of the impact differs greatly from visitor to visitor and may not become obvious for weeks or months. As the authors summarize, "in the end, what individuals learn depends on their prior knowledge, experience, and interest; what they actually see, do and talk and think about during the experience; and equally important, what happens subsequently in their lives that relates to these initial experiences."

During the coming years, science centers will need to continue to innovate and evolve. As Beverly Sheppard notes in "The 21st Century Learner" (Institute of Museum and Library Services, 2000): "The profound changes of the 21st century are transforming America into what must become a learning society." Science centers are well positioned to play an important role in our knowledge-based economy. Just as science itself continues to advance, science centers also must seek ever more effective ways to first attract visitors and then provide self-motivating experiences that enable them to create personal meaning. Their niche is "recreational learning," since non-school group visitors must come by free choice as a leisure activity. According to Mark K. Smith (George Williams College), "the point of education should not be to inculcate a body of knowledge, but to develop capabilities…The most important capability, and the one traditional education is worst at creating, is the ability and yearning to carry on learning." His statement encapsulates the special role that can be played by informal learning at science centers. The challenge is to engage the visitor as completely as possible in ways that make learning intrinsically enjoyable.

As an example, the approach we took when creating Science City at Union Station (www.sciencecity.com) in Kansas City was to create the totally themed environment of a city for visitors to explore, rather than exhibits. Over 50 different city settings, such as the Crime Lab, high-rise under construction, Music Park, and R&D Lab, let visitors engage in hands-on adventures based on science and technology. Costumed characters ("interactors") who "live and work" in Science City enhance and enrich the immersion experience, which places science into everyday context. The environments and experiences within them were based on market testing to ensure audience appeal, a prerequisite to engagement and discovery. This approach lent itself well to a science center designed to serve as the educational attraction of a new kind of urban entertainment center within a restored historical landmark. In a related direction, the "Adventure"

Science City

exhibit at the new COSI in Columbus (www.cosi.org) take visitors on a mythic quest drawing from the storytelling techniques of themed entertainment.

There is no single formula, however, for communicating science and encouraging inquiry. The approach must follow from the institution's specific mission, audience and location. For example, the Weizmann Institute of Science created a "Garden of Science" making use of Israel's favorable climate (www.weizmann.ac.il); similarly, science centers in India heavily use outdoor exhibits (www.ncsm.org), and the New York Hall of Science has created its own Science Playground (www.nyhallsci.org). For some institutions, the Internet is playing an ever-expanding role. The Exploratorium (www.exploratorium.org) and Franklin Institute (www.fi.edu) among others are devoting major efforts to using the web to encourage science learning beyond the limits of their physical facilities. Many institutions have created innovative educational programs, even creating direct links with on-site or nearby public schools and their curricula. More and more science centers are collaborating with libraries, community-based organizations, and other local institutions to develop synergies that enhance the impact of each partner.

Here at the National Academy of Sciences, we are beginning to create a science center that will draw upon the uniqueness of this institution, its prominent elected scientist members and the public policy studies carried out through its National Research Council. We are looking at ways to create exhibits and programs in Washington that draw from this content-rich organization, rather than those that might be more appropriate to a science center based elsewhere. In addition, we are seeking ways to share Academy-developed content with other science centers and organizations nationally and internationally.

continued on page 9

Science Centers, continued from page 8

Such efforts cannot only help these institutions address the needs of their local audiences but also leverage the resources of the National Academy. I would welcome the thoughts of APS members as we develop our Marian Koshland Science Museum (ucko@nas.edu).

Physicists can play an important supporting role. Many science centers, particularly smaller ones, lack depth in scientific resources.

Faculty can serve as advisors, volunteers, exhibit developers as well as encourage their students to become involved. In these roles, conveying the excitement of physics, going beyond the textbook by adding human interest and humor, would add great value. Researchers can include funds for outreach in their grant proposals and work with local science centers on ways to communicate their work to the public.

One of the most effective synergies might be working jointly with science centers on physics demonstrations developed for the classroom. Through modifications made with science center staff familiar with families and school children, these demos could reach far wider audiences. Try inviting someone from your local science center to the summer AAPT workshop session on physics demonstrations in exchange for an invitation to the ASTC Annual Conference held in October.

By creating linkages among "communities of educators," we each will be better able to serve the needs of our "communities of learners." Such cross-fertilization can bridge traditional boundaries, helping to transform the community at large into a campus for learning in the 21st century.

David A. Ucko, Ph.D., is Executive Director of the Koshland Science Museum and Science Outreach, National Academy of Sciences, Washington, DC

They're Having Fun...But Are They Learning?

Alan J. Friedman

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One hundred million people visit science centers each year, and equally huge numbers visit zoos, botanic gardens, natural history museums, and planetariums. Most of these visitors are families with school-age children, and children on school field trips. All of these informal science-learning institutions feature education in their mission statements, and indeed it is education that is most often cited by parents and teachers as the reason for the trip.

However, if you go along on a school field trip or take your family to any of the popular informal science institutions, especially on a busy day, what you see doesn't necessarily look like a learning experience. Everybody seems constantly in motion; there is a great deal of noise, laughing, and flashing lights. The children are clearly having a great time, and it is often hard to get them to leave at the end of the visit. But are they learning anything?

You can't tell by just looking

How can we tell whether our children are learning during a museum visit? Learning is rarely something we can observe by just watching, either in a museum or in a classroom. There is certainly a traditional view of the look of learning: it is what happens when an individual sits quietly and reads a text carefully, or listens attentively to a teacher, or concentrates hard on what he or she is figuring on a piece of paper. The last twenty years of research, however, have made it clear that learning is not so simply evaluated. A summary of this research was presented by an eye-opening video, A *Private Universe*, made by the Harvard-Smithsonian Center for Astrophysics. The video begins by interviewing Harvard liberal arts students on their graduation day. All had taken and passed introductory science classes. Yet when asked to explain basic phenomena of nature, like the phases of the moon, these students quickly got into trouble. It was clear they had forgotten what they supposedly learned in their classes, and fell back on naive notions (clouds cause the moon to look like a crescent), similar to those of elementary school-age children.

What looked like traditional learning in their Harvard science classes turned out to be only short-term memorization, quickly forgotten. Of course, these students did learn other things, particularly in their major fields and in classes that covered topics of passionate interest for them. What determines when learning really occurs, and when it only appears to be occurring? That's one of the key questions for current research. One preliminary finding is that having passionate interest in a topic is an excellent predictor that learning will occur.

There is also increasing research on learning outside of the classroom and the school-based curriculum. Just as conventional learning methods must be studied carefully to tell whether or not they are working, recognizing learning in the informal setting is not a simple matter of noting the level of noise or motion.

What we are learning about informal science education can help parents and teachers take the best advantage of the remarkably rich resources, which happen to be outside of the school building.

continued on page 10

Having Fun, continued from page 9

What learning looks like outside the school curriculum

> Few of us would deny the effects of our parents' influence...or our hobbies...or early experiences of travel and role models. We have long felt that participation in Girl Scouts and Boy Scouts is an important part of growing up and many of us can fondly recall the excitement of a secret decoder ring. We can still remember a particular day at the zoo or a visit to see DINOSAURS in the museum! But we don't remember learning something: learning is that painful thing that happens in school.
>
> —George Tressel, *in Informal Science Learning/What the Research Says.*

While not every exhibit works as an effective educational tool for every visitor at every moment, we have hard evidence that measurable learning does indeed take place in typical museum and science center settings. There are now hundreds of studies available to help us define and improve that learning.

- In a major study at the Franklin Institute Science Museum in Philadelphia, children in grades 7 - 9 were given both pre-visit and post-visit tests of science content. The results showed significant increases in scores as a result of the visit.

- A traveling exhibition on viruses developed by the New York Hall of Science was tested in New York and in other museums around the country. Teenagers who used the exhibition doubled their scores on several important questions about how a virus is transmitted from person to person.

- A study at the Natural History Museum in London demonstrated that even children who were not observed to read any labels on the exhibits nevertheless learned information that was only available on those labels. Apparently the information was transferred from those children and adults who did read to the ones who did not read, during casual conversations while walking through the museum, on the school bus or in the car, and over dinner or breakfast the next morning.

The other dimensions of learning

While studies like these measuring content learning are encouraging, learning in a museum or other informal setting is very different from classroom learning. We must be careful not to miss these other forms of learning, such as the acquisition of interest in a topic, which may be even more important results of a successful informal learning experience.

> The conditions of museum learning are very different from those of the classroom. Museum learning is self-directed rather than directed by a teacher. Exhibits replace the teacher as the central medium of instruction. Objects instead of words are the principal currency of discourse....There is no compulsory attendance law, career placement office, or even beloved teacher to induce attendance.
>
> —*Willard Boyd, in the preface to The Museum Experience*

One of the most striking demonstrations of how different the museum experience is from the classroom is the mad dashing about that we see, especially on the part of early elementary children at the beginning of a visit. Research is helping us understand what is going on here.

First, because informal science institutions are free choice environments and therefore offer as many attractive choices as they can pack in, getting the most out of a visit (at least a first visit) encourages many short stays, often only half a minute or so, at each station. Children especially want to be sure they have seen everything. Remember how terrible it was when you were a child to discover that you had somehow missed the very best thing in the museum/mall/circus (or at least so your older sibling assured you)?

Two kinds of learning are happening when children burst into a museum for the first time. In the beginning, youngsters are building up a mental catalog of what experiences are available. Towards the end of their visit, they will come back to a few exhibits that especially aroused their interest, even if they seemed only to push the button and run during the first time around. Youngsters also need to acquire a mental map of the environment to make it theirs. While they are too young to understand the kind of schematic map we put on the walls, physically being in every space and locating its landmarks (big objects) is a good way to construct a mental map. This cataloging and map-making activity helps explain why young visitors' stays at exhibit units tend to be short at the beginning, and to grow after the first circumnavigation is complete.

Finding passionate interests

Learning in the affective domain, creating those deep interests that motivate later learning both within and outside of the classroom, is another part of the informal learning experience that we have been discovering how to measure and study. Key elements in this kind of learning at museums include:

- Making quick connections between what is personally known and something new, resulting in new associations and relationships
- Having an authentic experience: seeing the real stuff (e.g., objects, artifacts, animals), or experiencing actual phenomena, or having access to the accurate, simulated device

continued on page 11

Having Fun, continued from page 10

- Having experiences that involve naming, identification, observation, imagination, fantasy, imitation and role playing, cooperation, demonstrations and discovery
- Being able to covet objects (guiltlessly)

—Stephen Bitgood, Beverly Serrell, and Don Thompson in *Informal Science Learning/What the Research Says...*

Some of these experiences can be accomplished in the classroom, especially with well-trained teachers and good curricula. Video, the Internet, and visiting experts can help. But museums, zoos, and other informal learning institutions are uniquely equipped to provide a great variety of appropriate settings for affective domain learning. What we learn on our own, and can think of as our own personal discovery, often has the most lasting effect.

My favorite early indicator of the success of an exhibit is observing a child suddenly step back from the exhibit, look around, and call out "Hey -- come look what I found!" Whether or not that child understood the full science content of the exhibit, whether or not he/she learned the correct scientific terms to use in describing it, it is clear that the child has just claimed ownership over something scientific. If that ownership can be nurtured, reinforced, and connected to later experiences, the basis for a lifelong hunger to learn may soon be in place.

Evidence for this process also comes from interviews with scientists about their earliest experiences with science. They often cite visits to museums as early sources of their interest, and can describe in remarkable detail a particular exhibit they saw 40, 50, or 60 years ago. The first glimpse of Tyrannosaurus at the American Museum of Natural History; the ball that bounced repeatedly up and down on the polished stainless steel plate at the New York Museum of Science and Industry; the first appearance of the stars on the dome of the Adler Planetarium in Chicago: those experiences, vividly recalled decades later, were critical elements of creating a lifelong, passionate interest in learning.

