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SUMMER COURSE ON RESEARCH IN PHYSICS EDUCATION

On July 15-25, 2003, a Summer Course on Research in Physics Education was held in Villa Monastero in the Italian town of Varrena. The Course was organized by the Italian Physical Society (SIF) in the tradition of the well-known "Enrico Fermi" Summer Schools on new fields of research in Physics, attended by young student-researchers since 1953. This was the first time that Physics Education appeared as a field of research in the Series.

On the first day of the Course, the President of SIF, F. Bassani, the honorary President R.A. Ricci, and two well-known members of the Society, Prof. G. Salvini and Prof. N. Cabibbo presented the history of the Fermi School with details on the course on particle physics.

The Course on Physics Education was directed by M. Vicentini, University "La Sapienza" and E.F. Redish, University of Maryland (USA) with the scientific secretariat of Carlo Tarsitani of the University "La Sapienza", Roma.

The lecturers and seminar speakers were chosen among USA and European countries researchers (United Kingdom, Italy, Spain, France, Germany, Belgium, Sweden).

The themes of the lectures looked at the interplay of the development of cognitive models for learning physics, problems related to the Physics content for contemporary and future society, teaching strategies and cultural aspects.

Information was also given on the organizations involved in connecting various aspects of Physics Education by J. Sahm on International Commission on Physics Education, G. Tibell on European Physical Society, H. Ferdinande on European Physics Education Network.

The lectures and speakers were:

- Introduction to Cognitive Models and the Structure of Knowledge. How metacognition and epistemology fit into modern cognitive models (J. Redish, USA)
- Research Into Practice: Formative Assessment for Learning (P. Black, UK)
- Reviewing Research into Classroom Formative Assessment (P. Black, UK)
- Testing Quality and Testing Systems (P. Black, UK)
- Role of Experiments in the Teaching and Learning of Physics (M. Euler, Germany)
- Student Resources for Tangibility and Coherence (D.Hammer, USA)
- How Should We Go About Attributing Knowledge to Students (A. De Sessa, USA)
- Coordination and Contextuality in Conceptual Change (A.De Sessa, USA)
- Principles for Computer-Based Instruction in Physics (A. De Sessa, USA)
- The Design of Teaching Sequences in Physics. Can Research Inform Practice?

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In this issue

WHAT PHYSICS SHOULD WE TEACH?

In its August 2003 Meeting, ICPE decided to recommend for IUPAP funding an International Physics Education Conference on "What Physics Should We Teach?" in Durban, South Africa on 5-8 July 2004.

The Conference theme was considered important for a number of reasons. Physics as a subject is changing rapidly, and yet many physics curricula focus on centuries-old physics. Advances in physics education research and cognitive science research have provided a great deal of information on difficulties students have with learning physics, how to overcome them, how students learn and implications for effective teaching. A common observation is that fewer students take physics at school or tertiary level. Many students perceive physics as a boring, difficult, or unrelated to daily life. Although few students choose to become research physicists, all students can benefit from studying physics.

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16TH INTERNATIONAL YOUNG PHYSICISTS' TOURNAMENT IN SWEDEN

A discussion between the participants from Germany and Poland in the final round

IYPT, the International Young Physicists' Tournament, organised its 16th event in Uppsala, Sweden, July 1 - 8, 2003, financially supported by the City of Uppsala and several other private and public sponsors. A record number of 23 teams participated from 22 different countries. The participants normally come from the grade just before university studies: final year of upper secondary school. New for 2003 were competitors from New Zealand, Indonesia and the United Kingdom. Observers from Brazil and Kenya had been invited, with the expectation of their teams participating next year when the tournament will take place in Australia.

Seventeen problems were discussed in the Tournament, published in October 2002 after a preparatory seminar in Uppsala. Examples of problems are:

Problem 2: Investigate and explain the movement of raindrops on a windowpane.

Problem 8: Construct a heat engine from a U-tube partially filled with water (or another liquid), where one arm of the tube is connected to a heated gas reservoir by a length of tubing, and the other arm is left open. Subsequently bringing the liquid out of eqilibrium may cause it to oscillate. On what does the frequency of oscillation depend? Determine the pV diagram of the working gas.

Problem 9: When a tall chimney falls it sometimes breaks into two parts before it hits the ground. Investigate and explain this.

Problem 12: Construct a torsion viscometer. Use it to investigate and explain the "viscous" properties of hen's eggs that have been boiled to different extents.

Problem 14: Find the optimum way of throwing a 'frisbee' as far as possible.

Participants from Australia having a discussion

Problem 15: Make a box that has a hole in its front wall and a membrane as its back wall. Hitting the membrane creates a vortex that propagates out from the hole. Investigate the phenomenon and explain what happens when two vortices interact.

The five qualifying rounds, or "selective fights", were set up according to the rules of the Tournament, with groups of three teams rotating through the roles of reporter, opponent and reviewer in each fight. With 23 teams it was necessary to have four teams in certain fights; then the

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SUMMER COURSE...*from page 1*

A – Lines of attention. Optics and solid friction

B – Doppler and Romer

C – Evaluating research-based innovations (L. Viennot, France)

- Thinking Physics for Teaching (M. Vicentini, Italy)
- Re-thinking Physics for Teaching: Research Problems (P. Guidoni, Italy)
- Cognition: The Evolution of Knowledge and/or a Definition of Learning (V. Otero, USA)
- Teaching Physics from a Cultural Perspective (N. Grimellini Tomasini, Italy)
- Laboratory Activities at University Level (R. Pintò, Spain)
- The Dependence of Knowledge Deployment on Context Among Physics Novices (J. Mestre, USA)
- Theory and Practice in Research on Physics Education (P. Heron, USA)
- Uncommon Knowledge: Students Behavior Correlated to Conceptual Learning (R. Thorntorn, USA)

The participants (42 students and 25 observers – the definition of the students status being ≤ 35 years of age) came mainly from USA and some European Countries (Italy, Spain, Portugal, Poland, Romania, Sweden, Slovakia, Albania) with one participant from Mexico. The gender distribution was 6 women and 11 men among the lecturers and seminar speakers, and 33 women among students and observers.

