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Asian Physics Education Network Adapts Active Learning Approaches

Asian Physics Education Network (ASPEN) has conducted a workshop in Laos, Vietnam, South Korea, Sri Lanka and Philippines in 1999-2001. The workshop provided venue for training physics educators to implement various active learning techniques and to present their developed-activity-based lesson plans.

ASPEN is working in close association with the United Nations Educational, Scientific and Cultural Organization (UNESCO) Regional Office for Science and Technology (S & T) in Southeast Asia. Its mission is to introduce the principle of active learning, the various student-centered learning and teaching techniques to member countries.

Various active learning curricula were developed in the United States, the curricula developed are: Important role of physics education research on exploring students' learning, difficulties in introductory physics courses and development of a relatively new area of interest in physics education research.

The active learning curricula have four categories: Full Studio Models, Discovery Laboratories, Lecture-Based Models and Recitation-Based Models. All students are engaged in the learning process called "Active Engagement or Active Learning Techniques."

The three underlying assumptions in the active learning perspective are: (1) learning by its very nature, should be an active process; (2) different people learn in different ways; and (3) learning is only meaningful when learners discover knowledge for themselves and make it their own.

The following techniques are employed to create an active learning environment inside the classroom: Instructors' facilitating technique to accomodate diverse range of student learning styles; opportunities are provided to constantly challenge students' misconceptions about basic principles of physics; and materials are prepared with a series of connected sequential questions that are carefully constructed to help students discover answers for themselves. As a result of the instructors' creation of active learning environment inside the classroom, the students cease to be mere receivers of information; they are given numerous opportunities to observe, experiment, discuss, and exchange ideas. The students work in teams or groups, busy with varied activities: experiments, computer simulations and interactive problem-solving.

The active learning environment is activity-based and student-centered, and carefully interpreted quantitative observations now become the foundation on which the physics understanding of the student is developed.

In This Issue

Research-Based Physics Teacher Education Meeting Held in Korea

The Physics Education Department College of Education, Seoul National University (SNU) hosted the International Meeting on Research-Based Physics Teacher Education last August 10, 2001.

Plenary talks and panel discussions were among the activities included in the meeting. The first plenary talk, "Education of Physics Teachers in Secondary Schools: A Swedish Approach," was given by Gunnar Tibell of Uppsala University, Sweden. The second plenary talk, "Ownership and Transformation: Teachers Using Curricular Innovations," was given by Jon Ogborn of the Institute of Physics, UK.

Taking the Physics Classroom into the World

by Christopher J. Chiaverina
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Physics may be one of the easiest subjects to teach because it touches virtually every aspect of our students' lives! The world outside the classroom provides endless possibilities for discovering and understanding nature's laws. Through experiments and exploratory activities performed in non-traditional settings, students of all ages can be made aware of the beauty and wonders of physics. Furthermore, such experiences make evident the myriad applications of physics in everyday life. This paper discusses how the use of auditoriums, parking lots, amusement parks, interactive science centers, home and other unique learning environments can make physics come alive!

Out of the Classroom Experiences

Although a school's physics laboratory is the traditional arena for hands-on exploration and experimentation, a host of alternative venues exist. We will first examine laboratory settings that lie outside the classroom, but in or near the school.

Our first stop will be the school auditorium. In an attempt to illustrate acoustical phenomena on a large scale, we have an annual "sound and light" show in our school's auditorium. The program consists of demonstrations of interference and reflection of sound waves and additive color mixing.

We begin by reviewing the principle of superposition of waves. This is accomplished by projecting a ripple tank interference pattern on a screen. The large image allows students to observe changes in the nodal pattern as the spacing of the sources and the frequency of the waves are changed.

A transition from water waves to sound waves is made by using two loudspeakers to approximate point sources. While these two sources (typically 2-m apart) are being driven in phase at a fixed frequency (for example, 500 Hz), students are asked to move around the auditorium and locate points where the sound level is low. By using a large number of students, an easily discernible nodal pattern emerges. While students remain in their seats where the sound level was determined to be low, the frequency of the sound and then the separation of the sources are changed. The resulting changes in the nodal pattern are observed as nodes and anti-nodes sweeping across the auditorium. Finally, music is played to demonstrate how a large number of frequencies played simultaneously give rise to a "washing out" of the nodal pattern.

The fact that the nodal lines in the interference patterns are not totally "dead" leads naturally to a discussion of virtual sound sources. These virtual sources result from multiple reflections from the walls, ceiling and floor of the auditorium. The plane-mirror analog is used to predict the location of the virtual sources of sound.

To reinforce the notion of virtual sound sources, a single speaker and a large sheet of plywood are used to set up an interference pattern. The sheet of wood serves as a reflector and hence a virtual source of sound. The interference pattern formed by a real source and its image is easily observed.

Before leaving the auditorium, we allow students to observe how the color of an object depends on the color of the incident light. We invite the students to join us on the stage and observe the color of their clothing under white light. Then the white light is turned off and each primary color is used in turn to illuminate the stage and its occupants. The perceived change in the color of the students' clothing is quite dramatic.