Suppose they don't know the words?

Measuring vocabulary is one of the easier ways to test learning. That's unfortunate, because learning vocabulary is one of the least important parts of learning science. However, it's often what is used to decide whether today's classroom experience or museum visit was worthwhile. "What did you learn today?" rarely gives a useful picture of what was actually learned. Many studies (like Jeff Gottfried's seminal thesis work at the University of California, Berkeley, studying children in the weeks after a field trip to a museum), demonstrated that children are much better at presenting their experiences to other children then they are at summarizing their learning with what adults regard as the proper vocabulary. A better way to ask, "What did you learn today?" would be to ask "How would you explain to your cousin what you did today in the museum?"

Of course we want children to learn the proper vocabulary eventually. They will need the words and the mathematics to communicate efficiently as their learning develops. Classrooms are usually better places than museums for learning vocabulary. But learning vocabulary either before or in the absence of internalization of the concepts and the generation of interest is likely to be a short-lived success, as the Harvard graduates demonstrated.

One of my favorite exhibits at the new Science Playground exhibit at the New York Hall of Science is the Standing Spinner. The Spinner is a merry-go-round for one. You hold onto a post in the center, which rotates with you. If you stand on the platform and shove off with one foot, you begin spinning around. The fun part is leaning in or leaning out. If you lean out, you slow down, nearly to a stop. But lean in, and you recover nearly all of your original speed. Lean out again, slow down. Pull in, and speed up. When you finally stop, you are dizzy and exhilarated.

You slow down when you lean out, and then, mysteriously, your lost speed comes back merely by leaning in. Where did the speed go in the meantime? What was it about leaning in that brought it back? It took some strain on your arms to pull yourself back in--was that connected with recapturing your speed? When you really want to know the answers to those questions, then you are ready to learn the words and the mathematics, and you can look forward to the classroom lesson on the physics of spinning bodies.

Did you learn any science at the Standing Spinner? Unless you read the pamphlet/guide, you probably did not learn the words "conservation of angular momentum" or "conservation of energy," and it is even less likely that you learned the equations which describe angular momentum and energy in terms of mass, velocity, and distance from the axis.

As a physicist, I certainly would want you to know the language, both English and mathematics, so that we could discuss the conservation of angular momentum in all its universal majesty (and it is a majestic concept). But I'd much rather you started out learning the feel of this remarkable phenomenon, and then learned what to call it and how to measure it precisely.

We still have a great deal to learn about learning, both inside and outside of the classroom. But at least one fact is clear:

continued on page 12

Having Fun, continued from page 11

learning and fun are not contradictory experiences. There may well be learning experiences, which are dull, and fun experiences, which involve no real learning. Reassuringly, there are also lots of experiences which are filled with both.

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Serendipity Times Two

John L. Hubisz

I'm firmly convinced that the key to scientific literacy in this country lies in the Middle Schools (called "Jr. High" in some places.) Part of the problem with the poor textbooks and the poor preparation of teachers at this level lies with us, and we have to do something about it. Let me suggest something from my own experience.

Many years ago I got a frantic call from a mother whose 5th grader was having trouble in school. Apparently he was very bright and extremely advanced in science and mathematics, but didn't want to do anything in his other subjects. He was very disruptive in school and the teachers didn't know what to do with him. I suggested that she bring him out to the college after school on Mondays and Wednesdays and leave him with me in my laboratory and pick him up by 8:45. I kept him busy with puzzles and problems and books and got him to help setting up and taking down labs. He enjoyed talking and working with my students. He even served as a good lab assistant. He certainly wasn't a bother and his troubles at school disappeared.

Sometime later his mother told me that she was taking both boys to San Francisco for a week while her husband attended a conference and wanted to know where she might take them. I immediately recommended the Exploratorium. I suggested other places if she could get them away from the Exploratorium. She couldn't and didn't. On returning the first thing that she wanted to know was how we could get a hands-on museum for Galveston. She did the work. She got board members from all the right places, got the Rosenberg Library to donate space for a monthly lecture series, and arranged for incorporation of "Science, Inc." Besides the lecture series (always packed even for Saturday morning talks), we had summer programs for children (so oversubscribed that even with extra sessions added we couldn't handle all those who wanted to take part). We also got the high school science fairs started again after a lapse of many years. We got small grants to build hands-on equipment from Exploratorium plans that were then cycled through the schools and we even got a building for a year, but that's another story.

Sometime later I was attending a meeting in a building that was the #1 tourist attraction (next to the beach itself) on the Island. During the break I took advantage of the "free admission" to wander about the building. I passed by a room where another group was meeting and could hear that they were talking about education. I slipped in. The attendees were almost all women and they were principals and assistant principals for the most part. At that point the discussion was about inviting speakers to the elementary schools. One woman expressed concern that they wouldn't be able to get scientists to come to elementary schools. I got the moderator's attention and pointed out that I had been running the lecture series at the Rosenberg Library for some time now and no scientist had ever refused to come and talk. Scientists love to talk about their work and it allows them to sit back and think about their work in a wider context. I mentioned that I had talked to kindergartners, Cub Scouts, service organizations, and just about every grade level about physics. I said I would be glad to help get speakers and left my card with the moderator and went back to my meeting.

Two weeks later I got a call from a school principal who had heard that I would be willing to help improve science and mathematics in elementary schools and would I come out to her school. Not quite what I had said I would be willing to do, but I agreed. Apparently the school board was concerned that while the school scored 2-3 grades above the national average in recent tests in most subjects they were

continued on page 13

Serendipity, continued from page 12

2-3 grades below the national average in science and mathematics. She wanted help in science and mathematics at all grade levels (K-6). I didn't know what to do so I started rummaging around storage spaces, talking to teachers, talking to classes about what they were doing, and so on. Requests for me to talk to classes increased so much that the principal had to set up a sign-up sheet for teachers to make specific requests. Each Wednesday I would get a call listing the classes that I would visit on Friday and the topic that the class was studying. It was a lot of fun and the students had great questions. I opened boxes of science equipment that I had found at the school and did demonstrations or more often got the students to do experiments. Realizing that there were no competitions in either mathematics or science like the ones that they had in most of their other subjects I designed a Physics Faire for students in grades K-6.

I made up simple rules and discussed them in all the classes. I trained judges in techniques for asking questions and made certain that parents and others were not allowed in the area while judging was going on and two of the questions had to be "How much help did you have?" and "What question were you trying to answer with your experiment?" Physics (capital "P") was defined as "natural philosophy" and there were four categories for entrants to choose from: biology, chemistry, geology, and physics (small "p"). The first Faire was very successful. The librarian declared that the library had never been used so much. A nearby elementary school asked to be included for the next year and they were and we had our first inter-school Faire held for the winners at all grade levels. Within three years we had 23 schools including home-schoolers (slightly modified rules) and over 300 entrants taking part in the countywide Physics Faire.

Within four years the original school scored 2.5-3 grade levels above the national average in science and mathematics in the same tests that started the project. I met many of the students over the nine years that I was directly involved with the Faire who credited their interest in science with the Faire. It continues with a former assistant of mine who went on to get a master's degree in physics and who is now a high school physics teacher.

None of this was planned. We can't tell what efforts might be rewarded, but we have to try. Become aware of the materials that can help Middle School teachers (e.g., **Powerful Ideas in Physical Science** from the AAPT and **Enhanced Science Helper** CD from the Learning Team.) Donate a CD or a set of PIPS materials through your local PTA. Visit your local Middle School. Volunteer!

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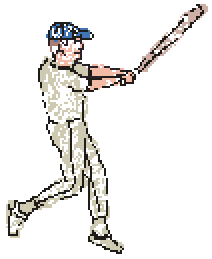
Why is a Sammy Sosa Home Run Like a Higgs Boson?
or *What's a Meta For?*

Judy Jackson



Everyone agrees that scientists need to do a better job of communicating what they do and why it matters. It is a rare science policy speech that fails to exhort scientists to communicate more and better. A recent quote from Congressman Vern Ehlers, member of the House Science Committee and one of two physicists in Congress, captures the prevailing tone.

"The scientists have done very badly," Ehlers said, "in terms of communicating with Congress and keeping Congress and the public informed—in an explainable way—what they're doing and why it is important."

While all scientists are tarred with the bad-communication brush, it often appears that physicists are tarred the blackest. Physicists above all others, say those both outside and within the field, are failing to get their message across. The clear implication is that the physical sciences would not be experiencing their current funding troubles if they would simply improve at explaining what they're up to. As a case in point, many cite the Superconducting Super Collider. Never mind the gazillion-dollar cost overruns, this line of thinking goes, if physicists had only done a better job of talking up the Superconducting Super Collider, we would be smashing protons under Waxahachie today.

It is true that it is critical to communicate from the science community to the rest of the world, not only for reasons of funding. It's also true that if it were easy, we would have done it already. It isn't easy. It's hard. And is it just me, or is it especially hard for physicists?

Think about it. Biology is easy to sell. Putting aside the benefits of medical research, it seems obvious that it's a good idea to study living things: *we're* alive, aren't we? Cosmology and astrophysics have a similar advantage: perhaps it's in human genes, a relic of our nomadic hunter-gatherer days of gazing heavenward for guidance while we wandered in the wilds, but for some reason, everybody loves to look at the stars.

Continued on page 14

Sammy Sosa, continued from page 13

The geologists have dinosaurs, one of the branding success stories of all time. True, chemistry's image has a certain down side, (Does the word "Bhopal" mean anything to you?) but the chemists surely have one of the great tag lines of the ages. "Better living through quantum mechanics" just doesn't have the same ring.

Physics, by contrast, is a hard sell. Why? Because, from the point of view of general comprehension, when physics left the realm of the visible at the end of the 19th century, it entered the world of the abstract. For all practical purposes, to those outside its own rarefied precincts, physics left reality behind and became an abstraction.

Of course, quantum mechanics and relativity have as much to do with the solid reality around us as does the structure of DNA or the fossil of a dinosaur. Maybe more. And true, quarks are every bit as real as viruses or stars. Nevertheless, to the average bystander they don't *seem* as real. They seem less like things you can touch and see and more like…..math. And, as anyone who has tried will tell you, if science is a tough sell, math is impossible.

So physicists did what they had to do when faced with the problem of communicating the abstract to a math-challenged world: they turned to metaphor. From the football-field-with-the-nuclear-pea-at-the-50-yard-line-and-the-electrons-in-the-stands atom to the bowling-ball top quark and Campbell's Cream of Primordial Soup, the search was on for the metaphors that would bring physics back from incomprehensible equations to understandable—and fundable—life.

It's a never-ending search, the metaphor hunt. A recent spate of news stories prompted by the CERN-Fermilab rivalry for discovery of the Higgs boson turned up many old favorites, as well as some interesting new examples. Predictably, a particle accelerator, or "atom smasher," is compared to "a giant racetrack," or "the world's largest microscope" or a "time machine" reproducing the Big Bang (which itself began life as a metaphor but has by now crossed over into existence as a more or less scientific term for a real phenomenon). The Higgs, again predictably, is "molasses-like goo" or "cold molasses" or "subatomic molasses." Peter Higgs, the physicist who started all this, is "ATLAS, a mythical figure with the weight of the world on his shoulders," which weight will only be removed with the discovery of the Higgs, to help shoulder the load.

Particle detectors look like "space ships" or "rockets on their sides" or "cathedrals" or, in one case, "a shopping mall." (There's more to that concept than meets the eye.) Particle collisions produce a "spray like shrapnel" yielding a "zoo of particles," or a "smashed watch" that physicists must reassemble from the scrambled springs and gears.