During the School a poster session was also organized and some participants gave oral presentations. Discussions took place after the lectures with a large participation of students and lecturers.

In these discussions, some differences in the focus of the research among the various countries emerged. A major attention of USA researchers is on cognitive aspects of learning physics (mainly mechanics and electromagnetism) contrasted by a major focus of European Researchers on Physics content (*e.g.*, Thermodynamics ad non-linear phenomena besides Mechanics and Electromagnetism). Teaching strategies and role of interactive communication among students were also important themes of the discussions. In a final round-table discussion (led by one director, two lecturers and two students from USA and Europe), the contrasting approaches were critically examined in the perspective of the convergence of future research lines.

The overall conclusion reached was the importance of research schools for young researchers, that is, another Varrena Course in physics education in the future. Proceedings of the Course will be published.

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UNESCO-ASPEN REGIONAL WORKSHOP ON ACTIVE LEARNING IN PHYSICS

The 4th General Assembly of ASPEN (Asian Physics Education Network) and a Regional Workshop on Active Learning in Physics, organized by the Postgraduate Institute of Science (PGIS) and the Department of Physics, University of Peradeniya were held from 29 November to 5th December 2002 at Peradeniya, Sri Lanka. Both events were supported by UNESCO. At the ASPEN General Assembly, Prof. Lakshman Dissanayake, Chairman of the PGIS Board of Study in Science Education and National Point of Contact for Sri Lanka of ASPEN was elected unanimously as the new Chairman of the ASPEN for the next five-year period. Dr. Alex Mazzolini (NPC, Australia) was elected as Executive Secretary.

Resource persons from USA, France, South Africa, India, Sri Lanka and other Asian countries conducted the 3-day workshop. Seventeen foreign participants representing India, Pakistan, Sri Lanka, Malaysia, Thailand, South Korea, Philippines, Japan and China, 27 local participants from universities and 13 A.L. Physics teachers from local schools attended the workshop. The aim of the workshop was to train Physics lecturers and senior school teachers in interactive methods of teaching Physics using computer-based, as well as computer-independent, techniques. Such interactive learning methods, where students participate actively in the teaching/learning process, are becoming popular and considered more effective than traditional methods of teaching Physics. The workshop sessions consisting of Interactive Lecture Demonstrations and hands-on laboratory activities were conducted by Prof. David Sokoloff (USA), Prof. Richard Hake (USA), Prof. Diane Grayson (S. Africa), Prof. Pratibha Jolly (India) and Prof. Rahman Omar (Malaysia). Dr. Minella Alarcon represented UNESCO, Paris.

Helping Cambodia to develop its Physics Education was among some of the follow-up activities identified at the Workshop. A three-member ASPEN team, comprising its Chairman Prof. Lakshman Dissanayake (Sri Lanka), Executive Secretary Dr. Alex Mazzolini (Australia), and Vice-Chairman Prof. Abd. Aziz Tajuddin (Malaysia), made a fact-finding visit to Cambodia in April 2003 to assess the status of Physics education at the Royal University of Phnom Penh (RUPP). A comprehensive report was prepared with an action plan to help RUPP develop its Physics education. The report is to be implemented during the next few years with support from UNESCO and other agencies.

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WHAT PHYSICS... *from page 1*

It is important to debate what physics should be taught to all students and what should be taught to future physicists, and how to cater to both populations. There is a need for debate on what should go into the physics curricula, in addition to physics topics, such as history and philosophy of physics, explicit teaching of scientific reasoning skills, and social and ethical issues. Debate is needed about what physics should be taught at school level, university level, and at the interface between the two levels (as in foundation or bridging courses). The extent to which physics courses should be interdisciplinary (*e.g.*, biophysics) or applied in focus (*e.g.*, industry or engineering) can also be a subject for debate.

Expected participants are those involved with physics teaching and curriculum development at school and higher education levels.

The Conference, organized by the South African Institute of Physics (SAIP), will follow the annual conference of SAIP on 29 June – 2 July 2004 in Bloemfontein. More details are in the SAIP website: www.saip.org.za

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16th INTERNAT'L...*from page 2*

teams rotated through an additional passive role. Even so, all teams assumed the roles of reporter, opponent and reviewer five times altogether during the four days of selective fights. An international jury judged each performance of the teams, on a scale from 0 to 10. After summing the points achieved, the conclusion of the jury members turned out to be that the teams from Germany, Poland and South Korea would be competing in the final round.

In the final round, the teams can choose which of the 17 problems to present. This is not the case in the selective fights, where the opponent team proposes aproblem whose solution the reporter should present. The three finalists chose problem 8 (Germany), 15 (Poland) and 12 (South Korea), respectively (see descriptions). After an intense and even final round, the German teams scored the highest, closely followed by the teams from South Korea and Poland. More details can be found on the IYPT web site http://www.iypt.org/

In accordance with the regulations of the IYPT there were also some cultural events arranged by the Local Organising Committee chaired by Dr. Sven Ljungfelt, a teacher at the competition venue, Fyrisskolan, Uppsala. One day was devoted to a visit to Stockholm, the Swedish capital, 70 km away from Uppsala. Another excursion was a trip to the 17th century castle, Skokloster, after a boat trip from the Uppsala center.

