International Newsletter on Physics Education

International Commission on Physics Education • International Union of Pure and Applied Physics

Number 43 April 2002

ICPE International Conference on Computer and Information Technology in Physics Education

The University of the Philippines National Institute for Science and Mathematics Education Development (UP NISMED) hosted the International Conference on Computer and Information Technology in Physics Education on December 4-6, 2001 in Metro Manila, Philippines. The conference, sponsored by the International Commission on Physics Education and International Union of Pure and Applied Physics (IUPAP) and was organized by three Physics organizations (the Physics Education Group of UP NISMED in cooperation with the Philippine Physics Society, Samahang Pisika ng Pilipinas, and the Philippine Association of Physics Instructors) and 14 other private institutions.

The theme of the conference was the use and integration of computer and information technology in physics education. Plenary talks, lectures, workshops, public lectures, video-conferencing, poster presentations, and multimedia software and computer-based experiments were presented. Some of the plenary talks included "Some Roles of Computer Technology in Helping Students Learn Physics" by Prof. Fred Goldberg of San Diego State University, USA, "The Integration of ICT in Physics Education in Holland" by Prof. Ton Ellemeijer of AMSTEL Institute, Amsterdam University, Netherlands, and "Interactive Engagement and IT-Based Physics Education" by Prof. Keum-Hwi Lee of Chonbuk National University of South Korea. Mr Niran Charoenkul of Mahanakorn University of Technology demonstrated some physics 'magic' in a public lecture entitled "Move Over Harry Potter: The Best Wizards Do Physics." Prof. Akizo Kobayashi of Nigata University, delivered a paper on "IT-Based Physics Education and Resource Sharing" through video-conferencing.

See ICPE INTERNATIONAL, Page 11

In this issue

GIREP Conference in Lund, Sweden Physics in New Fields and Modern Application

The Groupe International de Recherche sur Enseignement de la Physique (GIREP) will conduct an International Conference in Physics (new fields and modern applications) on August 5-9, 2002 at Lund, Sweden.

The use and application of physics in new fields in physics education will be the theme of the conference. The activities include: public lectures, demonstrations, seminars and exhibits.

See GIREP, Page 11

2002 International Union of Pure and Applied Physics (IUPAP) 24th General Assembly

The International Union of Pure and Applied Physics (IUPAP) will hold its 24th General Assembly and related sessions in Berlin, Germany on October 7-12, 2002. Forty-six IUPAP members are expected to attend in the triannual meeting of IUPAP officials (council members and commission chairs) at the Magnus Haus and the Humboldt Universitaet.

See 2002 IUPAP, Page 11

Time-Dependent Permeable Interface and IT-Based Physics Education*

by Jin S. Kim[a] and Keum H. Lee[b]
Chonbuk National University, Jeonju, South Korea

This is a condensed version of the plenary talk delivered at the International Conference on Physics Education in Cultural Context (ICPEC, 13-17 August 2001, Korea), organized by Korean Physical Society with support from IUPAP-ICPE, and at the General Forum of European Physics Education Network (EGF2001, 6-8 September 2001, Koeln/Cologne, Germany).

Education with Interface and Feedback

Any system of interest is a part of a larger whole with interface between the interested part and the rest. No interface is perfectly insulating so the system interacts with the rest, and the two develop together as one feedback system with changing interface. An educational system/activity, surrounded/divided by interfaces, is often characterized by space (classroom, school, country, &c) and time (class period, academic year, era, &c) variables and/or more complex ones (class subject, ethnicity, culture, &c) hence the time-dependency and permeability of interfaces must be taken into account for better result. Thus, any education should have feedback mechanism reflecting the societal change/need, and physics education is no exception.

Paradigm of Physics Education

Driven in part by a post-cold-war restructuring of the global economy, the current wave of science education reform focuses on a more scientifically literate society. Since physics is the foundation of modern science and technology, physicists are in a unique position to educate people the basic concepts of modern science. Engineers need better education in physics and industry needs well-trained physicists. However, the data indicate that we are not doing what we should. A drastic change in physics education is in demand. Effective solutions have already been offered, yet go unnoticed by large segments of our community. The physics education can be more productive.

Researches show a wide gap between what a teacher teaches and what the students learn. Active-learning (AL), including interactive-engagement (IE), is the key to narrow this gap. Although AL without IT is possible, the catalytic role of IT is well established. In real-time, the use of IT is a must for resource sharing at distance and for IE among teachers and students.

IT-Based and Active-Learning Solutions

In this era of knowledge-based economies, equal access to scientific knowledge is a fundamental prerequisite for sustainable development and keeping world peace. The use of new IT in promoting AL and IE modes of education, particularly through networking, will contribute greatly to improve educational quality for all, regardless of any barrier such as space and time. It is no wonder that the Science Agenda - Framework for Action (World Conference on Science, Budapest, 1999) stresses UNESCO's leading role in spreading IT use for science education.

The curricular solutions given below are research-based and often use state-of-the-art IT. The list (in English only, alphabetical order) is not exhaustive, merely representative.

- ***Advancing Physics***[1] is a new course (with CDs) for AS and A level developed by Institute of Physics (UK)
- ***Just-in-Time Teaching***[2] enhances interactivity and responsiveness among faculty and students, via web-based assignment turned in just in time so the faculty can adjust his/her next lecture reflecting such inputs
- ***Peer Instruction***[3] actively involves students in large lecture courses by interspersing brief mini-lectures with conceptual questions
- ***Physics by Inquiry***[4] is an inquiry-based course, which can be used with a lecture-based course
- ***Real Time Physics***[5] is a complete set of interactive microcomputer-based labs
- ***Tools for Scientific Thinking***[6] consist of small set of interactive microcomputer-based labs
- ***Tutorials in Physics***[7] are a complete set of carefully designed tutorials and may be used as labs/recitations
- ***Workshop Physics***[8] is an activity-based course without lectures

Educational Resource Sharing

In resource sharing among different educational units, be they inter-institutional or international, dedicated human effort is essential for its success since the educational paradigm is position and time dependent. The one-model-fits-all approach is not appropriate and diversity has to be accepted. The Asian Physics Education Network (9) has been working for resource sharing to improve university physics education in the Asia-Pacific region, with recent AL emphasis.