While many physics activities can be performed in non-classroom settings inside the school, some must be done outdoors. The following experiment takes place in our school's parking lot. To get a feel for Newton's Laws, students push a car. After using simple equipment to gather data, they apply Newton's second Law of Motion to determine the mass of the automobile.

First, three students are selected to push the car with the bathroom scales. The sum of the three bathroom scale readings provides the applied force. With stopwatch in hand, a student in the backseat of the car says "go" and the driver releases the brake. Every two seconds thereafter the timer chants "drop." While the student-powered car accelerates, a person in the passenger seat drops markers onto the pavement through an open door. The markers provide a record of the position of the car as a function of time. The students' reaction to the increasing distance between successive markers alone makes the experiment worth doing.

Using the measured distances between markers, the average velocity during each interval is calculated. From the slope of a plot of velocity versus time, students determine the car's acceleration.

The frictional force acting on the car is found by determining the force needed to keep the car moving at a constant velocity. The net force is then calculated by subtracting the frictional force from the applied force. The mass, found by applying Newton's second Law of Motion, is compared with data found in the car owner's manual.

Opportunities for doing on-campus physics activities outside the classroom are almost limitless. The *Physics Teacher* magazine is an excellent source of ideas for such activities.

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Physics to Go: Doing Physics in the Home

For some time now we have been taking advantage of yet another non-traditional laboratory setting: the home. Using simple materials, students are encouraged to do physics experiments with family and friends. Sometimes the materials needed to investigate physical phenomena may be found in the kitchen or workshop. When more specialized apparatus is called for, we create a "laboratory in a bag" by packing the required equipment in a plastic food-storage bag.

The materials used in our "laboratory in the bag" experiments are safe, simple and obtainable. Because of the low-cost nature of the equipment, students are usually allowed to keep the bag and its contents. Returning of materials is requested only when higher priced items, such as polarizing filters, are included in the kit. Still, the nominal cost of even these materials eliminates any concern about loss or breakage.

Though certainly not the focus of our physics course, these take-home experiments have greatly enhanced our program. The activities have allowed us to somewhat surreptitiously extend the time our students are thinking about and doing physics. Since many of the explorations focus on counter-intuitive phenomena, students delight in sharing unexpected outcomes with others. Equally important is the obvious satisfaction they derive from demonstrating their knowledge of physics.

Needless to say, parents love seeing what their children are doing in physics. We have received numerous written, email and phone messages from parents who have been intrigued by the experiments and delighted by their son's or daughter's involvement in science.

Each year, prior to the first at-home experiment assignment, we send a letter to parents explaining the purpose and nature of the upcoming activities. The letter also informs parents that their son or daughter will receive credit upon the return of a signed sheet indicating the student's successful completion of and the parents' involvement in the activity.

Sometimes the experiements are qualitative. Students may only be required to make observations and form hypothesis regarding the phenomena they witness. When appropriate, students may be instructed to make measurements, record data, construct graphs and perhaps draw vector diagrams.

"Physics to Go" experiments may be designed for virtually any topic in physics. The following optics activities are meant to be illustrative examples.

Identifying Sources of Ultraviolet Light

Inexpensive UV-sensitive plastic beads are used to identify sources of ultraviolet light. The reusable, chemically treated beads undergo a dramatic change in color when exposed to UV. Students expose their beads to radiation from as many sources as they can find in their environment. After identifying strong UV sources, they shield their beads from these sources with a variety of materials in an attempt to find the best absorber. Glass, plastic, water, suntan lotion are among the materials tested.

Camera Physics

Students learn about the workings of a camera by taking one apart. With the popularity of single-use cameras, it is possible to obtain a class set of used disposable cameras from virtually any camera store.

Students examine the camera's optics (these inexpensive cameras sometimes have up to three lenses!), flash electronics and film transport mechanism. They form images with the camera's principal lens and measure its focal length and f-number. Dissecting and analyzing a camera is one of our students' favorite take-home experiments.

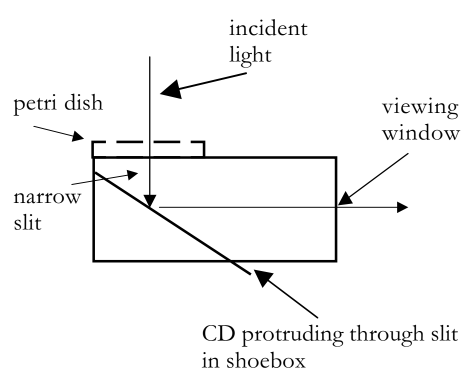
Exploring Color

This laboratory experiment allows students to explore the principles of additive and subtractive color mixing. Along the way, they are made aware of examples of color mixing going on all around them.