So far, so familiar. However, a recent Chicago Tribune story by Ron Kotulak yielded this delectable home-grown image of how physicists detect what comes out of a high-energy particle collision: "It's like standing on the corner of Waveland Avenue and watching a Sammy Sosa home-run ball come sailing out of Wrigley Field." The particles then "fall back into their low-energy state and become invisible again, just as Sosa's ball is quickly whisked away by a souvenir hunter."

Like Sosa, that description of particle detection is hard to beat.

One story compared physicists to wild geese, migrating to the high-energy physics lab with the highest energy. Another evoked CERN scientists as hungry souls with their noses pressed to the restaurant window while Fermilab experimenters sit down to dinner inside, presumably to a feast of roast boson under glass.

"A basic prejudice of the universe" for matter over antimatter perhaps does as good a job as any of explaining that peskily difficult concept, CP violation. And I know that I, for one, have a much clearer idea of how to produce quark-gluon plasma now that I understand that the interaction regions of Brookhaven's RHIC accelerator are "75-ton rings of steel, looming like giant handcuffs."

Hey, some metaphors work better than others.

And, in fact, feelings run high on the subject of just which metaphors work best for conveying the essence of frontier (now there's a metaphor that should be receiving overtime pay) physics. Among particle physicists, sharply different views, verging on dogma, have emerged about how best to describe high-energy physics. The partisans of the accelerator-as-giant-microscope school froth at the mere mention of accelerator-as-recreator-of-Big-Bang; while Big Bang adherents smile patronizingly at the microscopists. At times, it can feel like metaphor warfare. Maybe it's a physicist's need to reduce the complex world to a set of mathematical laws that makes it hard to accept that both of these metaphors work sometimes, neither works every time, and that occasionally they even work together.

When Mrs. Bartlett taught my ninth-grade English class about figures of speech, she used an example of metaphor that has stuck with me for 40 years, although its source eludes me: "The truth is a hard deer to hunt."

The truth *is* a hard deer to hunt. Physics is all about the hard hunt for truth, and the search for words and images to communicate the excitement of the chase and why it matters to us and to society is almost as hard. We're never going to find the single perfect formula for explaining it. But with a glorious mix of metaphors—stars, home runs, microscopes, shopping malls, handcuffs, whatever—we'll all die trying. Metaphorically.

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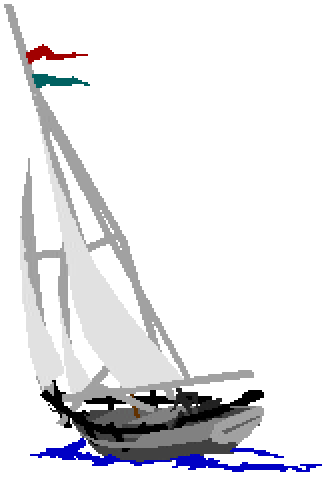
The Tale of a Leaky Boat

Howard Goldberg



Let me tell you a story of a leaky boat. A boat so leaky it may not float. But the leak can be fixed, with a little grit, and as the story unfolds I'll tell you how to do it.

The prelude to our story begins in September 1974 when my eldest daughter came home with her 2nd grade science book. It was amazing. Dozens of topics in Biology, Astronomy, Chemistry, and Physical Science. Page after page of text and highlighted words. Where was the mathematics, the experiments, the organization of science? Nowhere. It was science as language arts. The true language of science, mathematics, was ignored. So, David Boulanger in the College of Education at UIC and I, in Physics, decided to do something about it, and started a teacher education course that tried to show how math and science could be integrated into the curriculum through hands on quantitative experiments in grades 1 through 8. Soon Phil Wagreich from the math department joined us, and by 1978 we had our first NSF grant to train classroom teachers in the Chicago area on the experiments and ideas we had developed. The teachers in turn tried them out in their classrooms and came up with new ideas for experiments. It was great fun and the results were encouraging. But one teacher in a school does not a curriculum make.

So in 1987, when our story begins, we received an NSF grant for a five-year program to introduce TIMS (Teaching Integrated Math/Science) into 11 Chicago area elementary schools. Besides the idea of integrating math and science, TIMS focuses on the fundamental variables of science (length, area volume and mass and graduates to density, velocity, acceleration, force, work and energy), stresses the processes of carrying out an experiment, works hard to develop higher level thinking skills such as multi step logic, all the while using mathematics as the language of science. Balls bounce, drops spread out on paper towels, carts roll, as the children immerse themselves into the whirlpool of math and science.

TIMS tries to present a very systematic picture of science. Each experiment has two primary variables and one or more controlled variables. In the case of the two primary variables, the children set up the appropriate values of the manipulated variable, say the drop height of a ball, and measure the value of the responding variable, the bounce height. The floor and type of ball are the controlled variables. To provide a conceptual framework in each experiment, the children follow a 4-step format that contains the essence of the scientific method:

1) They draw a picture and identify and label all the variables.
2) They set up and record their measurements in a properly labeled data table.
3) They graph their results, and yes every experiment requires a graph.
4) They answer a wide range of questions that involve reading graphs, making and checking prediction, changing the controlled variables and finding out what happens and why, and do lots of proportional reasoning.

In TIMS we have also stressed 4 types of experiments:

1) with strongly correlated primary variables (like the Bouncing Ball)
2) with weakly correlated variables (like Arm Span vs. Height or plant growth)
3) Classification experiments (how do I organize systems with multiple properties like color, size and shape)
4) Probability experiments (like rolling dice, flipping coins, counting pockets).

TIMS supplies the student lab write up with room for pictures, tables, graphs and with questions, and for the teachers a Teacher Lab Discussion (TLD) for each experiment and a TIMS tutor for each variable. There is also a set of pre- and post-tests. (To purchase a CD-Rom of the 147 TIMS experiments, the TLD's, Tutors and Tests call Kendall/Hunt at 1-800-542-6657)

During the first year of our story (August 1987 to June 1988) we trained two lead teachers from each school who in turn, during the second year (September 1988 to June 1989) presented one experiment per month, in each grade, to their colleagues and together with their colleagues (and help from us) implemented these monthly experiments with the children. Each experiment lasted a week, so that by the end of the second year the 210 classroom teachers and 5000 children in the 11 schools had experienced 10 weeks of integrated math/science.

The 11 schools were chosen with an eye toward racial and ethnic diversity, as well as a range of student achievement as measured by the Illinois Goal Assessment Program (IGAP). Four schools placed in the upper end of the achievement scale, three in the middle and four at the low end. The participating children turned out to be 5% Asian, 41% Black, 22% Hispanic and 32% White.

Continued on page 16

Leaky Boat, continued from page 15

Thus we had a nice mix of students and a broad range of scores on the standardized tests.

Before the children started doing the experiments we gave them a TIMS pre-test (Sept '88) to see how well they knew the ideas we wanted to teach. There were questions on length, area, volume, mass, density and velocity; on manipulating and controlling variables; on reading and making graphs; and on proportional reasoning. There were word problems and picture problems, altogether a total of 39 questions. We then administered 4 post-tests (in June '89,'90,'91,'92) to measure what we hoped would be the sustained intellectual growth of the children. So that you can see where we are starting from, consider our first question. The children are shown a ruler and a rod placed parallel to and at the center of the ruler. They are asked to tell us the length of the rod. We thought this would be a snap. You can imagine our amazement when only 2% of the 2nd graders and only 30% of the 8th graders could answer the question. Inner city--outer city, it made no difference. And things only got worse as the questions got harder. So, whatever the children had been learning, it wasn't much. But, after one year of TIMS, 30% of the 2nd graders and 70% of the 8th graders could answer the question correctly. But it wasn't 100% and that is the reason we had a five-year program. The 2nd graders become 3rd graders but continue to see new experiments that probe the same basic concepts but in a wide variety of settings. We hoped this would result in a continued improvement. And indeed that is what we found. By the 5th grade 80% of our starting 2nd grades could now answer the question correctly (and most others too), but we began to notice some odd things going on and this is where our story takes a couple of strange turns.

Two years into the program one of our lead teaches asked us to write a letter of recommendation so that she could move to a higher paying teaching position at another school. The opportunity arose because her TIMS training made her a math/science "expert" and, therefore, marketable. This was the first of many lead teachers who left their schools. Greener pastures, early retirement, transfer by the district of other school, you name it, we saw it. But the end of the five years only half the lead teachers remained; we had no inkling this would happen. But this leak was nothing compared to the hemorrhaging of principals. You can imagine our shock and disappointment to find only 3 of the 11 principals remained in the schools after 4 years. One tragically passed away but several retired or went to new schools. Taken together only one of the eleven schools retained both its lead teachers and its principal. That is a batting average of 0.090, which is not very good in any league.

Now we come to the cohort of the original 2,835 children in grades 1 through 5 whom we hoped to study over four years. Talk about a leaky boat, after four years we could account for only 837 children who had taken 4 consecutive exams. This is a loss of 71% of the children. Were they just absent on exam day? Did they spell their name wrong? After careful checking we found that they were really gone and the teachers were not surprised. One said, "Oh yes, every year ten or so (out of 60) do not come back." Looking at the type of schools, we found that after 4 years the percent of children we remained was 40% for the predominantly white, 38% for the predominantly black city parochial, 32% for the predominantly Hispanic, and only 9% for the predominantly black city schools. These students are replaced by an equal number of new children. Thus, throughout the Chicago area there is this enormous mobility on the part of principals, teachers and students.

What did all this leaking of people have on the children that remained? Either not as prepared or not as committed, the new teachers often stopped doing the experiments, while just next door the "old" teachers soldiered on with 10 experiments a year. And the differences in the TIMS test scores between these two groups of children were amazing. The scores of the children continuing in the program continued to rise. But for those who stopped , the scores either stayed the same or fell often by as much as two years!

The degree of decrease depended on the type of school. For the high scoring IGAP schools the TIMS scores stayed about the same, but for the low scoring IGAP schools the TIMS scores went down even after one year of no experiments. Apparently, these children have a harder time retaining what they have learned when the source is shut off. Interestingly enough, when they moved to another room next year and were back on the experimental trail again, their TIMS scores started back up. So, for all the children, continuity is important, but for our inner city children it is essential.

This leads to a troubling question about education in our metropolitan area and, for that matter, the entire nation. How can we maintain educational progress when children, teacher and principals change schools at such a high rate? An inner-city child who moves out of a quantitative hands-on program (and 90% do so every four years) and into an ineffective conventional curriculum will lose, as we have shown above, much of what he or she has learned in just one year. The very group that needs help the most is the most at risk.

And this risk is exacerbated by the trend in many metropolitan areas, including Chicago, to decentralize in the name of school reform. Grassroots control of schools sounds fine in theory, but it doesn't work very well when teachers, principals and students have no roots.

It is clear that children, particularly those in the inner city, need stability and continuity at school. Yet our education reformers push decentralization, which promotes instability and discontinuity.

Continued on page 17

Leaky Boat, continued from page 16

How do you achieve wide use of successful programs, such as TIMS, when each school is allowed to do pretty much whatever it wants? And even when a school does adopt a program, somebody—principal, teacher, student or all three—is going to move to a school that doesn't use it.

So how do you fix this leaky boat? We certainly can't stop people from moving, but we can ensure that there is a continuity of instruction. In other words, we desperately need a national curriculum. With a national curriculum, no matter where the children, teachers or principals go, they would all have to come to terms with specific content—say, the TIMS bouncing ball experiment in the third grade, along with graphing, data taking, questions and math that the experiment poses. Schools of education would have to prepare future teachers to teach this basic math-science curriculum and principals would have to organize the school accordingly.

Before all the local school boards and school councils go through the roof, let me add that I'm not recommending a national curriculum for everything that is taught in school. Just the basics: math, science, reading, writing. The national curriculum might take up 50% of the year. For example, 18 TIMS experiments spread over the 36-week school year. The rest of the time could be devoted to tackling a textbook, helping those who are slow, enriching those we are ahead and dealing with regional or cultural specialties. We can still preserve a great deal of local school autonomy.