See TIME-DEPENDENT, Page 11

Some Roles of Computer Technology in Helping Students Learn Physics: Computer Simulations

by Fred Goldberg <fgoldberg@sciences.sdsu.edu>
Department of Physics and Center for Research in Mathematics and Science Education
San Diego State University, San Diego, CA, USA

In physics classrooms the computer can be used in many ways to promote learning. Over the last decade one of the most prevalent uses has been with microcomputer-based learning (MBL) tools (Thornton and Sokoloff, 1990). By connecting various probes, for example, sonar probes, force probes, sound probes, voltage probes, etc., directly to the computer, students can conduct experiments and collect data in real time. Research has shown that these tools can be successful not only in the laboratory setting (Thornton and Sokoloff, 1990), but also when used in short tutorial replacements for recitations (Redish et. al.,1997) or when performed as interactive lecture demonstrations (Sokoloff and Thornton, 1997).

Another major way the computer can be used to promote learning is through the use of computer simulations of physical phenomena (Steinberg, 2000; Snir et. al., 1995). The simulations, if designed appropriately, can serve several purposes: to help students extend their experience with hands-on experiments and collect additional phenomenological data; to make models explicit and help students collect model-based evidence; and to provide multiple representations of the same or related concepts. In this paper I will provide some examples of how simulators can be used for these three purposes. The simulators I will describe were developed as part of a comprehensive project called the CPU project.

The CPU Project

CPU, which stands for *Constructing Physics Understanding in a Computer-Supported Learning Environment*, is a national development and dissemination project funded by the United States National Science Foundation.[1] The CPU project developed a pedagogy, curriculum units and computer software to support a collaborative learning environment where students assume primary responsibility for developing robust and valid ideas in science.[2] Independent modular units were developed in the topical areas of Light and Color, Static Electricity and Magnetism, Current Electricity, Force and Motion, Waves and Sound, the Nature of Matter, and a special skills-oriented unit called Underpinnings. Special computer simulators were designed to facilitate the development of ideas within the various topical areas.[3] The CPU materials have been used mainly in courses for secondary and University students (Goldberg, 2000, 1997; Otero, et. al., 1999), and in workshops for teachers. The computer simulators and curriculum units are each available commercially.[4]

Each of the topical units is divided into Cycles[5] (See Figure 1). The goal of each cycle is to have students develop a set of robust ideas that can be used to help explain a set of phenomena that will be explored within that cycle. Each Cycle begins with an elicitation activity, in which students are asked to draw on prior experience to invent an initial explanation for some interesting phenomenon. This activity is carried out individually, in small groups, and as a whole class. The purpose of the elicitation activity is to raise relevant issues regarding the phenomenon, and to encourage the class to offer some intial ideas that could be starting points to address the issues.

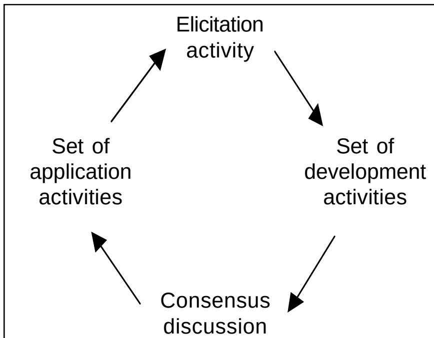


Figure 1. *Outline of the CPU Pedagogy Cycle*

Following the elicitation activity, each group of students tests and (if appropriate) modifies their initial ideas by working through a sequence of several *development* activities, students contribute to the consensus discussion activity. Then each group is responsible for proposing to the whole class a set of candidate ideas that it believes will best explain the range of phenomena encountered throughout the cycle and which it can support with observational evidence. The instructor then leads a whole-class discussion in which all the groups' candidate ideas are consolidated into a set of evidence-supported class consensus ideas. During the *application* activities the students apply the class consensus ideas to a wide variety of interesting and novel situations. During both the development and application activities students collect data with both hands-on apparatus and computer simulations. In the sections that follow I will describe three ways the computer simulators can help in this learning process.

See next page

Computers can help students extend hands-on experiments and collect additional phenomenological data to develop and test ideas

One of the ideas students should develop in the CPU Light and Color Unit is that an extended optical source can be thought of as a sequence of closely spaced point sources (Otero, et. al., 1999). This idea is developed within several different contexts (shadows, pinholes, mirror images, and light images). Figures 2, 3, and 4 illustrate how this is done in the context of shadows. Figure 2 shows the apparatus for an experiment students perform with two point sources (they use Mini-Maglites™), a square shaped blocker and a screen. After investigating the shadow formed with two sources, students add additional point sources and then explore what happens with a continuous line source (Figure 3). Figure 4 shows the portion of an activity document where students are explicitly asked to think about the relationship between a continuous source and a sequence of point sources, and includes responses of a particular group. The students were able to set up analogous experiments using the simulator and to paste screen shots into their activity document to use as evidence. (Figure 4 also suggests how students open the computer simulators. They click on links within the activity document.)

During one activity in Waves and Sound unit the teacher demonstrates the use of an actual ripple tank, then has students perform a series of experiments with a simulated ripple tank. The CPU Ripple Lab simulator allows students to set up several wave tanks simultaneously on the screen and explore how changing one or more parameters changes the resulting wave pattern. Figure 5 shows a snap shot from a single computer screen where four different wave tanks have been arranged simultaneously. The purpose of this sequence is to suggest how the wave pattern from a line source can be approximated by the wave pattern from a sequence of point sources.

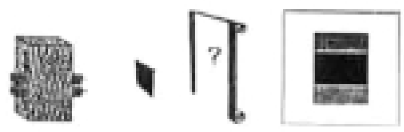


Figure 2. Experimental apparatus to study shadow with two point sources. On the right is a snap shot from the CPU Shadows and Pinholes simulator, showing the complex shadow formed with two point sources, a rectangular blocker, and a screen.