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INTERACTIVE LECTURE DEMONSTRATION EXPERIMENTS:
Conservation of Linear Momentum and Elastic Collisions
Teacher's Presentation Notes*

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Introduction

This set of sequential non-computer-based interactive lecture demonstration experiments on conservation of momemtum and elastic collisions is part of the "*Active Learning Classroom and Laboratory Activities*" project of the Asian Physics Education Network (ASPEN) funded by the UNESCO-Jakarta Office (Regional Office for Science and Technology for Southeast Asia).

The presentation of each activity follows this procedure (adapted from the Microcomputer-Based Interactive Lecture Demonstrations* developed by Dr. Ron Thornton of Tufts University and Dr. David Sokoloff of the University of Oregon):

1. The instructor explains the demonstration experiment.
2. Each student makes a prediction of the outcome of the experiment and writes his/her prediction on a prediction sheet. The instructor collects the sheets.
3. The students engage in small group discussions and agree on a common group prediction. They fill out a group prediction sheet.
4. The demonstration experiment is shown to the class and the results are discussed.
5. Analogous situations are discussed to deepen the understanding of the concepts.

The collision activities are limited to one-dimensional collisions involving carts with approximately equal masses or twice the mass of the other cart, and one of the carts being initially at rest. Except for demonstration 2, the collisions are non-contact so that elastic collisions may be assumed. From these conditions, the students can easily do the analytical solution, using the conservation of linear momentum and the conservation of energy. Although qualitative results are shown in this set of activities, quantitative measurements can be done using photogates or motion sensors.

Materials:

2 identical collision carts w/low-friction wheels & built-in magnets completely elastic collisions
track for the carts
set of weights
2 identical plunger carts with built-in plungers for collisions
1 bar to couple the collision carts
Note: This could be done using an airtrack.

Demonstration 1: The cart with a load is moving along the track at constant velocity (Fig. 1). Let the students predict what happens to the car when its load is suddenly removed.

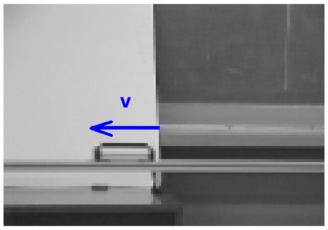
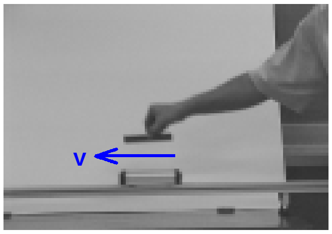


Figure 1. A cart with a load is moving along the track at constant.



Expected result: The cart moves faster when the load is removed as shown in Figure 2.

Figure 2. The car moves faster when the load is removed.

Demonstration 2: Two carts of equal masses are initially at rest on the track (Fig. 3). With their plungers completely latched, the two carts are placed against each other. Let the students predict the relative speeds of the carts when the plunger is released.

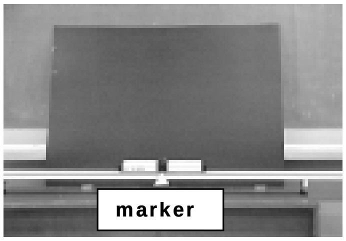
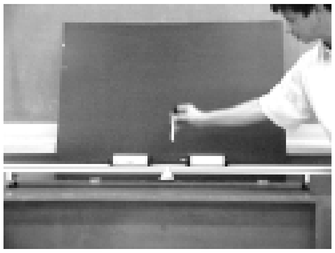


Figure 3. Two carts of equal masses are initially at rest on the track.



Expected result: The carts will move in opposite directions with approximately equal speeds as shown in Figure 4.

Figure 4. The plunger is released and the carts move in opposite directions with approximately equal speeds. Note distances covered relative to the marker.

Demonstration 3: One cart has twice the mass of the other. They are initially at rest at the middle of the track. With their plungers completely latched, the two carts are placed against each other (Fig. 5). Let the students predict the relative speeds of the carts when the plunger is released.

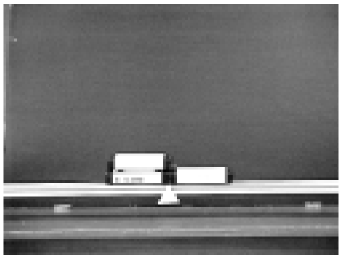
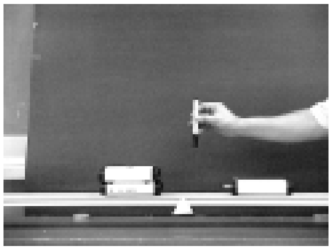


Figure 5. Two carts of unequal masses are initially at rest in the middle of the track.



Expected Result: The two carts will move away from each other. The less massive cart will have twice the speed of the other (Fig. 6).

Figure 6. The two carts move away from each other. The less massive cart will have twice the speed of the other. Note relative distances with respect to the marker.

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*Thornton, R. K. and Sokoloff, D. R. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics*, 58, 858-867.
Thornton, R. K. and Sokoloff, D. R. (1997). Using interactive lecture demonstrations to create an active learning environment. *The Physics Teacher*, 35, 340-345.