But the basic national curriculum—not national standards, they are too vague—would be in place. No more falling scores, nothing but progress. TIMS math/science is ready to go. With a little good will and common sense, we can do this in reading and writing as well. Why not?

Howard S. Goldberg is Professor Emeritus in the Physics Department, University of Illinois at Chicago and creator of the TIMS program. He participated in the Fermilab Fixed Target Program beginning in 1973, and in 1996 was Carnegie Foundation Professor of the Year for Research Universities.

Browsing Through the Journals

Thomas D. Rossing

"The nature of discovery in physics" is the title of an interesting paper by Nobel Laureate Douglas Osheroff in the January issue of *American Journal of Physics*. "It is often said that to make an important discovery in physics one must either be good or be lucky, but that good people manufacture their own luck," Osheroff begins. The paper is partly autobiographical, partly philosophical. "The hardest thing for an experimentalist to decide," he says, " is when to leave a study and move on to something new. Being the world's expert at something may ensure an ability to do good incremental research, but may make major breakthroughs less likely."

One question which often plagues graduate students is: How much must he or she know about a subject in order to contribute to mankind's knowledge of that subject? If one knows too much, one's mind may become constrained by current wisdom on the subject. Osheroff's policy is "one should understand the subject well enough to acquire a good physical intuition on how it should behave." "However," he continues, "one can never understand one's equipment too well."

Physics at Work exhibitions, designed to show school students how physics is relevant to them, have been held at Cambridge University annually since 1985, according to an article in the November issue of *Physics World*. The event, which attracts up to 2000 students from 50 or so schools, includes talks about research in industry as well as at the Cavendish Laboratory in Cambridge. Students frequently ask the physicist-exhibitors "How much do you earn?" As it happened, one of the companies represented was being floated on the stock market at the time, so students were surprised by the answer to that question.

Australian scientists are in uproar over the planned closure of *Quantum*, a science show that has run for 16 years on national television, and the axing of the Science TV Unit at the Australian Broadcasting Corporation (ABC), according to a news note in the 4 January issue of *Nature*. The Australian Academy of Science, which persuaded the ABC to begin science programs in 1964, branded the removal as "a leap backwards."

continued on page 18

Browsing, continued from page 17

A planned program using textual material, exercise workshops and small-group teaching has replaced lectures in the physics course at the University of Leicester (UK), according to an article in the December issue of *Physics World.* Only relatively recently have lectures become an important means for communicating information. In the last century, students were told to expect relatively few lectures, because most material can be found in standard textbooks. "There is nothing more tedious than yet another boring lecture," the author argues.

A different point of view on lectures is taken in a guest editorial in the December/January issue of *Journal of College Science Teaching* entitled "Creating a Motivational Learning Environment in Science: Adding a Personal Touch to the Large Lecture." A useful goal for each class session should be to have students leaving the class saying, "I never thought about it that way before." Students should come to class with expectancy and excitement, not with a feeling of boredom of knowing how each class session will proceed.

An interdisciplinary course "The Atomic Era: European Refugees, American Science, and the Atomic Bomb" is described in the February issue of *The Physics Teacher*. This course, at Southern Illinois University at Edwardsville, is taught by a team of three faulty members: one in physics, one in sociology, and one in German studies (who is the author of the TPT paper). A typical final exam asks the students to discuss the scientific, political, sociological, historical, and cultural events that culminated in the development and use of the atomic bomb, and it is graded by all three faculty members.

A centuries-old academic tradition in Germany, the notorious post-Ph.D. habilitation requirement, may be on the way out, according to a brief article in the 5 January issue of *Science*. The DFG, Germany's central research foundation, announced a new program of "junior professorships" that will provide independent support for young researchers. Young scientists will be able to apply for 3-year support for their own research or group projects they head. Under the present system, to be eligible for tenure, young scholars are required to work for 6 years or more as a kind of academic apprentice, dependent on a senior professor for support.

Asian nations continue to lead in science and math test scores, according to the results from the Third International Mathematics and Science Study TIMSS) summarized in an article in the 8 December issue of *Science*. Taiwan, Singapore, Japan, and South Korea are the star performers, while eighth graders from the United States are still near the middle of the pack, pretty much as in the first tests in 1995. The new findings, called TIMSS-R (for repeat) include longitudinal data that allow countries to measure their progress over time. The US is the only country to show a significant drop in both science and math achievement as its students mature.

"Turning Points 2000: Educating Adolescents in the 21st Century," a report released by the Carnegie Corporation in November, is summarized in the December/January issue of *NSTA Reports.* The report calls for middle schools that "teach a curriculum grounded in rigorous, public academic standards for what students should know and be able to do." The authors suggest that large schools be divided into "smaller learning communities with teams of teachers and students." Copies of the report ($18.95) can be ordered from Teachers College Press <tcp.orders@aidcvt.com>.

In celebration of the joint meeting of the American Association of Physics Teachers (AAPT) with the American Astronomical Society (AAS), most of the December issue of *Physics Teacher* is devoted to teaching astronomy. On the cover is a photo of Messier 82 (the Cigar Galaxy in the constellation Ursa Major) from the Suburu Telescope, and the customary December centerfold is on Women in Astronomy, including a brief biography of Caroline Herschel, first woman to discover a comet. Like her brother, astronomer William Herschel, she was trained as a musician (she a singer, he a conductor and composer).

The "Amateur Scientist" column, which has been a regular feature in *Scientific American* since 1928, is going to be discontinued, according to an interview with Shawn Carlson, the present columnist, in the January 23 issue of the *New York Times*. The column is to be suspended in March to make room for "other good ideas for columns" according to John Rennie, editor in chief. Carlson, who has written the column for the past 5½ years, is the founder of the Society for Amateur Scientists. Ironically, his efforts in promoting amateur science were recently recognized by the John D. And Catherine T. MacArthur Foundation with a grant of $300,000.

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

Physics in the Elementary School

Lewis E. Love

Preface, by James J. Wynne

As a youngster, I was very good in math and science and expected to be a physician when I grew up. But, during the summer between my junior and senior years of high school, I became concerned that I would not be able to use my math ability if I became a physician. In just one week at the beginning of my senior year, my concerns were cast aside and I decided to become a physicist. My savior was Lewis E. Love, my high school physics teacher. His method of teaching science, featuring demonstrations, student experimentation, and problem solving, made it transparent to me that my math ability was perfectly matched to the study of physics. And his enthusiasm was contagious. I had a party all year long. The highlight of the year was planning out an experimental demonstration of Michelson's rotating mirror measurement of the speed of light. (Although I did not actually complete this experiment during high school, I was prepared to carry it out in college, when I was able to acquire some of the requisite equipment.) Another of my high school classmates, Carl Bender, also became a physicist, as have many others of Mr. Love's students. I brought Mr. Love, as my guest, to my 30th high school reunion. To my surprise and delight, my non-physicist high school classmates remembered him with great affection. He was soon surrounded by his old students who asked him if he still did some of his old demonstrations. My classmates actually envied me for having become a physicist, especially when I told them that it was as much fun as Mr. Love had made it seem in high school. Through these next forty years, I have stayed in touch with Mr. Love, and it is now my pleasure to introduce him to the readers of this FEd newsletter. Although he is formally retired from a long and illustrious career as a high school physics teacher and a science department chair, his love of teaching and his belief in science continue to be reflected in his second "career" as a teacher of elementary school teachers.

Jim Wynne is the administrator of the FEd home page. He helped form the APS Forum on Education and served as the Forum Councillor for the first eight years of its existence. He has worked for IBM Research since earning his Ph. D. in physics in 1969.

Introduction

Young children in our country are our most valuable natural resource. With the vast explosion of knowledge, technology, and problems induced by many factors, we need this group of wonderful young people to assist us when they reach their maturity. Their science and mathematical literacy is crucial to our survival. Science in the curriculum is more than just a subject—science is a way of looking at the world around you. The teaching of science at the elementary school level is perhaps the most important step in developing the potential of human beings, because it provides the foundation, the tools, and the stimuli for enthusiastic young people in our care to learn and dream.

The exponential growth of scientific and technical knowledge makes it impossible for most citizens to keep themselves aware and knowledgeable of the increasing bounty of information that is presented to them on a daily basis. The Internet and the multimedia conglomerates have complicated things significantly, by providing an abundance of information that is not critiqued by qualified authorities and is therefore not necessarily accurate. Elementary school teachers have been asked to cope with this fantastic growth of information in science, mathematics, and technology, while continuing to address all their other responsibilities having to do with their students. Given the constraints of time and the myriad of competency examinations, standards, frameworks, and State Action Plans, elementary school teachers have been placed in an untenable situation, without being provided with mentors who can assist them in learning to handle their added responsibilities. Initial training and curriculum decisions at the university level in prior years have left these teachers without the background or training to cope with these demands, especially in science, mathematics and technology.

What can be done to solve this problem? One solution is to train the teachers and students together. This article presents an approach to this solution.

Keep It Simple Physics (KISP)

Physics is the basic science that is fundamental to all the other branches of science. Physics can be used very effectively to help students learn to think, read, write, use mathematics as a thought tool, and provide insight into our cultural heritage and social environment.

continued on page 20

Elementary School, continued from page 19

But physics is an area of study, which brings intellectual fear into the hearts of those people who have not been introduced to its simplicity, beauty, logic, and its ability to help us understand the world around us.

I propose that many important concepts in physics can be effectively taught to 4th and 5th graders. I also propose that you can train the teachers of these students to effectively do this through an in-service program developed by any high school or university physics teacher, incorporating a hands-on curriculum that I have developed. I have been experimenting with this curriculum for many years with elementary school students, high school students, and elementary school teachers that I have instructed at Hofstra University and at The National Labor College of the George Meany Center for Labor Studies. I would now like to extend this curriculum to other students and teachers.

The program, Keep It Simple Physics, or KISP, is based on a program called Keep It Simple Science, or KISS. KISS incorporates a series of hands-on experiences in science, mathematics, and technology and requires only inexpensive equipment. These experiences are simple to execute, are fun to do, and provide the teacher with all the elements needed to develop a program for the present and one that will evolve into the future. KISP consists of demonstrations, hands-on experiences, and techniques that can be used with children to get them to understand, appreciate, and enjoy science.

When a teacher is involved with KISP activities, students will be provided with experiences that reinforce skills, abilities, and concept development in reading, writing, mathematics, alternative thinking, problem solving, and a wider view of the world. These factors are an important consideration to many urban schools, where funds, facilities, equipment and training are at a minimum. In fact, administrators might endorse and support this program for its dual potential as a viable, powerful and important academic component to the school program, as well as one that requires a minimal use of financial resources.

Some Proposed Activities

Cryptic titles such as “The Magic Spoons,” “The Candle, the Egg, the Bottle,” “Dancing Raisins,” “The Maple Copter,” “The Soda Bottle and the Diver,” or “The New York Times and the Broken Board” provide a flavor of the activities that make up this curriculum.

E.g. In “Dracula’s Experiment,” the candlelight is polarized when reflected from a glass plate. By holding a Polaroid filter 57^{o} from the vertical, and rotating it in the proper direction, the image in the glass plate will disappear. Vampires don’t produce images!!

It is important for students to be involved in experiences that require creative and alternative thinking. Accordingly, the KISP program incorporates additional intellectual challenges derived from mathematical topics such as algorithms and cryptography.

KISP activities naturally lead students and teachers to make the necessary connections between facts, concepts, and principles they have learned to help them explain and interpret the world around them, as well as to appreciate alternative ways of viewing a solution to a problem. There are many activities, all of which have been field tested, that provide a broad scope of experiences.