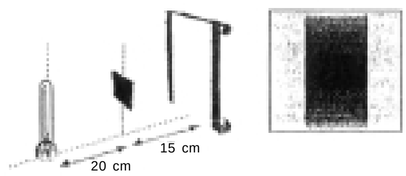
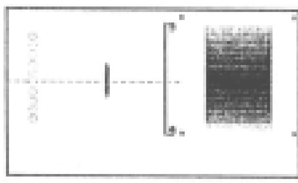


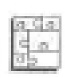
Figure 3. Experimental apparatus to study shadow formation with an extended source. On the right is a snap shot from the CPU Shadows and Pinholes simulator, showing the complex shadow formed with an extended line source, a rectangular blocker, and a screen.

9. After looking at the shadow formed with the long source, paste several point sources right next to the long source, making a chain of the same length. Then delete the long source and look at the screen view of the shadow. To return to the simulator click on **Act 1-D3 Sim 1.**)



The shades of gray using multiple light sources were more defined than when we used a single long light source. In the single light source there is no defined black area, wherein there is one when multiple light sources are used.

10. Do you think it is useful to imagine that a long extended source is made up of lots and lots of tiny and closely spaced point sources? Why or why not?



Yes, because a long light source is a bunch of tiny light sources touching each other.

Figure 4. Part of an activity sheet from an experiment on shadow formation.

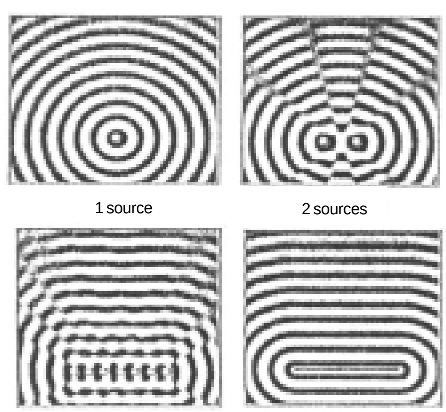


Figure 5. Snapshots from the CPU Ripple Lab simulator showing the wave patterns formed by one, two, and seven point sources, and a continuous line source.

Computers can help students test conceptual models

In addition to providing students with phenomenological evidence, the CPU simulators can also provide conceptual or model-based evidence. In this case the students manipulate a graphics-based model built into the simulator. Below we provide examples from the CPU Units on Light and Color, and Static Electricity.

In the Light and Color Unit, students are asked to construct light ray diagrams to explain how light behaves when images are formed with mirrors and lenses. One of the tools available in the Light and Color simulators is a light ray spray. For example, in the mirror simulator students can construct a set-up with an extended light source, concave mirror and, screen. They can then drag out a light ray spray from any point on the source and the simulator will show how the light rays reflect from the mirror. To help students understand the one-to-one correspondence between object point and image point, the simulator allows them to drag the origin of the light ray spray along the entire length of the extended source and observe what happens to the point where the reflected light rays converge. Figure 6 shows a sequence of screen shots corresponding to the student dragging the origin of the light spray from the top of the complex source, towards the bottom. As this is done, the corresponding image point is mapped out on the screen.[6]

See next page

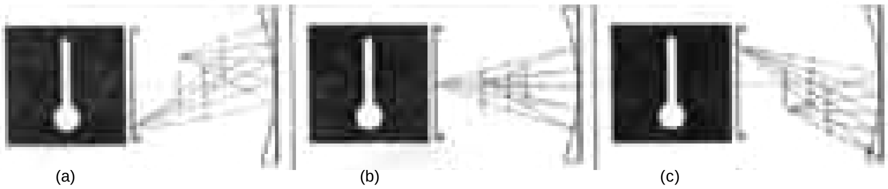


Figure 6. Snapshots from the CPU Mirror Simulator. Each shows a complex source in front of a concave mirror, with a screen to the left of the source. On the left of each snap shot is a window showing the image that appears on the front of the screen. In (a) through (c) a spray of light originates from three different points on the source, suggesting how each image point corresponds to a unique object point.

The static electricity simulators provide another example of how students can obtain and use conceptual evidence. During the Static Electricity Unit students gather evidence to support the idea that when certain dissimilar objects are rubbed together, the rubbed surfaces of the two objects are affected differently; that is, when each of these rubbed surfaces is brought near a third rubbed surface, different attraction and repulsion effects are observed. The simulator uses a simple coloring model to support these observations. When appropriate objects are rubbed together in the simulator, the rubbed surfaces are colored either red or blue, and the thickness of the colored layers depends on the amount of rubbing. (Later in the unit the red and blue coloring are associated with excess positive and negative charge.)

In one of the hands-on experiments, students use a soda can electroscope (Morse, 1992). This consists of a soda can horizontally mounted on an inverted styrofoam cup. A few strips of very light aluminum foil (tinsel) hang down from one side. When students bring a charged object near (but without touching) the other side of the electroscope, the aluminum strips are observed to stick out from the other side of the can (Morse, 1992). Their task is to try to make sense of this observation and to explain it in terms of the red and blue coloring scheme. By using the simulator to observe dynamically the coloring taking place when a simulated charged insulator is dragged near to the simulated (neutral) electroscope, the students are able to develop a reasonable initial explanation for the polarization process. Figure 7 presents several snap shots from the static electricity simulator that helps model the polarization process.

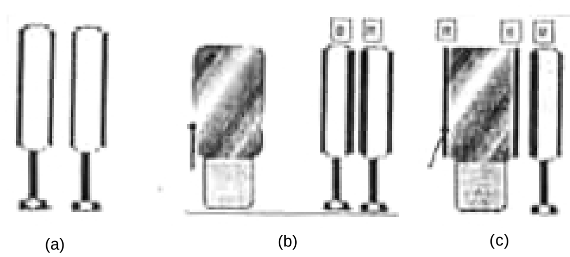


Figure 7. Snapshots from a CPU Static Electricity simulator. (a) Two neutral insulators are near each other. (b) After rubbing together, the rubbed surfaces are colored red (R) or blue (B). A neutral conductor with a conducting indicating flag sits nearby. (c) An R-charged insulator brought near a conductor causes the nearby surface of the conductor to be colored oppositely (B), and the far surface to be colored the same (R) as the charged insulator. This behavior models the phenomenon of polarization.