Each student is given six color filters (red, green, blue, cyan, yellow, and magenta) and a pair of inexpensive diffraction glasses. Students examine the makeup of white light by looking at an incandescent bulb through the diffraction glasses. They record what they observe with crayons or colored pencils. They then place each colored filter over the glasses and see that each filter removes a different portion of the spectrum. They again record their observations with colored markers.

To observe the effect of overlapping filters, they view white light through various combinations of the filters. The hope is that students will "discover" the rules of subtractive color mixing.

Placing a drop of water on the screen of a television or computer monitor reveals the wonders of additive color mixing. With close inspection of the drop, red, blue and green dots or rectangles are visible. Students realize that the myriad colors seen on the screen result from the additive mixing of these three primary colors.



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CD-Spectroscope

Using a shoe box and any compact disc, students may construct a no-cost spectroscope. Functioning as a diffraction grating, the disc's pitted surface separates incident light into its component colors. Both emission and absorption spectra are observable using this easily constructed optical instrument.

Interactive Science Centers

Interactive science centers have become extremely popular worldwide. Following the lead of San Francisco's Exploratorium, cities around the globe have created hands-on museums where the watchword is "please touch" and visitors are encouraged to experiment and explore.

Dr. Frank Oppenheimer, physicist-educator and founder of the Exploratorium, was acutely aware of the importance of engaging with the learner. According to Oppenheimer, "Students have to have the opportunity to ask 'what will happen if'. They can't just read. They have to have props to see, handle, and understand what's happening. Otherwise, teaching science is like teaching swimming but not allowing anyone near the water."

Inspired by the Exploratorium, art, mathematics and science teachers at New Trier initiated the Connections Project. The project is an ongoing multi-disciplinary endeavor whose mission is to create interactive, museum-type exhibits that illustrate connections between seemingly disparate disciplines. Teachers then use these exhibits to enhance concept development and demonstrate interdisciplinary linkages. Since the inception of the Connections Project, thousands of students have used the exhibits as extensions of the classroom. Through hands-on experiences, they have seen how science is intertwined with arts, humanities, engineering and mathematics.

The teachers and students involved in this initiative have thus far created more than 125 museum-quality, interactive exhibits. The multi-disciplinary exhibits are grouped into thematic clusters that include: curves, optics, visual perception, motion and energy, tessellation, iteration and fractals and symmetry.

An exciting aspect of the connections project is that it brings students and teachers together as co-learners. Students and teachers learn by producing exhibits that, in turn, are used to teach other students and teachers. The project also encourages collegiality and renews teacher enthusiasm.

The connections project are presented in exhibitions at New Trier and used in a wide range of classes in Chicago elementary schools. They are also used at local, state and national professional meetings, and in university classes.

The Amusement Park: An Unlikely Laboratory

In addition to thrill rides and cotton candy, what else does an amusement park offer? Would you be surprised if you were told that it's also the perfect place to study the laws of physics?

At an amusement park, virtually all the topics included in the study of mechanics can be observed operating on a grand scale. Furthermore, phenomena, such as weightlessness, which can only be talked about in the classroom, may be experienced by anyone with sufficient courage.

When we take our students to amusement park, they must quantify what they see and feel. Unlike textbook problems, no data is given. Therefore, students must start from scratch. Heights of rides, radii, periods of rotation, lengths of roller coaster trains and other quantities must be obtained before applying equations learned in the classroom.

Fortunately, only simple equipment is required to make such measurements. A stopwatch, meter stick and protractor are all that is needed to obtain data that will allow the calculation of such diverse quantities as a person's potential energy at the top of a roller coaster, the centripetal acceleration experienced by a rider in the English Rotor, or the speed of a passenger after 50 metres of free fall.

In recent years, a new type of recreational facility has hit the scene: the aquatic amusement park. Consisting of water slides, swimming pools and large wave pools, these parks allow the study of a variety of large-scale wave phenomena including traveling and standing waves. The centerpiece of most aquatic parks is an enormous wave pool. Waves in such pools may be produced by a large blade at one end of the pool that rhythmically pushes on the water or by blowers that pneumatically generate waves. At Magic Waters, a local pool we visit, pneumatic wave generators are employed.

When the water is excited pneumatically at the proper frequency, intricate interference patterns may be produced on the surface of the water. In the case of Magic Waters, not only nodes and anti-nodes are clearly visible on the surface of the water, but a beautiful standing wave is seen along one end of the wave pool while traveling waves move along the sides of the pool. Among others things, our students analyze the interference patterns, measure the frequency and wavelength of the water waves, and calculate wave speed using three different methods: 1) $v = f\lambda$; 2) v = distance/time; 3) $v = (gh)$. All three methods agree within 1 m/s. Conventional amusement parks and aquatic amusement parks offer wonderful kinesthetic learning opportunities. Where else can you ride an anti-node or relax while standing at a node?

Students would probably tell you that amusement parks provide the ultimate vehicles for learning physics.

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Conclusion

The activities outlined in this paper are intended to provide students with an awareness, appreciation and understanding of the natural phenomena that surround them. Such consciousness-raising can enrich their lives just as an appreciation of art and music can expand their horizons. Seeing the physics in everything from a rainbow to a rock concert can be rewarding and enjoyable; having an understanding of the underlying principles behind these phenomena serves to heighten the experience even more.