This program could operate on a four-week cycle, with periodic evaluation and anxiety reduction sessions. The teachers would meet once a week to discuss what they have accomplished, what works and what doesn't. At the end of the first four-week cycle, the teachers would begin to create a handbook, namely a compilation of curriculum materials that could be used by other teachers. Teachers would naturally incorporate new material into the handbook after successive four-week cycles. The teachers would have a sense of ownership and a vested interest in the making of these activities and techniques into viable and successful curriculum.

There have been two useful modes to carrying out the KISP program. The major portion of the program has each student, or pairs of students, using the hands-on activity structure to explore ideas in physics. The other mode features a directed discussion using demonstrations and discovery learning situations with the whole group of students.

Peer Teaching

I have trained talented and patient high school students to assist me in the implementation of the program. Any school district can follow the same procedure by identifying a cooperating physics class taught by a capable high school physics teacher. Initially, the elementary students and their teachers visit the high school where they work with the high school students on laboratory experiences and other activities. When the high school students have developed sufficient skill and confidence, the program moves to the elementary school, where the high school students continue to be supervised by the elementary school teacher and their physics teacher. When the teachers feel that the high school students can successfully and effectively operate on their own, these students continue without their physics teacher's supervision, under the guidance of the elementary school teacher.

What makes this component of the plan particularly interesting and exciting is the combined and positive community effort. The elementary school and the high school become a single instructional unit. Having the elementary school students visit the high school, making it possible for the high school students to mentor and bond with the elementary school students, creates a very powerful sociological experience for both groups of students. The benefits to the high school students go well beyond the very powerful enhancement of their own self-image through community service. Their understanding of the concepts of physics is strengthened.

Continued on page 21

Elementary School, continued from page 20

What better technique is there to achieving mastery than teaching what you have learned to others?

Important Ideas of Science

Many important physical concepts can be developed from this curriculum, e.g: "The universe is regular and predictable;" "Energy always evolves from more useful to less useful forms;" "Electricity and magnetism are two aspects of the same force;" "Everything: particles, energy, the rate of electron spin comes in discrete units and you can't measure most things without changing them;" "The surface of the Earth is constantly changing; no feature on the Earth is permanent."

The complete list, compiled by Robert Hazen and James Trefil, authors of The Physical Sciences: An Integrated Approach (Wiley, 1996, ISBN: 0-471-15440-7), is not "etched in stone." You, the reader, may have ideas as to what should be added or removed from the list and may even wish to modify the language of the statements. The purpose of the list is to get you thinking about these ideas in relation to the world around you.

Some Anticipated Outcomes

For teachers:

- Enrich the science and cultural background of the elementary school and high school teachers and create a closer education bond between the two groups that provides for mutual respect and purpose
- Provide a reservoir of experiences that provide a viable instructional program for the students
- Reduce anxiety about the teaching of science, and demonstrate how interesting and exciting the experience can be for elementary school teachers

For students:

- Provide many opportunities to grasp abstractions and apply them
- Enable them to explain and understand the world around them and appreciate how things function
- Facilitate the use mathematics as a thought tool
- Learn to follow directions intelligently and to read with understanding
- Learn to gather and organize data in an experimental mode and make connections
- Develop the skills needed for solving problems, be alternative thinkers, recognize patterns
- Provide a stimulus for some students to pursue careers in science

Conclusion

KISP enlists the cooperation of the elementary school and the high school to provide a valuable educational experience for all children. The teachers in both schools will appreciate the role that they play in the education of their students. The inevitable development of mutual respect and understanding provides the school district with a stronger academic program for the young children and young adults. High school students have an opportunity to see teaching as a very important and fascinating intellectual activity that could lead to a very exciting career choice. The processes of science make it possible to understand and interpret, to some degree, what is happening in the environment, where you are an important component. The knowledge derived makes it possible for the individual to make decisions, protect and conserve health, provide for the basic needs of life, and to extend the intellectual and moral potential for all human beings. KISP is a program that uses physics and its related ideas to initiate our youth into the scientific process.

Lewis E. Love has been teaching science for 50 years. He taught high school physics in the Great Neck, NY public schools from 1959 until his retirement in 1997. He now spends much of his time teaching elementary school teachers how to teach physics to 4th and 5th graders. His email address is lelsci@aol.com. He welcomes questions about his KISP program to explain the nature of any of the activities, the materials needed, how to perform the activity, and suggest the appropriate questions to ask, possible applications, and assessments you may wish to use.

The Time Has Come to Make Teaching a Real Profession

Kenneth J. Heller

Education is now in the national spotlight. Sifting through the clichés and rhetoric from all parts of the political spectrum reveals a consensus. Providing an improved education to the future generations is necessary to ensure the future existence of our country. This is not exactly a new insight. What's the problem? In a word, it's teachers. We don't have enough of them, they are not well enough prepared, and they allow classroom conditions that impede student learning. Teachers are not only the problem, they are the solution and, in fact, the entire ballgame. Teachers are by far the most important element in the education system. Despite decades of effort and many millions of dollars, no one has yet devised a teacher independent curriculum or technology that works for even a sizeable minority of students. Of course teachers need curricular tools and adequate facilities but first the well-prepared teacher must exist.

continued on page 22

Teaching, continued from page 21

Resolving important issues such as vouchers, charter schools, computers in the classroom, bilingual education, high stakes testing, racial or gender segregation, or even the teaching of evolution is just reshuffling the cabin assignments on the Titanic. One arrangement or another might optimize passenger comfort but the iceberg will still sink the ship. The ship of education is already grinding on the iceberg of a shortage of well-qualified teachers in most areas of the country.

Sometimes an important problem has a simple solution that can actually work. Our economic system has developed a successful mechanism for dealing with such a workforce shortage. Whether in hospitals, brokerage firms, industry, or pro basketball, salaries respond to market forces. If we recognize that teachers are important, we cannot simply fill those positions with warm bodies that can be trained. Competent people have many career choices within our economy. Professions compete for their potential workforce with a salary that compensates for the working conditions and qualifications required relative to other professions that are equally desirable. Below a threshold level, a profession does not get enough qualified people to survive. As a country we are clearly below the threshold for teachers. For example, one of the most recent national studies looks at the problem from the point of view of national security and concludes that:

> "*First*, we must *raise salaries for teachers*, science and mathematics teachers in particular, to or near commercial levels. As long as sharp salary inequalities exist between what science and math teachers are paid and equivalently-educated professionals make in the private sector, the nation's schools will lack the best qualified teachers in science and mathematics." From Road Map for National Security: Imperative for Change, Phase III Report of the U.S. Commission on National Security/21st Century. http://www.uscns.gov/PhaseIIIFR.pdf

Of course, there are always a few people so dedicated to the goals of a profession that nothing else competes at any salary level. The teaching profession always gets more than its share of these dedicated, talented, hard working, and well-qualified people. However, no profession requiring large numbers of members can survive by relying only on that small population. Our policy makers invent incredibly clever ideas to avoid a direct solution to the problem. For example, why not identify these talented and dedicated teachers, publicize them, and have other teachers emulate them? It does not seem to occur to our leaders that nothing else in our economy works that way. Most other teachers can't copy these master teachers because they are not the same people. In all likelihood they are not really the right people for the job. If the education of our children is so important, why bet the future on such high-risk plans? We must encourage the right people to get the right preparation from the beginning. This means paying a salary that will attract the type of people we want to be ordinary teachers. How do you determine this level? In our economy you let the market decide.

The only question should be, can we afford the solution? One can make an educated guess at the correct salary level by identifying another large profession whose ordinary members have a demonstrated successful performance under stressful conditions. The comparison group that comes to my mind is mechanical engineers. On the whole, the mechanical engineering profession keeps this country running and progressing. Mechanical engineering seems to attract about the right number of people to keep up with the demands of industry. The quality and preparation of mechanical engineers is adequate for industry purposes. Mechanical engineers have to master many skills and have a wide range of knowledge. They must learn new skills at a steady pace keep up with ever changing jobs. These professionals must work with others that are not of their choosing to produce a product to the specifications set externally under the pressures of deadlines and budgets. They are very practical problem solvers. I am not saying that the people who now go into mechanical engineering would necessarily make adequate teachers. However, the level of skills and performance is similar to what we demand of teachers. You might argue that teaching is more stressful, has a more important outcome, and demands a wider range of skills and knowledge than a mechanical engineer, but one has to start somewhere.

To begin the market iteration process, one needs to determine the salary difference between mechanical engineers and teachers. Then one can determine if the country can afford the salary adjustment. Instead of looking up the detailed statistics, let's approach this as a "Fermi problem". Salary levels are determined by local conditions for both teachers and mechanical engineers.

The median mechanical engineering salary in 1996 (http://www.ecn.purdue.edu/ESCAPE/fields/mechanical/stat_gifs/salary_d.html) was about $20,000 higher than the median teacher salary in 1998 (http://www.nea.org/publiced/edstats.) How many teachers are there in the country? There are roughly 17 students for each teacher (http://nces.ed.gov/edfin/graphs/topic.asp?INDEX=8.) How many school age children? There are nearly 60 million children between 5 and 19 (http://www.census.gov/population/estimates/nation/intfile2-1.txt.)

Continued on page 23

Teaching, continued from page 22

That means there are about three million schoolteachers in the U.S. If we raise every teacher's salary by $20,000 plus another 50% for fringe benefits and increased classroom support that these professionals would demand, we get $90 billion per year. That is a lot of money, but it could be phased in over a number of years. For example, first the starting salary of teachers could be raised by $20,000 while raising the salaries of all other teachers just enough to keep ahead of the starting salary. In other words, salary compression. Still, every teacher does get a significant raise. The next year, begin to undo the salary compression starting with the second year teachers until all teachers have the $20,000 raise (in constant dollars). It is still a lot of money, but the country can afford it. Assuming a linear increase in national teacher salary expenditure for 10 years gives $0.45 trillion or about 28% of the $1.6 trillion tax reduction being proposed. Less than 1/3 of the proposed tax cut would fix the fundamental problem of our education system. Of course there are details to work out. The tax reduction is for the federal tax but teachers are paid by state or local money. Block grants to states undertaking this salary increase could be used until a more permanent tax shift from federal to state or local taxes is implemented.

Won't this plan raise the salary of existing teachers? Paying more for the some old thing. Won't many of the teachers entering the profession with higher salaries be the same people who would have gone into teaching anyway? Yes, but we have to start somewhere. Attracting more and better-qualified people into teaching, means offering a reasonable and stable salary scale that is known to people when they begin to make career decisions. Most people make career decisions between the 8th grade and college. It will take about 6 years for such people to get into the system and their impact will probably not be felt for at least 10 years. This would be the fastest large-scale positive effect on the education system that has ever been achieved. With a professional level salary scale, we can require professional level qualifications. This could be a 5 or 6-year program that would have the depth of a regular college major in addition to practical teaching courses and carefully supervised classroom practice provided by a college of education. As with any profession, teachers would be employed for a full year. Teaching is the only profession I know, outside of sports and the arts, that tells its practitioners to find another type of job for 3 months a year. This is not very attractive to those who desire a stable family life. After all, families eat and pay bills all year round. There is plenty of work for teachers to do when they are not in the classroom. There is curriculum to plan, textbooks to review, new technology to implement, and new techniques to learn. With teachers employed for a full year, we could even increase the classroom time for children and make a different distribution of it through the year. Most of us don't need our children for 3 continuous months to tend the crops.

As a country we have a unique opportunity to solve an important and pervasive problem that has progressed to a stage that it is apparent. The solution requires no new knowledge, no research programs, no large-scale government programs, no complicated implementation bureaucracy, and no assumption of spontaneous human behavior changes. Making teaching a profession with competitive salaries will not be the end of educational reform but the beginning. Just as in other segments of our economy, the professionals who enter teaching will create a demand for improvements in curricula, technology application, and classroom conditions. The country has the means; all we need is the will to succeed.

Kenneth J. Heller is Chair of the Forum on Education and Morse-Alumni Professor of Physics at the University of Minnesota

What's Your Network?