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IMPACT OF EDUCATIONAL RESEARCH ON PHYSICS TEACHER PREPARATION

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The Problem

Within the next decade, an estimated 240,000 middle and high school mathematics and science teachers will be needed in the USA to fill teaching spots left vacant by retirement or teachers leaving the profession [1]. This impending teacher shortage is compounded by the reports of several US commissions, which have been highly critical of current teacher preparation programs [1, 2]. These reports have urged institutions to transform existing teacher preparation programs or develop new programs to address the following deficiencies:

- Inadequate subject matter preparation
- Lack of congruence between what is advocated, teaching for understanding, and what is modeled in both the subject matter and pedagogy courses and field experiences in the secondary school classrooms
- Lack of coherence within the teacher preparation programs, fostered by the lack of communication among subject-matter faculty, education faculty, and experienced secondary school teachers
- Inadequate and unsupervised school-based experiences for the preservice teachers

The physics-related professional societies in the US have also taken a stand on the preparation of teachers. In 1999, the American Physical Society, the American Association of Physics Teachers, and the American Institute of Physics approved a joint statement regarding the preparation of K-12 teachers [3]. That statement read, in part:

> *APS, AAPT and AIP urge the physics community, specifically physical science and engineering departments and their faculty members, to take an active role in improving the pre-service training of K-12 physics/ science teachers.... Strengthening the science education of future teachers addresses the pressing national need for improving K-12 physics education and recognizes that these teachers play a critical education role as the first and often-times last physics teacher for most students.*

In 2001, the US Congress passed the No Child Left Behind Act, which provides a "framework on how to improve the performance of America's elementary and secondary schools while at the same time ensuring that no child is trapped in a failing school" [4]. In addition to mandating annual testing of students in grades 3-8, state reporting of student progress, and corrective actions for under-performing schools, the act also addresses teacher preparation. Local education agencies are required to demonstrate annual progress in ensuring that all teachers teaching in core academic subjects are highly qualified. The definition of "highly qualified" is being left up to each state education department, and this is currently an issue of intense debate.

Overview of Teacher Preparation in the USA

Teacher preparation programs that are university based are currently the most common and can take one of many forms. In many states, preservice teachers pursue an undergraduate degree that combines study in the subject(s) they plan to teach, along with courses in pedagogy. These pedagogy courses include general topics such as child development, classroom management, and curriculum development, as well as subject-specific teaching methods. These programs include field experiences in primary or secondary classrooms and typically culminate in an extended period of student teaching. In other states, students who want to become teachers must first complete an undergraduate degree, and then enroll in a fifth-year program that focuses exclusively on pedagogy courses and field experiences. Often this fifth year provides the beginning of a Master's degree program for the preservice teachers, which they complete during their first few years of teaching.

In response to the growing demand for teachers in the US, many universities have also developed so-called "fast-track" programs. These programs are specifically designed for students who have completed their undergraduate degrees, have worked in their field for some time, and want to pursue a second career in teaching. Like the fifth-year programs described above, these programs typically involve a year (two semesters and summer school) of pedagogy courses and field experiences, leading to eligibility for teacher certification.

In addition, many states in the US are "de-regulating" teacher preparation, which has opened the door to certification paths other than the traditional university-based preparation program. In a typical alternative certification program, prospective teachers who have an undergraduate degree are hired by school districts and take pedagogy courses at the same time they are teaching. These courses are provided, in many cases, by the school districts or two-year colleges.

Another national program, Teach for America, has as its goal the short-term placement of recent college graduates in rural and urban classrooms [5]. In this program, college graduates participate in a five-week summer training program, and are then placed in schools for a minimum two-year commitment.

Educational Research Results

What can educational research tell us about effective teacher preparation? Unfortunately, the short answer is, not much. The Education Commission of the States has just released a report titled, *Eight Questions on Teacher Preparation: What Does the Research Say?* [6]. This report is based on an analysis of 92 research studies that were used to answer eight questions related to teacher preparation. The research studies chosen for the report, which were selected from a pool of over 500, were published in peer-reviewed journals or in similarly high quality formats in the last two decades. All of the studies selected were of teacher preparation in the US, and were empirical, offering quantitative or qualitative evidence to support their conclusions. Thus, this report can be considered a snapshot of what is currently known about effective teacher preparation.

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INTERACTIVE LECTURE ... *from page 4*

Demonstration 4: One of the collision carts is placed at one end of the track while the other collision cart is placed at rest in the middle of the track. Push the cart (at the end of the track) so that it makes an elastic collision with the other cart (Fig. 7). Let the students predict what happens to the carts after the collision.

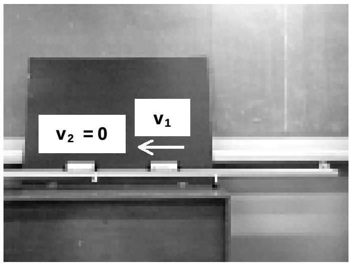

Figure 7. One of the carts approaches another cart of equal mass initially at rest in the middle of the track.

Expected result: After the collision the cart initially moving will come to a stop. The cart that was initially at rest will move with approximately the same speed as that of the initial speed of the other cart (Fig. 8).

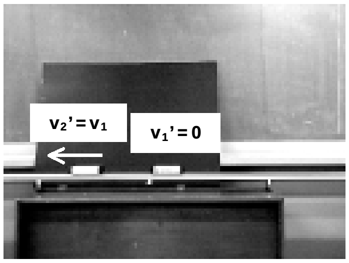

Figure 8. After the collision, the cart initially moving will come to a stop. The cart that was initially at rest will move with approximately the same speed as that of the initial speed of the other cart.