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Sheets of colored filters may be obtained from Arbor Scientific, P. O. Box 2750, Ann Arbor, Ml 48106, or any stage lighting outlet.

Inexpensive diffraction glasses are available through Arbor Scientific or Kipp. Brothers, P.O. Box 781080, Indianapolis Indiana 46278. When ordering from Kipp, Request "Laser Amazers."

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Solomon, *J. Physics, technology and society*, pp. 32-39.

Yanlai, Y., Lingda, K., & Huahan, L. P*hysics in ancient chinese chime-bells*, 62-66.

Thinking Physics for Teaching

by M. Vicentini

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In 1994, a conference on "Thinking Physics for Teaching" was held in Rome. The Conference aimed to unite researchers in physics, researchers in physics education, and experts in the epistemology of physics (on the scheme of a previous conference on Thermodynamics) and to start thinking about a change in the traditional content organization of the introductory Physics Courses.

This change was needed for two reasons: One, the research on students' difficulties in understanding classical mechanics raised some doubts in the belief that Newtonian mechanics is the first easy step to enter the physics world. Two, nowadays, there was a tremendous increase in knowledge with new paradigms of quantum physics and relativity.

Two main themes are important in conveying the learning problems to the larger community of university physicists. The first theme is concerned with the need to re-structure the traditional content and to provide a better fit (or a better possibility for conceptual change) between intuitive physics and scientific knowledge.

The second theme is concerned with the need for the researchers to be involved in conceptual clarification of disciplinary knowledge.

The strength of the traditional presentation is witnessed worldwide by the content organization of introductory physics textbooks. However, new approaches started to appear in conferences on Physics Education such as the GIREP meetings. These approaches were looked at with some

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Physics in Ancient Chinese Chime-Bells

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Introduction

The Set of Zeng Hou Yi Chime-Bells, which consists of 65 musical bells in the age of Confucius, is one of the earliest and most extensive surviving groups of ancient musical instruments in the world. Behind such an ancient cultural miracle, physics is richly involved, and it has recently become one of the most interesting topics for multimedia lectures in physics education.

Music was one of the most important elements in ancient Chinese culture. Bells that were assembled into chimed sets as percussion instruments played the dominant role in the music of Bronze Age China. Zeng Hou Yi chime-bells dating back to about 2500 years ago were excavated in 1978 from Marquis Yi's tomb in Hubei province, China.

Bells as musical instruments also developed in western countries during the seventeenth century about two millennia later. Although both Chinese and western musical bell were made of bronze, they were designed in different ways. Therefore their vibration mechanisms were different from each other and resulted in different sound characteristics. In this paper we will discuss the physics behind the almond-shaped Chinese bell and compare its unique musical properties with the western carillon.

Acoustic Properties of Zeng Hou Yi Chime-bells

The set of Zeng Hou Yi Chime-bells covered roughly five and half octaves, only a little less than the modern piano. It produces the entire 12 semitones, which like essentially the current C Major; in other words, all the notes found on a piano keyboard.

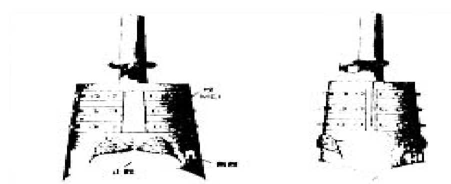

Fig. 1

As shown in Fig. 1, the Chime-bells are almond-shaped and have many nubs (called as Mei in Chinese pronunciation) distributed over the outer surface of each bell. The lower fringes of the bell are not in a plane, but are arched up a little between the side spines (called Xian in Chinese pronunciation). This special design results in its double-tone property. When the bell is struck at the so-called front drum point (or Gu), it produces one fundamental and a series of partials called A-tone. Two of those vibration modes with m = 2, n = 0 and m = 3, n = 1 are shown in Fig. 2(b) with maximum amplitude there around Gu. When the bell is struck at the so-called side drum point (or Sui), it produces different fundamental and another series of partials called B-tone shown in Fig. 2(c) with maximum amplitude there around Sui. That means the positions of the vibrating part of the bell depend on where it is struck. It should be stressed that the nodal lines go differently between A-tone and B-tone. The side drum point, i.e., Sui, is just located on the nodal line of the A-tone vibration modes, while the front drum point, i.e., Gu, is just situated along the nodal lines of the B-tone vibration modes.