Otero (2001) carried out a comprehensive study to examine the role that the computer-based coloring model seems to play in facilitating students learning in static electricity. As part of her study, Otero observed groups of students working through a sequence of activities, each involving both hands-on and simulator-based experiments. She determined the percentage of time groups were engaged in sense making (explaining predictions or observations in terms of models, engaging in peer instruction, recognizing unresolved issues, etc.). The data was separated into during laboratory experiments and during simulator experiments, as percentages of total time performing an activity. The results for one group are summarized in Figure 8. The data shows that in the first few activities, the group spent more time sense making when performing simulator experiments than when performing laboratory experiments. The situation reversed itself during the last few activities.

This data can be interpreted in the following way. During the first few activities, when students' own models were not well formulated or detailed, there was little discussion surrounding the laboratory results. The outcomes of the experiments either confirmed or disconfirmed their predictions, but there was little interpretation of the results. The simulator experiments, however, because they enabled students to focus on a simple coloring model that was visual and manipulative, generated extensive discussion when students made predictions and interpreted results. The group tested and changed ideas while working with the simulator. Eventually, their models became more robust. Towards the end of the unit, they were able to carry out extensive discussions around the laboratory experiments, while the simulator experiments seemed to be just repetitions of what they had done with the laboratory experiments, and generated little additional sense-making discussion.

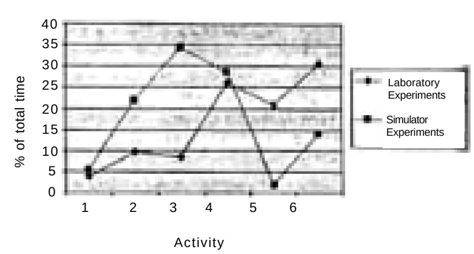


Figure 8. Percentage of activity time groups spent in sense-making when performing laboratory or simulator experiments. Data is shown for six successive activities during the CPU unit on Static Electricity.

See next page

Computers can provide multiple representations

Many simulators show multiple representations of the same or related concepts, and this can enhance students' understanding. For example, in the Current Electricity Unit students work with batteries and bulbs to construct a model to explain the behavior of circuits. They often use the Current Electricity simulator to extend their observations. Figure 9 is a snap shot from the simulator and shows multiple representations for the electric current. This circuit has three identical (1.5 volt) batteries and two different bulbs. A compass and an ammeter have been added. A separate compass window shows the compass deflection, and the ammeter provides a direct digital readout. The simulator can also represent current in terms of current arrows (whose length is proportional to the value of the current) and current numbers appearing alongside bulbs (whose magnitude is proportional to the current in the bulb). A yellow disk centered on each bulb symbol represents the brightness. (Actually, the area of the disk is proportional to the power dissipated in the bulb). As students change parameters in the circuit (numbers of batteries or number and resistances of bulbs), they can observe corresponding changes in all the current representations.

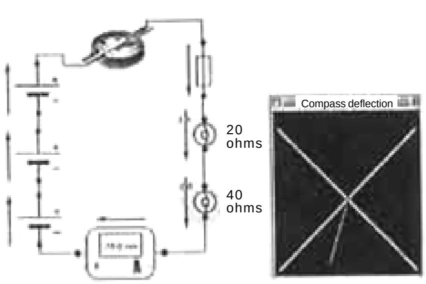


Figure 9. Snapshot from CPU Current Electricity Simulator showing circuit with three batteries, two bulbs with different resistances, a compass, switch, and ammeter. A separate window displays the simulated compass needle deflection.

Summary

In this paper I have briefly described three ways that specially designed computer simulators can provide support to help students learn physics. First, they can provide phenomenological evidence that students can use to extend the observations they make with hands-on equipment. Second, the simulations can provide conceptual evidence that students can use to compare directly with their own conceptual models. Third, the computer simulations can be used to provide multiple representations.

The simulators discussed in this paper were developed as part of the CPU Project. Research carried out within the context of this project suggests the complementary roles that hands-on and computer simulator experiments can play in the learning process.

Notes

[1] The CPU Project has been supported by United States National Science Foundation Grant ESI-9454341.

[2] Information about the CPU project is available on the web at http://cpuproject.sdsu.edu.

[3] The CPU curriculum materials and software was developed by a large team of physics educators. Principal authors and designers included Fred Goldberg (director), Patricia Heller (co-director), Sharon Bendall, Robert Morse, Jim Minstrell, Paul Hickman, Jennifer Hickman, Andy Johnson, Valerie Otero, Laura McCullough, Sandra Grindle, Roy McCullough, Jodi McCullough, Michael McKean, Arni McKinley, and Joseph Faletti. The software had been developed in collaboration with Physicon Ltd. (Russia), a member of Open Teach(c) Group.

[4] The *CPU Simulation Software* and the *CPU Curriculum Units* are available from The Learning Team, <http://www.learningteam.org.>

[5] This approach is an extended modification of the Learning Cycle developed by Robert Karplus and others as part of the Science Curriculum Improvement Study (SCIS) of the 1960s (Karplus, 1977).

[6] The CPU mirror simulator enables students to choose either a *real* or an *ideal* mirror, which either displays or does not display spherical aberration.

References

DeJong, T. and van Jooligen, W. R. (1998). Scientific discovery learning with computer simulations of conceptual domains. *Review of Educational Research, 68,* 179-201.

Goldberg, F. (1997). Constructing physics understanding in a computer-supported learning environment. In J. Rigden (Ed.) *Proceedings of the International Conference on Undergraduate Physics Education: Vol. 2. American Institute of Physics.*

Goldberg, F. (2000). How computer technology can be incorporated into a physics course for prospective elementary teachers. In A. Gayle Buck, G. Jack Hehn and L. Diandra Leslie Pelecky. *The role of physics departments in preparing K-12 teachers. American Institute of Physics.* College Park, MD.