Demonstration 5: Add some mass to the collision cart. Place the more massive cart at one end of the track while the other collision cart is placed at rest in the middle of the track. Push the more massive cart so that it makes an elastic collision with the other cart (Fig. 9). Let the students predict what would happen to the carts after the collision.

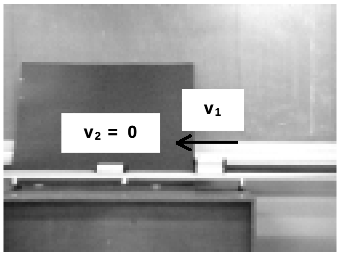

Figure 9. A massive cart approaches a less massive cart that is initially at rest.

Expected result: Both carts would move forward but the more massive cart's speed would be less than its initial value (Fig. 10).

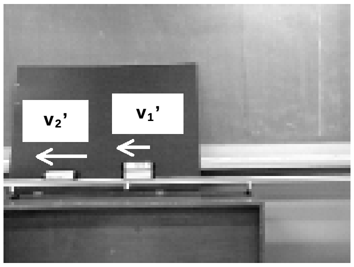

Figure 10. Both carts move forward but the more massive cart's speed would be less than its initial speed.

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IMPACT OF... *from page 5*

The first question in the report dealt with the subject matter background of teachers, specifically, the extent to which knowledge of the subject matter contributes to teacher effectiveness. While there is general agreement that teachers need adequate knowledge of their subject matter in order to be effective, little is known about what constitutes "adequate knowledge." The Commission found only moderate support for the importance of subject-matter knowledge in the research examined. This research was primarily focused on mathematics teaching and was not fine-grained enough to suggest exactly how much subject-matter knowledge was critical for teaching specific courses and grade levels. The research was also inconclusive as to whether teachers needed a major in the subjects they teach, or whether a graduate degree in the subject is an advantage. Interestingly, some of the research in mathematics teaching suggested that there might be a point after which additional subject courses are of minimal value in teacher effectiveness.

The report's second question dealt with the value of pedagogical coursework in relation to teacher effectiveness. The research analyzed provided only limited support for the link between pedagogical preparation and teacher effectiveness. The types of courses examined included general pedagogy courses focused on classroom management, student assessment, and curriculum development, as well as subject-specific teaching methods classes. In addition, what was less clear from the research was how this pedagogical knowledge is best attained, whether through university courses, field experiences, or on the job.

The next question was about the effectiveness of field experiences prior to certification. Unfortunately, while the Commission found a number of studies that addressed field experiences, nearly all were descriptive studies that did not provide solid evidence of the effectiveness of various types of field experiences. The studies did suggest that field experiences could change the beliefs and attitudes of prospective teachers, but there was little correlation with teaching effectiveness. The first three questions in the report addressed what are typically considered the most important aspects of teacher preparation, subject matter and pedagogical preparation, along with field experiences. Unfortunately, the research did not provide conclusive support of the value of any of these aspects of teacher preparation.

The fourth question dealt with alternative certification programs, which are becoming increasingly common in the USA. The research examined for the Commission's report provided limited support for the assertion that alternative programs produce teachers that are as effective as those prepared in more traditional programs. In addition, short-term retention rates for alternatively prepared teachers seem to be comparable to those for traditionally prepared teachers. However, there is as yet inadequate data on long-term retention rates in alternative programs, so little is known about the long-term benefits.

The next question focused specifically on hard-to-staff and low-performing schools, which are schools specifically targeted by many portions of the No Child Left Behind Act. In spite of the need for effective teachers in these schools, the report cites only limited support for the conclusion that deliberate preparation of teachers for these types of settings is beneficial. None of the studies considered for the rep0rt dealt with teachers from the

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THE POPULATION GAME:

A Socially Significant Laboratory Activity[1]

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Humankind needed about 5 million years to reach, in 1825, a population of one billion. We reached our second billion by 1930, our third by 1960, and our *sixth* by 1999. Population growth tends to be exponential, and thus surprising. All of us, scientists and non-scientists, had better understand these surprises. A game-like activity using simple materials can bring population growth home to all students while demonstrating many aspects of probability and uncertainty that are too often ignored in the curriculum. The activity can proceed at several levels of sophistication, from a simple demonstration of exponential growth through an elaborate modeling of life expectancy, developed versus developing societies, family planning, birth rate, and population momentum.

The Simplest Model (Random Exponential Growth)

Each team of 3 or 4 needs 100 identical dice-like wooden cubes, about 1.5 cm on a side, each painted on one face. You can make these by painting a board on one side (a different color for each team), and sawing it into 100 identical cubes. Each team also needs a small bucket, named "cubeland," graph paper, and a cardboard box.

Begin with all cubes in the box. Remove one cube, put it into cubeland, and toss it onto a level surface. If it comes up painted, it "reproduced" that year and the team should add one more cube to cubeland. Note that cubelanders procreate asexually, like bacteria (a simple variation can model sexual reproduction[1]). Put the 1 or 2 inhabitants back into the bucket and toss again. Add 0, 1, or 2 inhabitants to cubeland, depending on the outcome of the toss. Continue: each toss represents one year in cubeland history, and the number of painted sides showing on each toss is the number of "babies" that year. Graph the population N versus the year, beginning with $N_0 = 1$ in year 0. Cubeland's "carrying capacity" is arbitrarily set at N=100. The object of the game is "sustainability," which we arbitrarily define as survival of the population for 50 years without either dying out (N=0) or exceeding the carrying capacity.