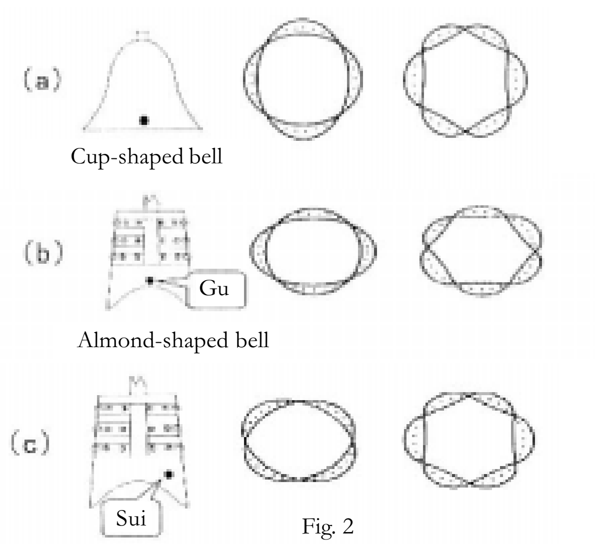

Fig. 2

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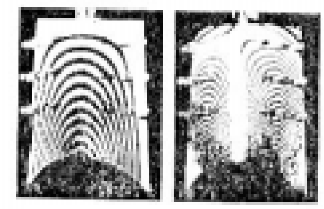
A round bell, no matter where it is struck, gives one harmonic tone with a fundamental and many partials as shown in Fig. 2(a), because the same pattern will form symmetrically with respect to the striking point. The almond-shaped bell does not have much axial symmetry as the western carillons do, but they have mirror symmetry. Such symmetry leads in two different sets of natural vibration modes, of which one is symmetric against the mirror plane while another one is anti-symmetric.

When the Gu is struck, all possible frequencies appear except those modes where the nodal lines are along the Gu. In other words, all the B-tone modes keep silent. When the Sui is struck, all frequencies appear except those modes where the nodal lines are along the Sui. In other words, all the A-tone modes keep silent. Therefore, the almond-shaped bell produces two distinctly different tones. Holographic interferograms show the two-tone bell vibrates in fundamentals of A-tone and B-tone respectively as shown in Fig. 3(a) and (b).



(a) (b)

Fig. 3

In addition to the intriguing double tone characteristics of the Zeng Hou Yi Chime-bells, one more property that should be mentioned is the frequency difference between the two tones of the bell is always approximately either a major third or a minor third. In fact, the frequency of a B-tone is always higher than A-tone by approximately either 400 cents or 300 cents. This fact demonstrates that not only advanced casting technique, but also the tone adjustment technique, were already available in Bronze Age China.

Those nipple-like "Mei"s (36 in total) around outer surface of the bell bring more ancient atmosphere to the two-tone bells. However, the purpose in building them around the bell is still a puzzle. Our recent work shows that those Meis do have some effect in making acoustic differences on those ancient music bells and the design of decoration. We cast a special almond-shaped bell for testing with tall Meis which are two times taller than usual. We simply struck the testing bell and measured the frequency spectra of the bell sound and then we ground the Meis to decrease their heights step by step. After each grind, the results of the Fourier frequency analysis are shown in Fig. 4.

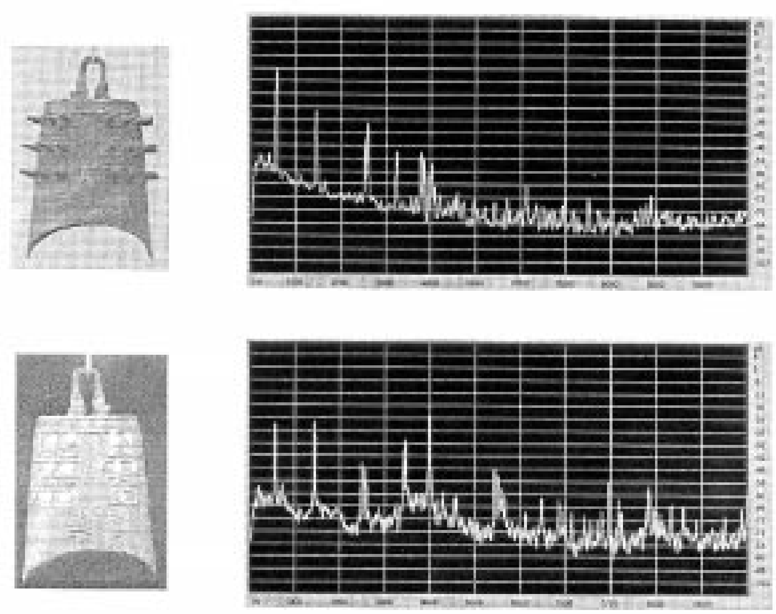


Fig. 4

It is clear that frequencies higher than 4000Hz do not exist before the tall Meis were ground as shown in Fig. 4. As those tall Meis are ground shorter and shorter, the partials higher than 4000Hz start to appear and the intensities gradually vary with the change of heights of Meis. The partials of high frequencies become stronger when Meis were totally ground off as shown in Fig. 4. We believe that the Meis were designed not only for decoration of the bell surface, but also, possibly more essentially, for filtering out those partials of higher frequencies and for adjusting the audio tone quality as well.