Hickman, P., Morse, R. A., Otero, V., Johnson, A., and Goldberg, F. (1999). *Static electricity and magnetism [CD]. In constructing physics understanding: curriculum units and simulation software [CD].* The Learning Team, New York.

Karplus, R. (1977). Science teaching and the development of reasoning. *J. Research Science Teaching,* ***14***, 169-175.

Morse, R. A. (1992). Teaching about electrostatics: *AAPT/PTRA workshop manual.* American Association of Physics Teachers. College Park, Maryland.

See SOME ROLES, Page 11

Computational Physics Using Simulations and Mathematical Packages

by Ian D. Johnston <idj@physics.usyd.edu.au>
School of Physics, The University of Sydney

Ever since the invention of computers, physicists have been right at the forefront of their development and usage. In the late 1940s and early 1950s, the large automatic computing machines, ENIAC, UNIVAC, ILIAC, etc. were constructed in physics laboratories in universities like Pennsylvania and Illinois. In the 1970s and 1980s, when the Internet was developed, computers enabled communications between CERN and high energy physics laboratories in the USA.

The effect of computers on physics research was immediate, not only on experimental physics, but particularly on theoretical physics. In astronomy, nuclear physics and hosts of others, theoreticians tackled problems that had been completely intractable for the preceding generation.

Today, essentially every research physicist uses a computer to aid their calculations and, most importantly, to visualize and interpret their results. Some decades back it seemed natural for the technical journals to speak of there being two kinds of physics – experimental and theoretical. In recent years, more and more scientists are saying that there should be three categories – experimental, theoretical, and computational physics.

The way physics is done has been transformed by the advent of the computer. What about the way physics is taught?

Computation and the teaching of physics

For many years the size and cost of computers meant that they could not be used by students, except at postgraduate level. But in the last two decades, the enormous advances in the computing power and graphical capabilities of personal computers, and more recently the emergence of the World Wide Web, have promised great changes in physics teaching. In other subjects, it is the possiblity of effective Computer-Aided-Instruction packages which teachers are excited about. Not so much in physics. Physics teachers, at university level anyway, seem unwilling to consider seriously the idea of programmed learning under the control of a computer. They firmly believe that a real live person is the only kind of teacher for physics students. But on the other hand, aware of the role computers have come to play in professional physics, they have been among the first to understand the need to teach their students how to use computers as a tool. For more than a decade now, computers have been ubiquitous in experimental teaching laboratories. But computation has not yet made very great inroads in the theoretical (lecture) curriculum.

It has always been acknowledged that what makes physics a difficult subject for students is its heavy reliance on analytical mathematics – often at a level of sophistication far beyond the students' expertise. Many physics departments, all over the world, have taken advantage of the advances in personal computers to alleviate some of these difficulties by teaching computational physics. In these courses, the main role of the computer is to replace some of the analytical mathematics with numerical computation, and to present the results in pictorial form.

There has been an interesting spin-off from this. In mainstream physics curriculums, there has always been a strong tendency to include material which is capable of being developed with relatively simple mathematics, and to avoid topics which demand elaborate analytical treatment. With the teaching of computational physics with powerful computers, this constraint is no longer necessary. Indeed it is now possible to teach material to students which used to be considered far beyond their grasp. Several papers in technical journals over the past decade have made the point that the introduction of computers into physics teaching changes not only how physics is taught, but also what physics is taught.

The different roles that computational physics can play in the physics curriculum are:

- ***Visualization***. The computer is used to make visible the results of theoretical calculations which are ordinarily difficult to appreciate because of their mathematical complexity. These occur especially in fields like relativity or quantum mechanics. Particular examples that spring to mind are a set of photo-realistic representations of a vehicle moving close to the speed of light produced by a group at the Australian National University in 1997;[1] or animations of the motion of a wave packet showing phase changes by means of colour-coding which were produced for the CUPS project in 1995.[2]
- ***Conceptualization***. The computer is used to clarify the meaning of a theoretical derivation by simplifying the logic, usually by replacing a

See next page

complicated analytical treatment by a much more straightforward, from-first-principles computation. Examples are an animation to demonstrate the concentration of surface charges on a conductor at points of small radii of curvature, by this author in 1995;[3] or a representation of the process of synchrotron radiation from a (very) rapidly oscillating charge, also produced for the CUPS project in 1995.[4]
- ***Extension***. Adopting a computational approach allows new subjects to be taught, which might otherwise be considered to be beyond the students' mathematical ability. Examples are a proper study of Fresnel diffraction, made possible through the use of another simulation from the CUPS project (1996);[5] or the introduction of a course on percolation theory at the author's home university in 1992.[6]

There are other roles that computational physics can play, and many other examples that could be quoted, other than those the author happens to know about. But the main point is that computational physics clearly can be a valuable part of physics curriculums. The question to be asked is: Has it in fact become so?

Implementation

In Australia (the context which this author knows best) something of the order of 50% of physics departments offer students a course called *Computational Physics* or *Computational Science*. However, nearly all of these courses are designed for students at advanced levels: third year, fourth year or postgraduate. The number of departments offering such courses to first or second year students seems to be small.

In other countries, information is more difficult to gather, but much the same pattern seems to occur. In the USA for example, a reputable web site, maintained by the newly appointed editor of *The American Journal of Physics*, lists 27 universities which offer such courses (the list was compiled in 1999 by asking academics to register their interest).[7] – Of these, judging by the code numbers given to those courses, nearly all aimed at high level students.

The information presented here is, admittedly, scanty; and obviously no firm conclusions can be drawn. But this author believes that there is no evidence that computational physics has made great inroads into ordinary physics curriculums, particularly at first and second year levels. This must be considered unfortunate because numbers show that the majority of students who start studying physics at university do not proceed beyond first or second year level.[8] Therefore many students are not being introduced to physics as it is practised today.

However the courses that do exist offer valuable insights into the teaching of this subject. If a department were thinking of introducing such a course, with a significant hands-on component, a number of decisions would have to be made.