Exponential growth is identifiable in either of two equivalent ways: (1) The percentage (or fractional) increase per unit of time, P, is unchanging. (2) The doubling time T (the time for any population N to grow to 2N) is unchanging. Since cubeland's expected fractional increase per year is 1/6, its population growth is exponential. Students can pursue many activities and questions about exponential growth.[1]

It's not difficult to see[1] that the expected population in the kth year is $(7/6)^k$. Time is in the exponent, which is why we call it "exponential growth." Solving $(7/6)^k = 2$, we find a doubling time of $T = 4.497 \approx 4.5$ years. Solving $(7/6)^k = 100$, we find that the expected population reaches overpopulation in about 30 years. Individual student graphs, and the class average graph, could be compared with the theoretical expected values. Using the standard relationship[1] $PT \approx 70$, ask the class to find the doubling times for China (P = 0.6% y^{-1}), the U.S. (1.2% y^{-1}), Pakistan (2.8% y^{-1}), and the European Union (0.1% y^{-1}).

Life Expectancy

The above model is highly unrealistic because death is not included. The game can model life expectancy by simply specifying a fixed lifetime for all inhabitants, using the recorded data to remove the necessary number each year, and otherwise playing the game as described above. Suppose, for example, that the lifetime is 10 years. Then 1 cube should be removed from cubeland at the end of the 10th year (because 1 cube was "born" in year zero); for any year k>10, the number removed should be the same as the number born in year k-10.

What is a reasonable life expectancy for cubelanders? It can be shown, either theoretically[1] or experimentally, that the median age of a cube at the time of its first baby is a little less than 4 years. Thus a primitive cubeland would have a life expectancy of 5-6 years, just a little larger than the childbearing age. Different teams should try life expectancies of say 4, 6, 8, 10, 12, and 14 years.

> ***Among nations, Japan's 82-year average life expectancy—three or four times the human childbearing age—is the world's longest.***

Average life expectancy in the most advanced nations has risen linearly for 160 years and could reach 100 within six decades.

Cubeland societies with a 4-year life expectancy will probably become extinct (N=0) during the first few years. There is also a high probability of extinction with lifetimes of 6-8 years. There is a lesson here, of course: Populations that are both small and very undeveloped are highly susceptible to extinction. These teams should then start over with a new graph and a longer assigned lifetime. Teams with lifetimes of 12-14 years will probably reach overpopulation well before 50 years, mirroring the fact that the human population explosion is a consequence of increased life expectancy. This suggests that advanced societies cannot survive without family planning.

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[1] This article is reprinted here in condensed form, with permission, from: *The Physics Teacher*, Volume 31, pp. 227-233 (April 2003). For further details, see the original article, which can also be found at the author's web site http://physics.uark.edu/hobson. The original article has been translated into Chinese and will appear in the Chinese physics education journal *The Physics Bulletin*.

IMPACT OF… *from page 6*

Teach for Americal program described above.

As noted earlier, the No Child Left Behind Act calls for “highly qualified” teachers in the core subjects. One response to this call may be to increase admission requirements in teacher preparation programs; the topic addressed in the sixth question. Only three studies addressed this issue, and so the question remains essentially unanswered. Another reaction to the call for highly qualified teachers may be to require that teachers graduate from accredited preparation programs. The most common accreditation in the US is by the National Council for the Accreditation of Teacher Education [7]. Again, only three research studies addressed this issue, and so the research is inconclusive on this question. Another way to address teacher quality is for institutions to provide warranties of their program graduates; this was the topic addressed in the final question. Currently teacher education graduates in Georgia and Kentucky, as well as at individual institutions in 20 other states, are given institutional warranties that guarantee their effectiveness in the classroom. No research has yet been conducted on these institutional warranties, and so very little is known about their contribution to teacher effectiveness.

The results of the Commissions’ analysis suggest that, while ideas abound on what constitutes effective teacher preparation, very little systematic research has been done to confirm the effectiveness of the various aspects of that preparation. These results call out for empirical research on the various aspects of teacher preparation and the link to teacher effectiveness. Granted, this is not simple research to conduct, given all the confounding variables and the long time frames involved. However, it is clearly time to move past “what feels right” in designing teacher preparation programs. Careful and long-term research on teacher preparation is critically needed to answer all of the questions posed by the Commission.

The Work of PhysTEC Institutions

In response to the call for physics departments in the US to become more involved in teacher preparation, the societies that issued that call have joined together to form the Physics Teacher Education Coalition (PhysTEC) [8]. With funding from the National Science Foundation, US Department of Education, and private corporations, the societies are supporting work at seven institutions to improve the preparation of teachers, and have invited collaboration with three other institutions. The institutions that receive PhysTEC funds have all agreed to the following set of changes, which address the concerns about teacher preparation noted earlier:

- Reform of physics courses, using results of Physics Education Research
- Reform of pedagogy courses, to model the kind of teaching expected of future teachers
- Involvement of a Physics Teacher-in-Residence, to provide a “reality check” in university programs
- Collaboration between departments of physics and education
- Involvement of physics faculty members in field experiences for preservice physics teachers
- Development of mentoring programs for beginning physics teachers

The seven project universities are Ball State University (Indiana), California Polytechnic University (San Luis Obispo, CA), Oregon State University, University of Arkansas, University of Arizona, Western Michigan University, and Xavier University (Louisiana). These Primary Program Institutions (PPIs) range from large research-focused institutions to smaller institutions that prepare large numbers of teachers, and all serve a wide variety of student populations.