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It has been noticed that those bells in the tallest row on the Frame of Zeng Hou Yi Chime-bells called Niu bell, which are responsible for high tones, do not have any Meis at all. Those bells on the middle row of the frame called Yong Bell, which are responsible for the middle tones, possess Meis with normal sizes. Whereas the bells on the bottom row of the frame also called Yong Bell are responsible for base tones, all have the biggest Meis. It is so marvelous and obvious that we could say that ancient Chinese music people who designed those Meis with different sizes around the bell's outer surface did not have any purpose for their acoustic results!

The third feature of the chime-bells is their short sound lasting property, i.e., the bell sound is damped relatively quickly after the bell is struck, while the sound from the cup-shaped Western carillon lasts longer. To give an explanation, we believe this acoustic property originated from its unique almond-shape. Its two almond-shaped curves which meet at the bell's spine which is called Xian, and the top stem of the bell which is called Yong, are responsible for this short sound lasting property. These parts are the thicker parts with higher stiffness. The Xian damps the vibration modes of the A-tone, because the anti-nodal line vibrates along the Xian, while the Yong damps the vibration modes of B-tone, because its heavy stem that is close to its anti- nodal lines to obstract the vibration at Sui. In short, the sound from a circular bell lasts longer than its counterpart from the flat one. Almost one thousand years ago, a famous ancient Chinese scholar, Shen Guo (1031-1095) was the first one to reflect on the difference between bells with round as opposed to almond-shaped cross-section. He stated: "When a bell is round, its sound is long; when it is flattened, its tone is short. When the tone is short, it is abrupt; when the tone is long, it is undulating." For set of chime bells, each individual bell should not vibrate for long, otherwise, it would interfere with the others. This acoustic property, therefore, makes it possible to play short melodic phrases by being struck with a mallet, however in comparison, the Western carillons being struck with clappers can only play slower music phrases.

Conclusions

In conclusion, The Zeng Hou Yi Chime-bells brought us great inventions of two respects. One is its almond-shape, which generates not only two distinct tones but also short sound lasting property, and at the same, makes the set of chime-bells covering broader octaves with less weight and volumes compared with western carillons. The other is the nipple-like design of Meis, which, from a physics point of view, act as extra loads to inhibit certain vibrations of higher frequencies of these chime-bells.

Inspiringly, in the process of exploring the acoustic effects resulted from those historic inventions in the cultural context referred to the ancient music instruments in Bronze Age China, physics is richly involved and some physics principles are well applicable.

* The Tone-changeable Bell is cast by Chinese Bronze Company (www.chinese-bronze.com), auxiliary to Jiao Tong University, Shanghai, 200030, China.

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suspicion by those attending the meetings and not many of them found their way into specialized journals.

Now, something seems to be changing.

Thermodynamics is a good example for discussing the content issue.

The traditional didactical presentation places the teaching of the subject between mechanics and electromagnetism thus presenting a wrong picture of the historical development that had seen a convergence of mechanical and electromagnetic ideas. Another false impression of the historical development is that little attention is devoted to the study of processes toward equilibrium which is anyway limited to thermal processes.

From another point of view the historical development is taken into account partially in the didactical approaches, which led to a shift from the principles of classical thermodynamics to statistical interpretation and development. I say partially because, besides statistical mechanics, phenomenological thermodynamics has seen a subsequent development.

To summarize the advances in this last field, two main features are considered, the coming together of different sectors of physics under the same overarching framework of equilibrium and dissipation, and the re-establishment of a strong connection between the dynamic processes and the statics of equilibrium (time is definitely a thermodynamic variable).

These two features are, in a way, more connected with the intuitive ideas of students than the traditonal presentation with little use of these processes.

Students show that, from their everyday experiences, they have a scientific frame in which some characteristic of the processes involving temperature changes are reasonably taken into account. In this frame "time" is an important variable, changes in temperature may be caused by the transfer of heat or work, a equilibrium is in no need of explanation.

One may then plan a teaching approach which starts from an accurate discussion of the phenomenology of different processes toward equilibrium (flow of liquids, approach to thermal equilibrium, movements of solid bodies, discharge of a condenser, diffusion) in a generalized kinematic description.

The use of energy as a primitive concept and the atomic hypothesis allow an intuitive introduction of the variable internal energy. A thorough discussion of conservation/dissipation is then needed for the introduction of entropy.

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Physics, Technology and Society

by Joan Solomon
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STS: First phase of being a responsible scientist

The first wave of Science, Technology, and Society (STS) arrived early in the UK. It arose out of the anxiety of a whole generation who watched the dreaded mushroom cloud envelope Hiroshima at the end of the Second World War. In particular, the scientists felt that they had a responsibility to explain the dangers of atomic bombs to lay people.

A group of young university physicists in Britain, led by Dr. Bill Williams of Leeds University, rented an empty railway-carriage which they furnished with educational materials, and travelled across the country teaching the public about radioactivity. The logical but slightly naive nature of this public education phase seems a remarkable and admirable example of 'long-termism' as we would call it today.