Elizabeth McCormack

For most of us, our research communities have been critical to our career development. This has certainly been the case for me, and until recently, this community was pretty much unrivaled in my professional life. Lately however, I've been enjoying a second community just as enabling and informative and most importantly, just as inspiring. This network is the web of interactions surrounding Project Kaleidoscope (PKAL).

PKAL is a growing set of connections between individuals and institutions concerned with and committed to efforts to improve undergraduate science, math, engineering and technology (SME&T) education. PKAL's work addresses the full scope of this endeavor including issues concerning faculty, curriculum, research and facilities, as well as joining in broader institutional and national debates on education in fields of SME&T. Interacting with this community has enriched my classroom and teaching labs and led to a new level of enjoyment and success in working with students both at the undergraduate level and the graduate level. It has guided me in thinking broadly about my role in my department, in my institution, and in articulating goals for teaching that compliment my research goals.

Below are listed some of the activities that constitute PKAL. In the last ten years nearly 4500 academics representing more than 850 diverse college and universities have participated in PKAL-sponsored events and activities. As PKAL enters its second decade, its goals have grown to

continued on page 24

Kaleidoscope, continued from page 23

include broadening its network to make more connections with educators and researchers at universities including young scientists, postdoctoral fellows and graduate students just embarking on academic careers.

PKAL Summer Institutes and Workshops

The Institutes take place for two weeks each summer—in 2001, they will be in Snowbird, Utah. They are thematic, changing each summer, with several programs running at the same time. They provide unique planning opportunities for teams to develop tailored approaches to meet departmental and institutional goals to reform and improve undergraduate science and math education on their campuses. They facilitate faculty and institutions to take new directions in classrooms and labs by embracing key developments in science and technology, by addressing new societal challenges to education and by encouraging all educators to affect the lives of their students on the campus and beyond. PKAL has effectively served as an intelligence-broker and network-builder by hosting over 100 workshops that serve as a venue to exchange best practices about "what works" to strengthen student interest and learning.

PKAL Faculty for the 21st Century (F21)

Most would agree that quality education is critically dependent on faculty who are intellectually energetic, up-to-date in their field, passionate about student learning, implementing new technologies and pedagogies, and committed to research as an effective learning experience for students. To sustain systemic reform in science and math education, PKAL has built a network, now over 1000 strong, of faculty from a diverse set of institutions that constitutes a broad community of educators that meets annually at a PKAL F21 National Assembly to inform, challenge and support each other.

Publications

PKAL collects and publishes materials that emerge from the various institutes and workshops and distributes them for the larger community. These are valuable resources. Major volumes addressing critical issues in transforming science and math education serve as handbooks for reform. PKAL Volume I—*What Works: Building Natural Science Communities* has served many faculty and institutions working to strengthen their programs for over a decade. PKAL Volume III—*Structures for Science: A Handbook for Planning Facilities for Undergraduate Natural Science Communities* is regularly used by campuses planning new science buildings. The most recent publication, *Then, Now & in the Next Decade: A Commentary of Strengthening Undergraduate Science, Mathematics, Engineering and Technology Education*, sets forth new goals and parameters for reform efforts in the 21st century.

How can you get involved?

- Visit the PKAL web site http://www.pkal.org to learn more about PKAL activities and publications.
- As an academic dean or Provost, sponsor a promising young faculty member to join the Faculty of the 21st Century. As a faculty member, ask your dean to nominate you to become a member of the Faculty of the 21st Century.
- Put together a team of both faculty and administrators to attend a PKAL Summer Institute to learn about and plan for reform in science and math education on your campus.
- Attend a PKAL F21 National Assembly as an F21 member to focus on "what works" for student leaming, recruitment and retention and to make connections with colleagues across all disciplines to talk about career related issues that go beyond disciplinary boundaries.
- Contact a PKAL Faculty of the 21st Century member near you by visiting the PKAL web site at http://www.pkal.org/faculty/f21/index.html and start networking and find out what PKAL has done for them.

I invite you to learn more about this truly transforming community. Share your own experiences in SME&T education and learn from others.

Elizabeth F. McCormack, Ph.D., is an Assistant Professor on the Rosalyn R. Schwartz Lectureship in the Physics Department at Bryn Mawr College and PKAL F21 Class of 1996.

Growth in Undergraduate Physics at the University of Arkansas, Part II

Art Hobson

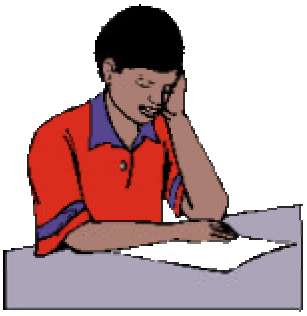
As reported by my colleague Gay Stewart (Fall 2000), physics course enrollments are up at the University of Arkansas, the number of undergraduate physics majors is up, and the physics baccalaureate graduation rate is sharply up from 2.5 per year during 1990-97 to about 15 per year beginning in 1998. In the early1990s our undergraduate program was a typical example of the general physics slump of recent years, with under-enrolled classes and low graduation rates. Looking for solutions, we decided to pursue several new paths. The thrust is toward more flexible, practical, and student-friendly paths for three categories of students: non-scientists, non-physicists who can use a physics degree outside of physics, and future physicists. Stewart reported on our BS degree program for future physicists, where stronger enrollments are a result of a reformed University Physics II course, improved TA training, three new non-Ph.D. degree tracks, more undergraduate research opportunities, and better mentoring. I will report on our programs for non-scientists, and for non-physicists who are pursuing a physics degree.

Reaching out to non-scientists

A healthy physics profession must be rooted in the entire society, rather than in scientists alone, because ultimately it is legislators, voters, parents, teachers, and other non-scientists who will determine the fate of physics. Thus it behooves us to develop large and effective physics literacy programs on every college campus.

Nearly 80% of the students at the University of Arkansas are majoring in fields outside of science, mathematics, and engineering. Our department reaches these students with two introductory courses for non-scientists: Physics and Human Affairs, and Survey of the Universe. We currently teach 750 per year in the physics course and 410 in the astronomy course. This works out to about 40% of the non-science undergraduates on our campus who take one or both of these two courses at some point during their undergraduate career.

The American Association for the Advancement of Science and others have called for science literacy courses that are not simply de-mathematized versions of the standard technical courses for science majors but that instead approach science as a human endeavor within its full cultural context. In line with such recommendations, Physics and Human Affairs includes such societal issues as global warming, technological risk, energy resources, and nuclear weapons, and devotes more than 50% of its lectures to modern and contemporary physics. Scientific methodology is a constant refrain. The course uses no algebra, but includes "numeracy" skills such as graphs, percentages, probabilities, estimates, powers of ten, and large and small numbers. Despite large class sizes, the course makes extensive use of the "peer instruction" techniques pioneered by Eric Mazur and others. Both courses are well received. Faced with a choice between several introductory courses that satisfy the science requirements for non-scientists, students enroll in physics and astronomy at rates that exceed that of the other offerings (geology, biology, and chemistry), so that physics and astronomy are always full by an early date in the enrollment cycle.



These two large popular courses for non-scientists give physics a good image on our campus, and make a substantial contribution to the science education of Arkansas' general population. They make it more likely that students from outside of physics will consider majoring in physics. In fact, during the past few years we have recruited several students from these two courses into our Bachelor of Arts program in physics. These courses also contribute strongly to our "student-semester-hours per faculty member," a significant statistic on our campus,

A physics degree path for non-physicists

Physics degrees shouldn't be only for physicists, any more than history degrees are only for historians or English degrees are only for writers. Our department believes that it would be healthy if non-physicists had undergraduate degrees in physics. Thus, we have initiated a Bachelor of Arts (BA) degree for students desiring a physics background as a basis for careers in law (e.g. patents, environmental law), business, medicine, journalism (science reporting), music (acoustics), K-9 teaching, or indeed any profession.

The BA program is more flexible and less technical than traditional BS programs, allowing students time for outside electives and professional requirements in other fields. It is algebra-based, beginning with the "College Physics" course rather than the calculus-based "University Physics" course, although some BA students elect to take our calculus-based courses. The BA requires 24 hours of physics as compared with 40 for the BS, 4 math courses including at least one calculus course, and 3 courses at the junior-senior level in some non-physics "special emphasis area" in which the student expects to be employed. Students take one semester of modern physics beyond the two-semester introductory course, a seminar, and 11 credit hours of physics electives.

Continued on page 26

Arkansas, continued from page 25

Many students elect our two BA courses "Physics in Perspective," presenting the human implications of physics, and "Physics of Devices," applying physics to significant technological devices. Other electives include three astronomy courses, optics, and several self-paced electronics modules, or any of our BS-oriented courses. The program is sufficiently flexible to allow students to develop considerable expertise in an employment area outside of physics, without amassing extra credit hours beyond the number required for a Bachelor of Arts degree. In consultation with other departments, we have worked out curricula for students headed for graduate school or employment in business, medicine, law, journalism, and education. For example, our recommendations for business-oriented students include 9 courses that our university's Business College recommends for admission to their Master of Business Administration program, allowing our students to complete the MBA program in only one year. We have a cooperative dual-degree program in journalism and physics, and we hope in the future to set up such programs with other departments. Because of its less technical orientation and greater flexibility, the program draws many students who would otherwise have vigorously avoided anything with the word "physics" in its title.

One boon from the successes of our BA and BS programs is fuller physics classes. Our junior- and senior-level classes in astronomy, mechanics, electricity and magnetism, and quantum mechanics, have had two to four times as many students during the past four years as compared with 1990-96.

One problem is that it is difficult to advertise the BA program. Except for the small fraction of students who decided early on a physics career, few undergraduates give the least thought to majoring in physics. Good high school contacts do not help much, because the students likely to be attracted to the BA program are probably not enrolled in a high school physics course. Thus, this program has expanded rather slowly during the past four years, now graduating about 5 students per year-about half the graduation rate of our BS program. "Physics literacy" courses for all high school students would be a great boon for our BA program, and for the BS program as well. We believe that the BA program has a much larger potential that can be attained only after it has become better known throughout Arkansas.

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Understanding and Appreciating Physics from Pre-school On (or *The Search for Intelligent Life in the Universe Should Start Here on Earth*)

Wayne Snyder

Several years ago I had the privilege of giving the keynote address to New Hampshire Science Teachers. While preparing, I went searching for some readership numbers for the top selling newspapers in the U.S. With the aid of a helpful librarian I found them. Coming in at number three was the Sunday edition of the New York Times at 1.2 million readers. In second place was the Friday edition of USA Today at 1.8 million. And leading the way, with a whopping 4.4 million loyal readers, was The National Enquirer! And these are people who at least are reading. What about the masses of people who are glued to their television sets with rapt attention to every Talk Show of the Terminally Bizarre that comes on? Why do they not feel the same appreciation for the wonders of science, particularly for physics? When was the last time The Jerry Springer Show had a topic like "I know light is a particle, but my wife insists it is a wave"? Why are we excited that the percentage of high school graduates in this country who have taken a course in physics has risen above the 20% mark when the number should be 100%? And why, when one announces in a crowd that he or she teaches physics, the crowd moves away as if your popularity ranking rates somewhere between those of an incurable leper and a curable leper?

The seeds are planted in the child back through the primary grades. Research shows that the years of elementary and middle school determine the student's future participation and interest in science and math, and that the reputation of physics in particular is reinforced through high school and college as boring, elitist, and impossibly difficult.