The PhysTEC project is just beginning its third year, and so little data is available on new teachers who completed their preparation at one of the PPIs. However, preliminary data suggests that the reforms being implemented are having an impact on student understanding and improving collaborations among faculty members regarding teacher preparation. All of the PPIs are revising their introductory physics courses to reflect interactive engagement and a student-centered approach to learning science. Some PPIs have focused on the calculus-based, introductory physics course and others on the algebra-based course. Others began the project with a complete re-design of their laboratories. Some are revising both the laboratory and the lecture components simultaneously. Half of the PPIs have revised, or are creating, laboratory-based, integrated physical science courses for elementary school teachers. Many of the PPIs are collecting data on student conceptual understanding as measured by the Force Concept Inventory (FCI) [9] and the Conceptual Survey of Electricity and Magnetism (CSEM) [10]. The following table indicates results from the 2002-03 academic year; the normalized gain scores shown are averages over the revised courses. It is important to note that this data was collected for the purposes of program evaluation, and not necessarily using a research protocol. In addition, this data represents the first full year of course revisions at the PPIs. Although it should be interpreted as very preliminary data, it does suggest that the course revisions are having an impact on student understanding.

Institution	FCI Normalized Gain	CSEM Normalized Gain
PPI #1	0.36	0.30
PPI #2	0.39	0.31
PPI #3	0.34	0.27
PPI #4*	0.18	0.10

*Note that this PPI had only made revisions in the laboratory portion of their courses when this data was collected.

In addition to evaluating students’ conceptual understanding, data collected at some of the PPIs indicates that students in the revised courses are also out-performing students in non-revised courses on solving standard physics problems. Further, student evaluations of the revised courses and their instructors are high.

The involvement of a Physics Teacher in Residence (TIR) is a cornerstone of the PhysTEC project. This is an experienced secondary physics teacher who spends a year working on the PPI campus, helping to reform and teach courses, supervising field experiences, and providing a “reality check.” After their year on campus, the TIRs return to their classrooms and mentor beginning physics teachers. All of the PPIs hired TIRs who brought with them an average of 25 years of teaching experience. The TIRs’ work included re-writing laboratories, helping physics professors make their lectures more interactive, team-teaching educational methods courses with education faculty, and providing practical advice to preservice teachers.

See next page

THE POPULATION... *from page 7*

Family Planning

To model universal one-child family planning (all inhabitants have at most one child), choose a lifetime such as 14 years, corresponding to an advanced nation, and play the game with no family planning until the population passes, say, N=60. At this point, a cubeland physicist notices the population problem and recommends a one-child family planning (two-child family planning can also be modeled[1]) policy beginning next year. On all future throws, all the cubes that come up painted should be put into a special "no further babies" zone outside of the bucket (these must still be counted as citizens of cubeland). In order not to make mistakes, the team should keep careful track of births, deaths, and population increase each year.

There is one additional proviso: Deaths must come *proportionally* from *both* the no-babies zone and from the bucket. For example, if there are about twice as many in the bucket as in the no-babies zone, then about 2/3 of the deaths should come from the bucket and 1/3 from the no-babies zone.

Students can now observe "population momentum": Rapid growth continues for a few years after family planning has started. This can carry cubeland to overpopulation even when family planning starts at, say, N=60. But if planning starts at, say, N=40, the graph will probably continue rising but at a reduced rate, and then level off and decline in a bell-shaped curve.

Students can model various scenarios such as a nation that proceeds through the "demographic transition": a less developed period of short life expectancy and no family planning, followed by a development period of longer life expectancy and no family planning, followed by a developed period of long life expectancy and family planning. Different teams can experiment with different life expectancy and family planning assumptions.

Teams can compete to attain some pre-determined population goal such as N=50 after, say, 50 years. Each team chooses a particular set of assumptions, and plays the game with those fixed assumptions. The team coming closest to the goal wins.

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IMPACT OF... *from page 8*

Another key aspect of the project is a focus on increasing collaboration between physics faculty and education faculty, two groups that historically have had little to do with one another. Four of the PPIs had an active collaboration, with two institutions having science educators in the same building as physics faculty. At one PPI, physics faculty members taught the elementary methods course for preservice elementary school teachers. Another PPI, which had very little contact with education faculty prior to PhysTEC, established solid links with a secondary science education faculty member, who will be part of the PhysTEC-supported staff for Year Three.

At most of the PPIs, no teachers have completed the teacher preparation program and entered into the mentoring portion. At one site, however, two new physics teachers completed the program in 2002. One of those teachers is working out of state, and the other one will be participating in a beginning-teacher mentoring program. The goal of this program is to help this new teacher be successful in his first years of teaching and increase the likelihood that he will remain in the teaching profession.

Conclusion

According to the just released report, *Status of the American Public School Teacher, 2000-2001* [11], 43% of the USA's 2.9 million teachers have 20 or more years of teaching experience. Thus, many of these teachers will be retiring over the next five to ten years. In addition, 50% of new science teachers leave the teaching profession within the first five years of teaching, due to reasons related to lack of professional support more often than low salaries [12]. Thus, we are faced with several challenges—preparing highly qualified teachers to replace those who are retiring as well as those who are leaving the profession, reforming teacher preparation programs to address the concerns cited earlier, and gathering empirical evidence on what constitutes effective teacher preparation in order to further improve teacher preparation. While educational research currently provides little guidance to teacher educators, PhysTEC and similar projects are poised to contribute to the research base, by systematically collecting data on the effectiveness and retention of the teachers they prepare.