- Will the students be asked to do their own programming, or will any packages or simulations they are asked to work with be completely prewritten? There are arguments in favour of both. On the one hand, a detailed understanding of all stages in the solution of a problem will give them depth of understanding. A black-box approach will relieve them of a lot of (unimportant) sources of error and let them concentrate on the physics.
- Will the development of mathematical competence be an important aim? Many computational physics courses are essentially training in the use of Mathematica or MatLab or other mathematical packages. The physics being discussed is not important in its own right it is merely a vehicle for the computation.
- Will the physics content of the course be chosen so that it reinforces, or is reinforced by, a parallel lecture course? This is a problem inevitably faced by those designing courses in experimental physics. Often it is too expensive or too inconvenient to keep lectures and laboratory in step with one another. The same can be true in computational courses where supporting software has to be written or purchased.

Once those decisions have been made, the actual method of implementation needs to be chosen. Below is a list of some commercially available packages which the students can work with.

- ***M.U.P.P.E.T***. The Maryland University Project in Physics and Educational Technology was developed in 1988, based on the philosophy that students should be in charge of their own learning - not the computer.[9] They should be actively involved in every stage of the problem solving process, which meant they had to do at least some of their own programming. The language chosen was Pascal in the version *Turbo Pascal*.[10] What M.U.P.P.E.T. contributed was a few well designed utilities to smooth the organization of data input, the setting up and drawing of graphs, and the making of program direction choices.

See next page

- ***CUPS*** (Consortium for Upper-level Physics Software) This very extensive project, was carried out in 1996.[11] The authors were an international group of 27 scientists and they developed computer simulations and associated texts for the nine junior/senior level physics courses, which comprise most of the undergraduate physics major curriculum. The simulations are complex, often realistic, calculations of models of various physical systems, and each comes with sets of student problems. They were designed to be used in lecture demonstrations or to create computer models for the testing of physics theories and used by students in a computer laboratory setting.
- ***Physlets*** (Physics applets) are small, flexible Java applets designed to be used in a wide variety of WWW applications.[12] They were originally written in about 1996 by physicists at Davidson College, North Carolina, who had been involved in the CUPS project. Many of the first physlets reproduced simulations that had been included of the CUPS software for the WWW. Their main usefulness is to be included in larger html documents prepared by individual teachers. Lately many other physics-related Java applets have been produced around the world. Many of these are included among the "official" physlet collection.
- ***STELLA*** is a "modeling software" package, originally designed for use by people in business, the humanities and social sciences.[13] It claims to be built on the systems approach to problem solving, with emphasis on interrelationships and interconnectivity rather than on a collection of variables. It builds mathematical models in a pictorial fashion – icons to construct a graphical representation of the input parameters, from which the software automatically creates equations that are needed to simulate a model. The solution to the problem can be viewed as graphs, tables, or animation. Because of the way it avoids explicit mathematics, it is used extensively in the earth and the life sciences. It has also been used successfully in some German high schools to solve physics problems that essentially involve second order differential equations.
- Matlab/Mathematica. There are today several mathematical software packages available, of which these two are perhaps the best known. Mathematica, developed in 1988, describes itself as a comprehensive technical computing environment.[14] Its specialty seems to be its ability to handle analytical mathematics, although it does numerical calculations as well. MatLab (1994), on the other hand, describes itself as a "full-featured calculator."[15] It is therefore particularly powerful in handling numerical computations. Either of these could be used in a computational physics course where acquiring mathematical expertise was important.

Computational physics at the University of Sydney

Twelve years ago, in 1989, the School of Physics at the author's university made a policy decision, after a twelve-month trial, to introduce computational physics courses into its undergraduate curriculum. In the planning, three main aims were articulated:

1. to expose students to the use of computation as a way of doing physics,
2. to give them the chance to solve a wider range of problems than in a traditional lecture course, and
3. to allow them to acquire a marketable degree of computer literacy.

It is against these aims that the success of the change must be judged.

It was originally decided to use M.U.P.P.E.T. in these courses, though in time this was changed. After a few years these courses were in place:

- A semester-length course at second year level for mainstream physics and engineering students, which dealt with quantum mechanics; and later, another dealing with electromagnetism. These involved a change in the structure of the teaching program – from 4 hours lectures and 4 hours laboratory per week, which it had been previously, to 3 hours lectures, 3 hours laboratory and 2 hours microlab. Later when the curriculum changed and Electromagnetism was no longer offered in the same semester as the corresponding computational module, a new module was designed based on the optics part of the *CUPS: Waves and Optics* simulations.[16]
- A similar course at third year level, which involved the teaching program being changed from 5 hours lectures and 7 hours laboratory per week, to 4 hours lectures, 6 hours laboratory and 2 hours microlab (for one semester only). When the course structure was changed to stand-alone modules in 1998, the computational course remained as a 4-unit module. The material covered in this course depended on lecturers' areas of expertise. Most recently it dealt with Fourier Transforms.
- A smaller course at first year level designed for students in the advanced stream involving 3 hours work per week in the computer laboratory for 3 weeks. The material covers simple harmonic and chaotic motion of oscillating systems.

These courses were taught in a microcomputer laboratory and required

See next page

students to write (or modify) Pascal programs in order to explore the solutions of sets of problems related to the topics in question. Most recently, in 1998, a course on Scientific Computing was introduced at the third year level. This is somewhat related to the three computational physics courses, though considerably wider in the kind of computing techniques it covers.

A number of important lessons were learned from the experience of running these courses over the decade.

i. If possible, the subject matter covered should be closely tied to a current lecture course. If it is not, students, particularly engineering students, often fail to see why they are being asked to do the work. It reflects the unfortunate fact (known to organizers of experimental laboratories) that students seem to feel that lectures are the only "real" source of knowledge. All else should support the lectures.

ii. Though using a computer would seem to be an intrinsically individual activity, students seem to learn about the science best when they work in groups of three per computer. In 1995, a research project followed a group of students through a complete microlab course, and showed that, at each stage in a problem solving process, 30% of the time was spent talking to one another.[17] Examination of the content of the conversations supports the findings of Kelly and Crawford that such talk is an indispensable part of the learning process.[18]

iii. This is not a particularly cheap way of teaching. It is different from some other forms of Computer-Aided-Learning. In this kind of work the student must extract the science from what the computer is calculating, in the same way as they must extract the science from how an experiment behaves in an ordinary laboratory. They need tutors to help them. It is difficult to get the tutor: student ratio below 1:16, which is about what it is in most experimental labs.