Like other contemporary movements such as *The British Society for Social Responsibility in Science, Pugwash,* and those who ran the *Bulletin of the Atomic Scientists* in the United States, the scientists who started the STS movement in the UK believed in their duty to be 'socially responsible,' rather in the same way as doctors should treat their patients responsibly. Their aim was to educate lay people so that they could exercise their democractic decision-making rights more effectively. At that time the greatest emphasis in the UK was on nuclear power, the testing of nuclear bombs and new ways of generating energy using natural phenomena such as wind and wave-power. Many left-wing scientists, mostly physicists, belonged to Scientists Against Nuclear Armaments (SANA) and took part in the protest marches against the testing of nuclear bombs.

Second phase of STS: The teaching begins

The second phase of STS was tied to a strong popular belief in democracy. No longer was it the scientists who would guard the interests of the man-in-the-street. Now the aim was to help them to make up their own minds and to act on their own ideas. Of course science education would be required, but not of the type for training more scientists. Our young students would need to learn it in association with an understanding of how technological industry worked and what regulations would be required and also how democratic civic processes worked. There would be no room here for the elitist or patronising attitudes of Hogben and Wolpert.

To understand how the second phase of STS operated we could look at Donald Campbell's evolutionary model of learning which he called Blind Variation and Selective Retention (BVSR). It was based on Darwin's theory of Natural Selection. In biology, one could speak of a kind of 'learning' on the part of the organism which takes place by means of random variation through genetic mutation, followed by the brutal process of selective survival of some, or none, of the mutant individuals. The learning about, for example, what structure of limbs favours a quick turn of speed, or how to glide from one branch of a tree to another by means of a membrane of skin stretched from wrist to torso, is produced by the variations in the animal's structure. Selection, which is like evaluation of learning, takes place in the physical environment which in this case is the classroom. This is similar to the success or failure of engineering artifacts, like the shape of aeroplanes' wings which are tried out in the environment of wind tunnels and rejected if they fail (Vincenti 1990), or to what might be called 'the struggle of conjectures' to solve problems within an open learning environment (Popper 1972). Campbell wrote of BVSR that it was **"fundamental to... all genuine increases in knowledge, to all increases in fit of system to its working environment." (1960, p. 380)**.

Donald Schon's famous notion of teachers operating 'reflection-in-action' seems to be of this same sort of innovation. He worked out the theory of this continuing process in considerable detail, and just equating reflection with cognition, which is all there is time for here, certainly does not do justice to his argument. Teachers' action was creative and should be allowed freedom to move from one classroom to another. For fairly obvious reasons large-scale government-inspired educational reforms in Britain, or any other country, are not often guided by such a naive free struggle between a great number of individual teachers' different methods of teaching.

There was just such a need for new ways of teaching if students were to see the social nature of science and technology. This was quite new for science. It would no longer be enough to teach about astronomy or radioactivity as 'wonderful' advances in scientific theory. Teachers had to show how the new ideas would affect people's thinking about the world and whether this would produce conflict with older and valued cultural ideas. They would also have to consider the risks of radioactivity and the rights of citizens to know how this might affect them, before it happened! Physics

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teachers needed, as we saw at the beginning of this lecture, to hear the voices and opinions of their students. How could this be done? There were several practical answers to this including role-play (eg, The re-trial of Galileo, Solomon 1992). All were new and took time to learn both by the teachers and by the students. By 1983 the first public examinations in the subject were created and there were reports of students enjoying their lessons very much and valuing what they had learned.

So this second very energetic phase of innovation in STS which tried to help our youngsters to learn how to act in a democracy (Carr and Hopkins, 1996) could not last. Two particularly heavy blows were struck at the early STS movement. The first was a hostile government report in 1978 on STS courses at the tertiary level, to be followed at the end of a decade, by the arguments about raising educational standards in schools and going 'back to basics' (which was reinforced by Prime Minister Margaret Thatcher's personal problem with understanding what the word 'society' might mean, once memorably announcing **'There is no society, only people!'**)

The Thatcher government wanted to reform education and emphasize only the basic skills which they believed were being eroded. They began by breaking the power of the teachers' Trade Unions, as they had already done for the coal miners.' Then they announced that no social or economic issues were to be considered in the science classroom. The normally independent British science teachers could only wait for the next moves.

Third Phase: The government enacts social Darwinism

The social Darwinism connected with the names of Herbert Spencer and Adolf Hitler, has been almost universally rejected as being intolerably elitist, brutal and racist. However that rejection was not because Darwinian theory should not be applied to human beings. Social Darwinism advocated direct actions that society should follow in order to reinforce the selection processes. If you find weaknesses amongst the poor or disabled or badly educated, it was not enough to rely on evolutionary selection — you had to help wipe out the disability. Here, there was none of the respect for the creative potentiality of variation which is so essential in BVSR which, as we have seen, can get passed on through teaching to construct new ways of learning. The crude methods of social Darwinism used to reinforce selection are reminiscent of a more precarious human existence at earlier times when kindness to the weak was a very rare commodity. Now, in more civilized and affluent times, it should have no place in either our general thinking or in our educational practice.