But it doesn't have to be this way. Elementary children are fascinated by physics. No, they don't want to sit and memorize long words and spit out boring definitions or do seemingly random mathematical calculations. But give them the chance to experience physics and it is hard to tear them away. They are fascinated by magnets and magnifying lenses. They enjoy the process of studying sound and electricity. Physical science experiments can make other subjects such as math and reading come alive. Young students are naturally inquisitive and creative and observant, at least until they are socialized by the combination of society and system. Is it a hopeless situation, as is so often trumpeted in the media and from the statehouses? The pathway for any reformation in science education must pass through the

continued on page 27

Search for Intelligent Life, continued from page 26

elementary classroom. So what are the hurdles faced by the education community? How can we get our elementary students out of the starting blocks and into the race to be scientifically literate citizens?

Preservice

A great many elementary teachers are physics-phobic, and the students can instantly sense it. I readily observed this in a college physics classroom of students seeking elementary education certification. In this particular college, such certification includes content courses in both biological and in physical sciences. The future elementary teachers are almost all female, have accepted the mindset of their society, and will be key role models to all of their students, and even more so to the eager little girls they will teach. The stark reality of the first couple weeks: most of them hated that they were required to be in a physics course, almost half of them were not confident enough to light a match, and several were paranoid to even plug in an extension cord. What message will these teachers convey to their students if left unchanged themselves?

There is a happy ending to this example. Although a content course, the methodology is heavily inquiry based. The future teachers quickly learned that they can understand the physics concepts and that they enjoy it. Before long rumors were flying that the dorms were filled with flying Doppler bees, strange polymers that act like both liquids and solids, and homemade planetariums. The final exams demonstrated that the students had a comprehension of the terms and the concepts that was deep and will hold them in good stead when they themselves are leading their students down the path of scientific knowledge and appreciation.

College Course Work

There is more recognition now than ever before that science course work is as important for elementary teacher preparation as is course work in reading and math. However a requirement itself is not sufficient. The course must be tailored to the specific needs of the target group. It is not uncommon for a college to require nursing students, elementary education majors, and first year chemistry majors to all take the same introductory chemistry course, a course designed for the latter group. The result of such a requirement is the total turn-off to chemistry by the first two groups. It could be argued that the reverse would be more beneficial, that a rigorous course that led to a detailed conceptual understanding of the concepts would benefit all three groups. The science majors would have the foundation of understanding to better comprehend why they were doing all of those complex mathematical computations. A subject matter course for elementary teachers should be rigorous in expectations, should be heavily inquiry based, should be separate from the methods course they will take, should focus deeply on the conceptual understanding, and should cover appropriate topics to appropriate depth and at appropriate speed, these topics correlated to the "big ideas" from the National Standards.

In Service Training

One of the most successful teacher training projects that the NSF has funded is Operation Physics (OP). This project started in 1988, and is still active today in local efforts, as part of the Physics Teaching Resource Agent (PTRA) program, and in its 2.0 version now being funded by NSF, Operation Primary Physical Science (OPPS). The unique aspect of OP that pioneered new territory was that educators had to train and work together as a team, a team consisting of a college professor, a high school physics teacher, and an elementary or middle school teacher. This team brought very different experiences, knowledge bases, and paradigms together. Those teams that meshed had a great impact in training elementary and middle school teachers across the country. The program was based on existing research in science teaching and learning, used hands-on learning, and included a strong training component. A curriculum alone without training and support will seldom succeed. The OPPS program is updating much of the OP teacher training by bringing in more up-to-date understanding of education. Instead of a series of activities about a topic, the topic is developed in a spiral fashion that continually reinforces and builds on the key ideas.

Textbooks

I have done impromptu surveys, asking a roomful of adults how many of them have read a textbook for enjoyment in the past few months. Is it a loaded question? Of course it is. So the better question is why is it a loaded question? The answer is that all adults instinctively consider that science textbooks are boring and uninteresting and filled with hundreds of dry definitions to be memorized or hundreds of pages of derivations of mathematical formulas to be ignored. Furthermore, an analysis of a typical textbook shows that there

is so much information shoved into the book, even many teachers cannot determine what is very important, what is less important, and what is actually unimportant. If a key idea is important enough to be covered, then it should be covered in a depth appropriate enough to have meaning and relevance, and the bridges should be evident to both the teacher and the learner. Yet even as the publishing industry grows ever more profitable and the glossy pictures grow ever glossier, the actual philosophical format of the textbooks remains rooted in a continual cycle of repetitious failure. Standardized test scores have dropped steadily with the decades of use of traditional texts and straight lecture. But unfortunately, in today's

continued on page 28

Search for Intelligent Life, continued from page 27

era of Legislated Excellence, the publishers have developed more political power than ever before. In many states they have more power to dictate curriculum and pedagogy than professional science and science education organizations.

That said, it should be noted that I have an elementary teacher friend who borrowed my copy of Paul Hewitt's Conceptual Physics, and I finally had to buy her a copy of her own to read for enjoyment or risk losing mine forever. Textbooks can be extremely valuable resources. The written page has been a primary resource since the invention of the printing press, and it will continue to be so even with the growth of the electronic information era. The reading resource, the textbook, should be something that the student wants to read, and it should be appropriate reading in style, in objectives, in content. The education community, from the classroom teachers to the practicing scientists need to push for what is best for the students, and that includes more properly developed reading resources.

Emphasis on Reading

One major issue in elementary science today is the emphasis on reading scores. The emphasis itself is not bad, particularly when and where students are not meeting minimum requirements. But it is becoming commonplace for principals to give ultimatums that "all instruction up through lunch will be reading and after lunch you can do everything else like science and history and math and the arts." My immediate response is "what are they reading?" Why not use "everything else like science and history and math and the arts" to help the students become better readers and writers? Why not use graphic organizers to help the students understand the scientific passage at the same time they are improving their reading skills?

Ironically, science represents one of the areas that most emphasizes writing and reading. Scientists keep journals. They read and evaluate articles. They write papers. They give presentations. In the CAPSI model (Caltech Precollege Science Initiative), journals and reading have been an essential component since the beginning. The combination of inquiry based science (using nationally available quality kits such as STC, Insights, or FOSS.) with the keeping of scientific notebooks or journals has had a noticeable affect. One area it is especially powerful is with non-English speaking students. They can concentrate on learning the science by recording in their primary language, and can then take the time to focus on the language translation. In one study soon to be published, the El Centro School District in California has found a direct correlation between student reading test scores and their number of years doing inquiry science and keeping science notebooks (as determined by which teachers the student has had).

Assessment

The most abused part of education today is assessment. Assessment should be used as a tool to ensure that all students have equal opportunities for their future. Instead assessment is being used to determine which students have what opportunities in life. Based on test scores that may or may not have much relevance to what they are used for, students are classified, excluded, and tracked based on these scores. Standardizing expectations and assessment has many benefits, as can be witnessed by the concept of the driver license tests across the nation. But what makes the driving assessment work (except maybe for that occasional idiot on the freeway)? It must include specific objectives and expectations, explain exactly what the test will assess, give opportunity to practice and prepare, assess by both written and performance assessment, and give formative feedback for improvement. Some assessment programs today are striving to go in that direction, but there remains a long way to go, especially with the standardized tests presently being rushed in as some type of religious salvation.

Conclusion

So with all of these hurdles, is there hope? Of course there is. One has only to get into the classrooms to see examples of quality teacher training, quality teaching, and quality learning. But it will not happen by itself. It is like the second law of thermodynamics. Everything is moving towards greater entropy, and it takes a great expenditure of energy to prevent this deterioration. It takes only a little more energy to progress. So the secret is to continue to progress, to improve, to grow. And this applies to all of the players listed in the National Standards, from the preparers of teachers to the teachers to the educational systems. Thomas Jefferson argued that American democracy cannot survive unless all Americans have a quality education. We must provide all of our students a quality science educational experience that opens opportunities and opens the mind. And that experience must start in the earliest years, progress throughout formalized schooling, and extend into the realm of life-long learning.

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Cosmic Rays Through the Heartland

Daniel R. Claes and Gregory R. Snow

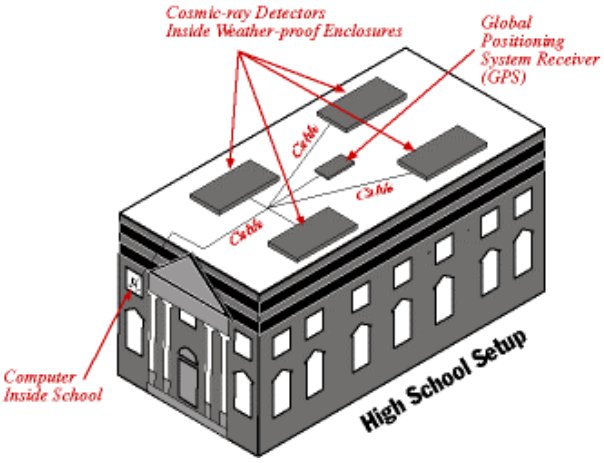
Introduction

The National Research Council's National Science Education Standards [1] call for enhanced "science as process" in which students *actively* develop an understanding of the scientific process as combining knowledge with reasoning skills. This "process" should include opportunities for students to engage in extended investigations. The cookbook style "experiments" through which high school students are too often led tend to give the expectation that scientific results should follow 40-minute exercises, or worse, that such frustrating efforts are best finished by fudging easily predicted data.

At the University of Nebraska-Lincoln (UNL), an innovative program is underway to build high school teachers' technical skills and knowledge base, as well as provide for student participation in a genuine long-term research experience.

UNL's **C**osmic **R**ay **O**bservatory **P**roject was launched in earnest in the summer 2000 when 20 participants from five Lincoln/Omaha area schools attended the first summer research program. CROP is a statewide outreach experiment whose goal is to involve Nebraska high school students, teachers, and college undergraduates in a multi-faceted, hands-on research effort to study extended cosmic ray air showers. We like to think of CROP as a means of merging the three primary missions of professors at a land grant institution: research, teaching, and outreach.

Particles from extended showers will be sampled by arrays of student-built and maintained scintillation counters placed on high school rooftops, while a PC-based data acquisition system located inside the school building records events. A GPS receiver will provide a time stamp so that time coincidences with other sites, signaling the presence of extended cosmic ray showers, can be detected. Student participants will compare data with other sites via the Internet and share experiences through regional workshops organized around the state's 19 Educational Service Units. A schematic of a typical high school setup is shown in the figure.



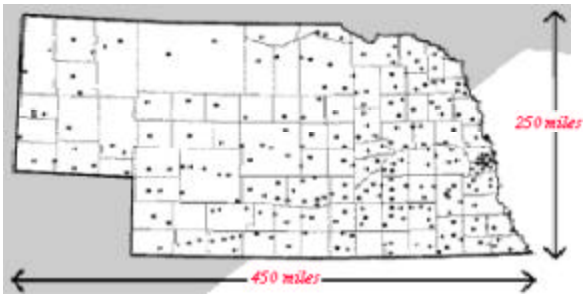
In 4-week summer research experiences, CROP will provide intensive teacher/student training in state-of-the-art particle detection and computer monitoring. This will be followed by year-round, long-term studies of cosmic rays. The experiments begin right in the classroom, continue through the school year, and via coordinated Internet sharing of data, extend beyond the schoolyard's boundaries. Conceived as a genuine research project, CROP will be developed in stages, and its success measured incrementally.

The Scientific Potential of CROP

An excellent and accessible review of observations made to date of ultrahigh-energy cosmic rays can be found in [2]. Although the main thrust of CROP is to expose its participants to the physics of cosmic rays, air showers, particle detectors, data acquisition and analysis, CROP addresses physics topics which will complement major ground-based arrays (CASA [3], AGASA [4], the Pierre Auger Observatory [5]) in three areas. Primary cosmic ray energies and direction-of-origin distributions will be collected for (i) building-sized showers ($E \approx 10^{15}$ eV, plenty of rate) using the detector array at each school and (ii) city-sized showers ($E \approx 10^{19}$ eV, much lower rate) using time-coincidences among schools in populated areas like Omaha and Lincoln for comparison with the above experiments. In addition, CROP will make a unique scientific contribution, since CROP detector sites will eventually cover the 75,000 mi^2 area of the state, many times the coverage of the above arrays. A map of Nebraska with dots showing the locations of the state's 314 high schools is shown below. The sparsely spaced sites in western Nebraska will allow CROP participants to investigate very long-distance correlations which would indicate extensive cosmic-ray bursts. In simple terms, when an Omaha school detects an energetic shower, does the ***whole state*** light up?

continued on page 30

The scientific impact of CROP will be strengthened in proportion to the number of sites collecting data simultaneously, making expansion across the state the primary goal after the pilot year.