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WEB SIMULATIONS FOR PHYSICS EDUCATION

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There is a growing trend towards integrating computer technology for physics education. Mode of dissemination of physics knowledge is no longer confined to diagrams, pictures and text on a printed paper, technology is able to convey clear and logical presentation of the basic concepts and principles of physics to strengthen the understanding of concepts and principles through animations, simulations and three dimensional models, *etc*. This project mainly focused on developing simulations of physical phenomena for tertiary level physics. The computer-based lessons can be prepared for the use of classroom teaching or the self-learning purposes. Self-assessment tests can be provided to assess the level of understanding and links can be provided to elaborate explanations. Further, interactivity can be integrated for such lessons to sustain the student's continuous attention and to promote the curiosity.

This presentation illustrates “Electrostatic Simulator”, prepared as teaching aids for advanced level physics, using macromedia technology®. Simulations are embedded in web pages with the view of uploading them into the *Internet* in the future. The CD version can be prepared for the users who do not have access to the Internet.

Electrostatic Simulator is developed to teach the Coulomb force and the electric field, electric potential due to point charges and the other concepts in Electrostatics. Simulator uses “click and drag” sequences that allow students to move a “*point charge*” against fixed-point charge(s) on the screen to investigate how Coulomb force and the electrical potential vary. The integrated activities and exercises may improve the understanding and enable students to self-evaluate.

Financial assistance received from University of Kelaniya for this project is greatly acknowledged.

INTERACTIVE LECTURE... *from page 6*

Demonstration 6: Interchange the position of the two carts. The more massive cart is now at the middle of the track and initially at rest. Push the less massive cart so that it makes an elastic collision with the less massive cart (Fig. 11). Let the students predict what happens to the cart after the collision.

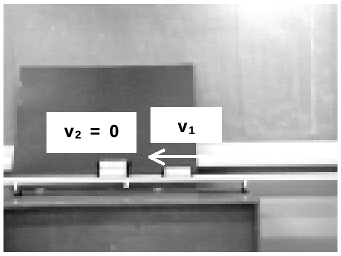

Figure 11. A light cart approaches a more massive cart that is initially at rest in the middle of the track.

Expected result: The more massive cart moves forward while the other cart moves in the opposite direction after the collision (Fig. 12).

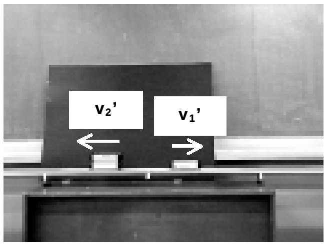

Figure 12. The more massive cart moves forward while the other cart moves in the opposite direction after the collision.

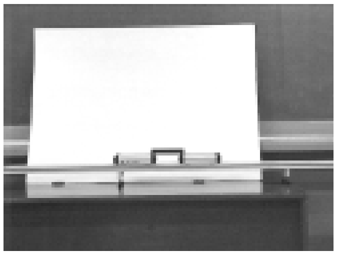

Figure 13. A bar initially couples two collision carts.

Demonstration 7: A bar temporarily couples the two collision carts (Fig. 13). The bar will cause the two carts to move with the same velocity. The tracks are fitted with end stops with magnets for elastic collisions. While the coupled carts are moving with constant velocity the bar is removed (Fig. 14). One of the carts collides with the end stop and moves in the opposite direction (Fig. 15). It then collides with the other cart. Let the students predict what happens to the carts after their collision.

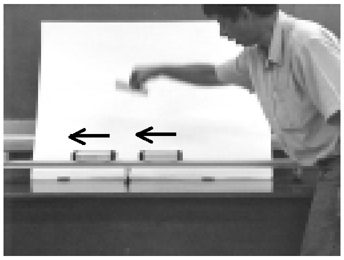

Figure 14. While the coupled carts are moving with constant velocity the bar is removed.

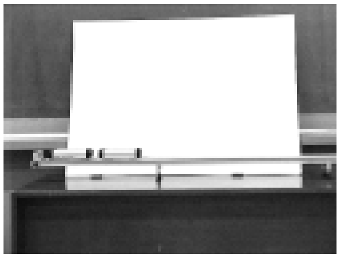

Figure 15. One of the carts collides with the end stop and moves in the opposite direction.

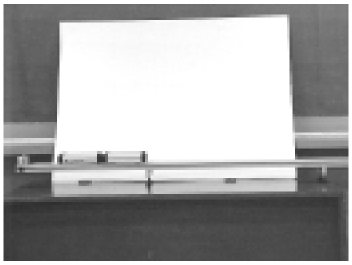

Figure 16. The two carts come to rest after the collision.

Expected result: The two carts come to rest after the collision (Fig. 16).

THE POPULATION... *from page 9*

Conclusion

The simplest model, the life expectancy model, and the life expectancy plus one-child family planning model, were tested at two physics education workshops in Guilin, China. There were about 25 people in each workshop, divided into 7 teams. Each workshop spent about four hours playing all three versions of the game and discussing the pedagogy and the societal implications. See the original article for graphs of typical results. The results demonstrated the significance of population momentum, the slow growth of less developed societies, the necessity for family planning in industrialized societies, and the importance of instituting family planning early.

Variations on this game can also demonstrate radioactive decay, resource depletion, and the approach of a thermodynamic system to statistical equilibrium.

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