When the government imposed its own educational reforms, the children themselves did not appear to be the targets of the new policy. Of course their knowledge, manners, dispositions towards learning, and mechanical ingenuity may all be outcomes of their education and would affect what they retained of new instruction. But school children have no direct power in education. They have never closed down an educational system, even when it was both physically brutal to them and also elitist. College students did try to do this in continental Europe in 1968 but not very much was achieved. Indeed children still at school are almost the only group in society which usually has no voice at all in the movements for educational reform, but they do suffer the results of it, so we must always proceed with great care and caution.

At first it was the headteachers who were most vociferous in their criticisms of the new 1989 Education Act which linked education to the operation of crude market forces. Schools were to be paid according to the number of students in their classrooms, and how well the students had performed in multiple choice examinations would be published for parents to read. They would select their child's school by consulting the list and the 'failing' schools would be closed down both by the inspectors and also by the lack of funds. There was to be no move to help those schools which were in the poorer regions of the country!

Many of us saw at once that this process would suppress any creative variation amongst schools and amongst their teachers. This meant that very little STS teaching, which was so new and innovative and whose aims were not to be found in the words of the new science curriculum, would survive. There would also be a blurring of the values on which the whole concept of STS was built. And yet the ideal of an STS education, which would support citizenship and democracy, did not completely disappear.

During the 1970s and 80s, Malcolm Skilbeck and some other general educational theorists had been examining the aims of school curricula through a series of books and articles. He proposed that one of the main aims of all education was to provide the next generation with skills for critiquing their own culture.

Is there a rebirth of STS education?

Now, in our new Labour era with a frail but just surviving STS movement, the British National Curriculum in science for the year 2000 has given some cause for hope. The emphasis started moving towards considering contemporary cases of science-based 'controversies,' 'evaluating evidence,' and considering uncertain 'ethical issues'. The hard pressed teachers looked at this with some amazement and suspicion. Did the government really mean it?

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Most recently, some help was at hand and it came not from science educators but from a professor of political and social science. In November of 1997, the Minister of Education set up a group to report on "Education for Citizenship and the Teaching of Democracy in Schools." Their published aim was as follows:

> **We aim at no less than a challenge in the political culture of this country both nationally and local: for people to think of themselves as active citizens, willing, able and equipped to have an influence in public life and with the critical capacity to weigh evidence before speaking and acting.**

They left the details of the curriculum vague but were quite sure, as STS teachers had always been (Solomon 1988), that

- the students should think about moral issues, and voice a personal opinion
- they should contribute to discussions and debates
- they should use their powers of empathy to consider the problems of others
- they should role-play the situations and opinions of others, and
- they should take part in school and community activities, and reflect upon them.

Conclusion

At the beginning of this paper I promised to look at STS education as a conflict between educational utopianism on the one hand, and a *realpolitik* which includes industry and economics, on the other. I hope it is easy to see the high ideals for a new sort of utopianism permeated this movement. At first the scientists began, as it were, looking at their own responsibilities. The Second World War had been called the 'Physicists' War' because it had, in the last stages, been won by the use of atomic power which few non-physicists understood. This made scientists wonder whether their advanced knowledge gave them a special responsibility towards the rest of the population. It was as if they might have to be stewards of the world. But the population of lay people were not content with that and began to demonstrate for peace and against nuclear weapons even though they had little understanding of either.

Once the idea entered the schools it was no longer a question of physics students being stewards, the science teachers wanted to educate all the children. They saw at once that in a democracy, the citizens should be involved in decision-making and that meant all of them should be taught the appropriate science. So now, there was another set of high ideals which permeated STS courses.

However, it takes a truly democratic government to allow their students to be given knowledge with which they might decide to oppose the government (not to rebel, but either to demonstrate peacefully or to vote against it). The Thatcher government was certainly not of that sort. At the same time industrial forces also began to worry about STS. Would it activate the students against their operations against industrial pollution and against transnational companies which were upsetting the development of the poorer countries? The combination of Government and Industry was too hard for the frail educational forces behind STS and it nearly died.

Now that STS is starting again, it seems that a few lessons have been learnt, but we cannot be sure. However, by putting Citizenship alongside Science in the new STS programmes, balance has been struck. We must work hard in our classrooms and hope for the best.

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Students should be introduced to both approaches as they exemplify two souls of physics knowledge: a reductionist soul, which sees a possible unification of topics at the microscopic level, and an holistic soul which sees unification at the level of emergent properties.

This brings about the importance of introducing, in the teaching of the contents, some epistemological considerations, in particular for clarifying the relation of models and theories with phenomenological and technological aspects.

Technology: the "New versus Old" Comparison for a student of our contemporary world reveals a mismatch between the examples considered in the teaching practice (often related to an old technology) and the new artifacts which pervade their everyday lives. A true understanding of the functioning of some of these artifacts requires an understanding of the contents of modern if not contemporary physics.

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