CROP detector sites at Nebraska high schools

Recycling Hardware

The main CROP detector components - acrylic scintillator tiles, photomultiplier tubes (PMTs), and power supplies - are being recycled from the now-complete Chicago Air Shower Array (CASA) [3]. Operated between 1990-1998 by physicists from the Universities of Chicago, Utah and Michigan, CASA employed 1089 separate detector stations arranged in a 0.25-km^2 grid within the Dugway Proving Grounds (operated by the U.S. Army) in western Utah. Each station housed four 61 cm × 61 cm scintillation counters and a low- and high-voltage power supply. The retired CASA equipment has been donated to CROP. Spare CASA counters formed the basis for prototype detector development led by our undergraduate assistants.

In late September 1999, a CROP team traveled to the CASA site and loaded a rented truck with sufficient hardware to outfit the first 10 CROP schools. Most of the equipment was found to be in good working order. We had originally planned to make annual trips to Dugway to recover additional materials as needed, but the Army base now insists that the site be cleared promptly. Hence, we are making plans for a single, large-scale retrieval effort in May 2001.

We are also grateful to Fermilab for the long-term loan of a large supply of electronic modules previously used in high-energy physics experiments—NIM crates and modules. These are used for pilot-year measurements at the schools and for instruction during the CROP research workshops.

Funding History

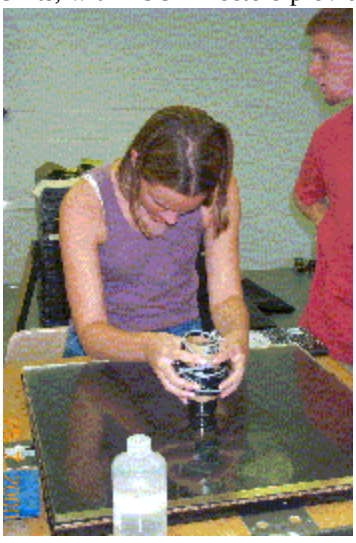
During the R&D years prior to 2000, CROP caught the attention of UNL administrators and was awarded seed grants from various internal sources. Our Vice Chancellor of Academic Affairs sponsored the 1999 equipment recovery trip to the CASA site in Utah. As collaborators on CERN's CMS experiment, we also received support from its Education/Outreach task, since CROP serves as a model for local outreach efforts led by active high-energy physicists. A major boost came with the award of a 4-year, $1.34 million grant from the National Science Foundation. The grant is funded jointly by the Division of Elementary, Secondary, and Informal Education and the Division of Physics. During its February 2000 Committee of Visitors review, the Division of Physics repeatedly cited CROP as an exemplary initiative helping to meet its education and research charge. CROP's unique collaboration between university researchers and high schools in a long-term, viable experimental program was recognized as having great potential to increase the impact of experimental physics research on the nation.

The NSF grant primarily supports the participant workshops and educational assessment activities described below. We have had success finding funds for supplementary hardware from individual school districts and state of Nebraska sources. Identifying funding sources to ensure our expansion across the state and the continuation of CROP post-NSF funding is a primary goal of our institutionalization plan.

CROP's Inaugural Year – Recruitment

First-year recruitment focused on the Lincoln and Omaha metropolitan areas through presentations at regional Nebraska Association of Teachers of Science and Nebraska-AAPT meetings as well as a special Lincoln Public School in-service day conducted at UNL. This local focus has facilitated frequent meetings and maximized the supervision necessary in the initial effort to get multiple detector sites up and running.

Through blanket e-mail solicitations to Nebraska high-school physics teachers and word of mouth we have accumulated a waiting list of schools across the state which are anxious to become CROP participants. Almost daily, we also receive inquiries from schools in adjacent states, across the country, and abroad. In the next few years, teams will be recruited from each of Nebraska's 19 Educational Service Units, with ESU Directors providing insight into the unique needs of their region. We place high priority on the recruitment of teachers and students from groups underrepresented in science, which in western Nebraska includes schools in very remote, rural locations.



The Summer Research Experience

The first annual summer session was held in July-August 2000.

continued on page 31

CROP, continued from page 30

Six physics teachers with a total of 14 students represented five participating high schools: Kent Reinhard from Lincoln Northeast High School, De Tonack from the Lincoln Science Focus Program, Father Michael Liebl from Mount Michael Benedictine High School in Elkhorn, Bruce Esser and Sharon Genoways from Marian High School in Omaha, and Dennis Miller from Norfolk High School.

Days typically were divided between morning classroom sessions and afternoon lab work. Mini-courses explored relevant topics in high-energy physics, astronomy, charged particle detection, Monte Carlo applications, triggering, data acquisition, and the Global Positioning System. Afternoons were devoted to hands-on work with prototype detectors. Participants polished scintillator and glued PMTs, wrapping and checking their assemblies for light leaks which required them to learn to use an oscilloscope. They also measured the detection efficiency of each counter. Through these exercises, they became familiar with the assembly, testing, and operation of the detectors they now use at their own high school. The photograph shows Marian High School student Amanda Carney preparing to glue a PMT to a scintillator tile. Teacher input has proven crucial to the evolution of the detector set-up which we feel helps guarantee its safe, durable, and foolproof operation. The logistics of, and possible problems with, the installation and operation in a variety of school settings were discussed in the summer session.

During the summer 2000 session, "All Things Considered", National Public Radio's afternoon news program, carried a story on CROP which was produced locally by Nebraska Public Radio and featured interviews with both students and teachers in the project [7].

First-Year Mini-Experiments

The schools have embarked on two mini-experiments to be performed during the 2000-01 academic year. The first -- measuring the (small) variation of cosmic-ray rate vs. barometric pressure with detectors stacked in a vertical telescope – will help us determine how well the school teams, working independently, can measure the same effect. The second – measuring coincidence rates with detectors spread horizontally in various configurations – will help us optimize the detector set-up for each school's study of extended air showers.

The school teams have impressed us with their ideas for supplementary measurements which become independent student projects. Mount Michael H.S. is busy checking for diurnal variations with 15-minute runs made six times a day. Norfolk H.S. varies the detector separation in their vertical telescope, effectively controlling how narrow a window they view of the sky. Marian H.S. is assembling small trigger counters to map the light-collection efficiency across the face of their scintillator tiles (studying signal attenuation).

Academic Year Workshops

Twice each school year, nominally December and April, one-day workshops will be scheduled as an opportunity for team leaders to meet, share experiences, critically evaluate the program, and make plans for both continued data-taking and statewide expansion. On December 2, 2000, our first academic year workshop was held at UNL, attended by the summer participants, the UNL CROP staff, and the project's Advisory Panel. Students from each school reported on their progress, and collectively we discussed how to complete the mini-experiments that were just getting underway. Some of the teachers whose school teams will join CROP in the summer 2001 also attended to get oriented.

The CROP Advisory Panel

CROP is guided by an 8-member Advisory Panel with varied expertise in high-energy and cosmic ray physics, secondary science education, hands-on science museums, other science outreach programs, and high school science teaching. One full Panel meeting per year overlaps with the autumn participant workshop, and selected Panel representatives observe the summer and spring workshops. At its meeting in December 2000, the Panel heard progress reports from the first-year school teams, witnessed their enthusiasm, and joined a business meeting with the CROP staff. The Panel's report provided a valuable critique of the pilot year and suggestions for the future. The report included ideas for ensuring effective communication with the schools during the academic year, technical development hints, and a program of supplementary experiments the teams can perform with their cosmic-ray detectors.

Educational Evaluation

Significant energy is devoted to formative and summative assessment. CROP has enlisted an external evaluator whose activities are supported by NSF funds. The Advisory Panel and UNL's Center for Instructional Innovation also contribute to project assessment. While critiquing CROP's success at establishing a statewide network of detector sites, the evaluation's primary focus is the educational value that CROP experiences provide participating teachers and students, using established assessment tools. Among other topics, the evaluation team will study teachers' self-efficacy for conducting CROP research and classroom activities and changes in students' interest and attitudes about science.

Preliminary assessment results from the pilot year are encouraging. Pre- and post-testing at the 2000 summer workshop revealed that the participants improved their knowledge of cosmic-ray physics and particle detection techniques and

continued on page 32

CROP, continued from page 31

gained sufficient expertise in operating their detectors to perform the assigned mini-experiments during the upcoming academic year. Participant exit interviews identified which content presentations were deemed most useful and a number of ways to enhance the laboratory activities of the workshop. There is also evidence that participating in CROP leads some students to look more favorably on majoring in physics or another science in college.

Technical Developments in Progress

The ability to link GPS time-stamped data collected by participating schools depends on developing an inexpensive electronics card designed to handle the triggering, signal processing, GPS timing, and data acquisition. The card will interface directly to the data-taking PC. The GPS-timing part of this card has been developed by our CROP affiliates at Iowa State University. Its performance was presented by ISU undergraduate student Nick Mohr at the workshop "Cosmic Ray Physics with School-Based Detector Networks" held in Seattle in September 2000 [6].

Statewide Expansion

During each of the remaining years covered by our NSF grant, we will add 5-6 schools, drawing participants from each of the state's ESUs. A wide geographical distribution of strategically placed sites will facilitate our expansion across the state. By identifying and training local leaders to serve as regional experts, we will form the centers around which CROP will grow post-NSF funding.

As installation and training become streamlined, more will be handled through long-distance learning: web-based help pages, videotaped installation and testing instructions, hotline response phone numbers. By the conclusion of this project's NSF funding, we hope to be able to reduce the duration of the summer workshops and gradually replace them by small regional workshops operated in part by experienced teachers in the area.

Conclusion

CROP started as a dream by two high-energy physicists (the authors) – use existing high-school sites as the grid for a ground-based cosmic-ray experiment, and train teams of remote teacher and student investigators. Now that the project has begun, the reality is more exciting than the dream. High school physics teachers represent an untapped source of enthusiasm and resourcefulness for frontier physics research. CROP is participant-driven, and the teachers and students guide the project step-by-step in both its technical and educational aspects. We are forming a true collaboration, not unlike a large high-energy physics experiment with collaborating institutions spread all over the country and the world. We look forward to our first Physical Review publication, some few years from now, authored by the CROP staff and our large team of high-school colleagues.

More information about CROP, including milestones passed to date, can be found on the web site:
http://www.physics.unl.edu/research/crop/crop.html

References

1. See http://www.nap.edu/readingroom/books/nses/ where the standards are available in html form, as well as information on purchasing the publication in hardcopy.
2. "Observations and implications of the ultrahigh-energy cosmic rays", M. Nagano and A. A. Watson, Rev. Mod. Phys. **72**, 689 (2000).
3. See the Chicago Air Shower Array (CASA) web site, http://hep.uchicago.edu/~covault/casa.html.
4. See the Akeno Giant Air Shower Array (AGASA) web site, http://www-akeno.icrr.u-tokyo.ac.jp/AGASA/.

[5] See the Pierre Auger Observatory web site, http://www.auger.org.

[6] Workshop talks can be accessed through http://www.phys.washington.edu/~walta/workshop_transparencies/.

[7] National Public Radio's feature on CROP can be heard by visiting www.npr.org, selecting "All Things Considered", and finding Cosmic Rays in the Archives under August 3, 2000.

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