Since the inauguration of the courses they have been changed were caused by several factors. Firstly, the Computer Science department no longer taught Pascal, until then almost a universal student programming language. Then, some years back, Borland ceased to support *Turbo Pascal*. In 1999, when upgrading some of the computers to 300MHz, it was discovered that Turbo Pascal would not run on very fast machines. It is known to be a bug in Turbo Pascal, but Borland declined to accept responsibility. There is a patch that can be applied, available on the Web, which will keep things working for a few years,[19] but it was clearly time to shift to another platform.

After extensive consultations, it was decided to move to MatLab.[7] Even though MatLab seems primarily designed as a kind of super calculator, it can be used as for some high-level programming. So by learning to use it, students should gain some of the skills we have considered important in the past. Furthermore, at Sydney University, the Engineering and Mathematics departments use it. But a lot of effort was involved. All the teaching materials developed over the years had to be rewritten. The physics and the mathematics were the same and didn't have to be rediscovered but they were not the problem; it was the programs in which they were embedded in that spawned all the bugs, and caused all the angst. Rewriting them was as long and tedious a process as it was initially.

Is this one solution?

As a result of all this experience at Sydney University, a particular way of teaching computational physics has developed. It seeks to include the advantages of the interactive simulation with a focus on the details of problem solving that the mathematical packages provide.

Students are asked to work through a set of exercises, in quantum mechanics, or oscillation theory, or Fourier transforms, or whatever.[20] The exercises are mathematical, and require numerical solutions. They do this using MatLab. Many of the calculations are repetitive, and therefore, as they work through these exercises, students are asked to construct quite sophisticated mini-packages which are capable of accepting new input data and of displaying the results in whatever form is most appropriate – numerically, graphically, or with animations.

In order that they do not waste time setting up the necessary graphical user interfaces, these are given to students in the form of small computational objects, bundles of MatLab code which perform one specific job. There is, for example, an object which will find the zero of some general function of a single variable by performing a binary chop, displaying the intermediate steps in the process. These are all written by the instructors of the course.

In the end, the students are constructing simulations, which can be used just like a physlet or a CUPS simulation. The difference however is that they are not closed black boxes. They consist of a number of self-contained computing objects connected together, which can be used independently and changed at will. A good name for these might be *semi-simulations*.

See COMPUTATIONAL, Page 11

TIME-DEPENDENT (Continued from Page 2)

It is to be noted that the Korean Physical Society has recently been reorganized for strong emphasis on education and strives for educational resource sharing at the national as well as international level.[10]

Notes

[1]http://post16.iop.org/advphys
[2]Novak, G. M. et al., *Just-in-Time* Teaching (Prentice Hall, 1999).
[3]Mazur, E., *Peer Instruction* (Prentice Hall, 1997).
[4]McDermott, L C. et al., *Physics by Inquiry*, (John Wiley & Sons, 1996).
[5]Sokoloff, D., P. Laws and R. Thornton, *Real Time Physics* (Vernier Software, 1995).
[6]Sokoloff, D. and R. Thornton, *Tools for Scientific Thinking* (Vernier Software, 1995).
[7]McDermott, L. C. et al., *Tutorials in Introductory Physics* (Prentice Hall, 1998).
[8]Laws, P., *Workshop Physics Activity Guide* (John Wiley & Sons, 1997).
[9]http://www.swin.edu.au/physics/aspen/
[10]AAPT Announcer, Vol. 31, p. 10 (Summer 2001).

*Supported by Korea Science and Engineering Foundation

[a]Secretary of Education, Korean Physical Society (jin@moak.chonbuk.ac.kr)

[b]Chair, Asian Physics Education Network (khl@moak.chonbuk.ac.kr)

2002 IUPAP (Continued from Page 1)

The IUPAP General Assembly is held under the auspices of IUPAP and is organised by the German Physical Society (Deutche Physikalische Gesellschaft) and the Berlin Universities (Humboldt Universitaet Berlin, Freie Universitaet Berlin, Technische Universitaet Berlin).

For inquiries, write to:

Prof. Dr. Juergen A. Sahm
(ICPE Commission Chair)

Mr. Holger Dietz
(Organizer)
Technische Universitaet Berlin, Sekr. PN 1-1, Hardenbergstr 36, D-10623, Berlin, Germany
Phone/Fax: 49-30-314 23056/57

ICPE INTERNATIONAL (Continued from Page 1)

Two hundred fifteen (215) foreign and local participants, consisting of physics educators, teachers and students attended the conference. Twenty-six foreign participants came from eight countries: South Korea, Japan, Netherlands, USA, Australia, Thailand, England and China.

The multimedia software and computer-based experiments competition, which was sponsored by the Department of Science and Technology, highlighted the conference. Among the nine entries submitted, the "Temperature Sensor Interface" developed by Marko E. Arciaga, Louella Judy A. Vasquez and Melvin F. Estonactoc of the UP National Institute of Physics, bested eight (8) other entries to win first prize. The best multimedia award went to "The Mysterious Egg" developed by Alexander Canabano, Joan Dorato, and Joey Estorosos of the University of San Carlos, Cebu City, while the best interfacing experiment was awarded to the "Video-based Tracker" of Marilou Catadal, et. al. of the UP National Institute of Physics. Two other entries received consolation prizes. The winners received cash awards and a plaque.

GIREP (Continued from Page 1)

Speakers from different countries are invited. Some of the confirmed invited speakers are: Per Erik Bengtsson: Physics in Combustion; Ian Griffin: (Out) Reaching for the Stars, The Space Telescope's Role in Education; Paul Hewitt: Teaching Conceptual Physics; Jessica James: Physics and Finance; Enrik Lundstedt: Living with Our Stars; Leopold Mathelitsch and Ivo Verovnik: Physics of Acoustical Phenomena; John Rigden: Marketing Physics: An Untapped Resource; Max Thompson: Physics in Peace Keeping; Michael Vollmer: There is More to See than Eyes Can Detect; and Dean Zollman: Teaching the Physics Related to Medical Diagnostic Instruments.

SOME ROLES (Continued from Page 6)

Otero, V. (2001). *The process of learning about static electricity and the role of the computer simulator*. Unpublished doctoral dissertation. San Diego State University, USA.

Otero, V., Johnson, A. & Goldberg, F. (1999). How does the computer facilitate the development of physics knowledge among prospective elementary teachers. *Journal of Education 65*, 45-54.

Redish, E. F., Saul, J. M., & Steinberg, R. N. (1997). On the effectiveness of active engagement microcomputer-based laboratories. *American Journal of Physics, 65*, 45-54.

Sokoloff, D. R., & Thornton, R. K. (1997). Using interactive lecture demonstrations to create an active learning environment. *The Physics Teachers, 35*, 340-347.

Steinberg, R. N. (2000). Computers in teaching science: To simulate or not to simulate? *American Journal of Physics, 68*, S37-S41.

Smith, S, J., & Grosslight, L. C. (1995). Conceptually enhanced simulations: A computer tool for science teaching. In D. Perkins, J. D., West, S. M., & Wiske, M. (Ed). *Software goes to school: Teaching for understanding with new technologies*. NY: Oxford University Press.

Thornton, R., & Sokoloff, D. (1990). Learning motion concepts using real-time microcomputer-based laboratory tools. *American Journal of Physics, 58*, 858-867.

COMPUTATIONAL (Continued from Page 10)

These new ways of teaching computational physics have only been used at Sydney University for two years, very successfully by all usual measures. It remains to be seen if, in some years time, they can be judged to be a viable and reliable way of teaching this subject, and whether the original aims, mentioned above, have been achieved.

See next page

Notes

[1]Hiller, J. M., Johnston, I. D. & Styer, D. (1994). *Quantum Mechanics Simulations, 6,* CUPS Project. John Wiley Sons, NY.

[2]Walker, P. J., & Jonston, I. D. (1995). Computer Modelling of Spontaneous Charge Distribution. *Computers in Physics, 9(1),* 42-45.

[3]Ehrlich, R., Roelofs, L., Stoner, R. & Tuszynski, J. (1994). *Electricity and Magnetism Simulations, 3,* CUPS Project. John Wiley and Sons, NY.

[4]Christian, W., Antonelli, A., Fischer, S., Giles, S., James B. W., & Stoner, R. (1994).

[5]*Waves and Optics Simulations, 9,* CUPS Project (1996). John Wiley and Sons, NY.

[6]Johnston, I. D., & McPhedran, R. C. (1993). Computational physics in the undergraduate curriculum. *The Australian & New Zealand Physicist, 30(4),* 67-73.

[7]http://sip.clarku.edu/courses.html.

[8]Mulrey, P. J. & Nicholson, S. (2000). Enrollment and Degrees Report. *AIP Statistical Research Center Report.*

[9]Redish, E. F., Wilson, J. M., & Johnston, I. D. (1993). *Microcomputer: The MUPPET Utilities.* Physics Academic Software, NC.

[10]Turbo Pascal, copyright Borlard International, 1983-89.

[11]CUPS general

[12]See the web site *Physlets* at http://webphysics.davidson.edu/Applets/Applets.html

[13]The developers of STELLA are High Performance System Inc. See their web site: http://www.hps-inc.com/

[14]*Mathematica*, copyright Wolfram Research Inc. Their web site is: http://www.wolfram.com/

[15]*MatLab*, copyright The Maths Works Inc., 1984-96. Their web site is: http://www.mathsworks.com/

[16]CUPS Waves/Optics

[17]Hogg, K., Johnston, I. D. & Crawford, K. (1997). How do students use computers? Student use of CUPS in a physical optics course. *OzCUPE3: Proceedings of the Third Australian Conference on Computers in University Physics Education, (7-11).* In Moore, I. & Webb, J. (Eds.), UniServe Science, Sydney.

[18]Kelly, C. J., & Crawford, K. (1996) Students' interactions with computer representations: Analysis of discourse in laboratory groups. *Journal of Research in Science Teaching, 33(7),* 693-707.

[19]A patch which claims to fix the problem is available at: http://www.geocities/SiliconValley/Bay/9553/tpbug.htm

[20]The complete set of materials for the second year (quantum mechanics) course are available at: http://www.usyd.edu.au/ugrad/iphys/CP2QM_site/cp2qm.htm, and the materials for the first year (oscillations and chaos) course at: http://www.usyd.edu.au/ugrad/jphys/jphys_webct/cp1chaos.html.

IUPAP ·ICPE
International Commission on Physics Education
International Union of Pure & Applied Physics

For comments, questions, or to be added to or deleted from the mailing list, please contact the editor:

Editor:
Vivien M. Talisayon
University of the Philippines
National Institute for Science and Mathematics Education Development (UP NISMED)
E. Quirino Avenue, UP Diliman 1101
Quezon City, Philippines
Fax: (632) 928-1563
E-mail: vmt@ismed.upd.edu.ph
Assistant Editor: Ernie McFarland

Editorial Assistant: Ginette Nolasco-Almaden
Design & Layout: Rosita R. Cruz, Ginette Nolasco-Almaden and John Jerry Maramag

The International Newsletter on Physics Education
is a publication of the International Commission on Physics Education and is produced twice a year.

VISIT OUR WEBPAGE AT :

http://www.physics.umd.edu/ripe/icpe

ICPE Newsletter Editor
University of the Philippines
National Institute for Science and Mathematics Education Development (UP NISMED)
E. Quirino Avenue, UP Diliman 1101
Quezon City, Philippines
Fax (632) 928-1563