ASCD

SINGAPORE

REVIEW

Vol 1 No 3 July 1991 MCI (P) No 134/9/90

Information Technology in Education

Association for Supervision and Curriculum Development (Singapore)

ASSOCIATION FOR SUPERVISION AND CURRICULUM DEVELOPMENT

ASCD (Singapore) Review is published three times a year in March, July and November. The views expressed in this journal do not necessarily reflect the official position of ASCD (Singapore).

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Published by Association for Supervision and Curriculum Development (Singapore).

Printed by Mentor Printers Pte Ltd, Blk 155 Kallang Way, #01-10, Singapore 1334

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REVIEW

July 1991 Vol 1 No 3

FOCUS: *Information Technology in Education*

OTHER TOPICS

IDEAS

LOOI CHEE KIT

Artificial Intelligence Meets Education : An Overview

How Artificial Intelligence techniques can be used in education.

Advances and innovations in the history of education have been few. The incorporation of Artificial Intelligence (AI) techniques into education dates back to the early 1970s. Public interest in this has blossomed, in part due to sensational but misguided publicity about AI. The application of AI to education is intended to provide new and effective ways of teaching and learning, and will help make them more individualized than is possible with traditional computer-aided instruction. This is based on the notion that current AI techniques can permit a computer program to solve the problems which it sets for the user, in a human-like and appropriate way, and then reason about the solution process and make comments on it.

In this article, I shall give a brief overview of the various approaches being pursued in applying AI to education, and highlight issues and questions which have to be addressed before AI-based educational software can meet its promises.

AI and Education

The application of AI in education can be divided into two major subfields or approaches:

1 the development of computer-based learning or exploration environments: environments which encourage discovery learning (i.e. learning by doing). This takes the form of providing a computer-based environment in which the student can watch or build simulations in some microworld with possibly coaching advice given by the system as he does his exploration.

2 the development of programs that mimic tasks undertaken by human tutors, such as explaining concepts, finding errors, providing remedial instruction, and so on: this area is known as Intelligent Tutoring Systems (ITSs). An ITS attempts to produce behaviour in a computer program which, if performed by a human, would be described as 'good teaching'. In contrast to exploration environments, ITSs advocate a paradigm where students learn largely by being told.

A smaller and less-known subfield of work is the use of AI to provide computer tools, such as advanced writing tools, to assist in the early phases of courseware development projects. During these phases, instructional designers, teachers, and domain experts meet and discuss such matters as defining the purpose of the courseware, defining the audience, creating course and lesson plans, scripting, storyboarding, flowcharting, etc. Traditionally, discussions are recorded on paper. This area concerns the use of the computer to improve productivity during the early phrases of courseware development.

Coming back to the two major subfields, it is often argued that in order to build effective ITSs that manifest more than simplistic approaches like "present it, test it, assess it, maybe reteach it", we need to consider educational theories, develop computational theories of teaching and learning, and incorporate them into the ITS. While this area is one of the most important in applying AI to education, it is also a difficult research area. Woolf (1988a), for example, compares computer tutoring to a police chase of bank robber - neither can be planned ahead of time. One does not plan before the robber comes to town, which streets and buildings to search for the robber. The police must respond and react to every action taken by the robber. In computer tutoring, we cannot decide what is going to happen after the computer asks the student a question. The system must plan the possible outcomes in an opportunistic and dynamic way.

To illustrate the relationships between the above described approaches and the traditional educational software available in the market, consider Figure 1.

The choice of which position to take on the spectrum is not simply a matter of personal conviction, but also a function of the nature of the expertise to be taught. Abstract and general concepts may be better taught within an exploratory learning environment that offers a suitable viewpoint in a computer-based microworld. The teaching of skills which are basically problem solving in a specific domain can best be achieved by monitoring and

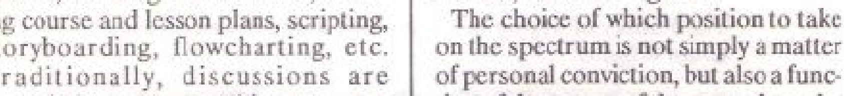

Fig. 1 The spectrum of educational software

coaching the problem-solving process in an ITS. For tasks which are more concrete and specific, and for the teaching of basic facts, concepts and terminology, traditional CAI may be sufficient.

Exploration Environments

The approach of instruction in an exploration environment involves the use of the computer to simulate a device or a task environment, to permit students to assemble and test their knowledge in the environment, or to provide practice of a skill that is motivated by a game. The computer makes it possible to demonstrate certain principles rather than merely talking about them. Complex devices can be simulated readily on the computer screen, and points of view offered that might not even be possible in the real world (eg. what would happen to an object free-falling if there is no gravity?).

AI techniques provide ways of incorporating intelligence into exploration environments. They can be used to make the environment reactive by responding to manipulation by the student and guiding the student in that exploration. They can be used to make the system articulate in explaining itself. They can be applied to provide some sort of coaching and advising as the student solves a problem in some domain.

Another kind of exploration environment is a programming language which permit the student to build simulations. An example of such an 'open-ended' learning environment is the LOGO language which introduces students to the world of geometry through the use of robot 'turtles' and 'turtle graphics' techniques. The student learns by direct programming rather than by direct instruction. Basically, this kind of discovery environment allows a student to specify a process or an algorithm, and then to see a simulation of that process or algorithm being carried out. An important problem with discovery environments is that students often fail to do the specific experiments that might teach them something. This is a good reason for applying AI to supplement the environment with an intelligent coach that assesses the student's behavior and provides instructive advice.

The computer makes it possible to demonstrate certain principles rather than merely talking about them.

Intelligent Tutoring Systems

The idea of computer tutors has its roots in one of the basic goals of AI : replicating human intelligence. ITSs are intended to take some of the part of a human private tutor, much in line with cognitive psychology which emphasizes learning as an constructive process. Other basic ideas include the separation of teaching materials from the teaching strategies, and taking at least some of the initiative in an educational dialogue. The structure of an ITS is often described by components representing knowledge of these areas:

1 the subject matter to be taught (domain expert module)
2 the person being taught (student modeling module)
3 teaching strategies (tutoring module)
4 the tutor/student interface (communication module).

The domain expert module contains the knowledge of the subject area we want the student to learn. Using this knowledge, the system should be able to answer student's questions or diagnose his errors, and give him advice. By representing deep structure knowledge instead of surface knowledge, this module is assumed to know what it teaches, in contrast to traditional CAI where only frame sequences that are prepared beforehand are displayed to the student.

The student modeling module represents the knowledge used by the system to find out the thinking and strategies of the individual student on the specific subject matter he is learning. The system generates and maintains a student model for each student which may be a subset of the domain expert's knowledge or a variant of that containing misconceptions. The student model is used by the tutoring module for addressing the specific needs of the student.

The tutoring module represents the rules, strategies and processes that govern the way the system communicates with the student. It decides when to interrupt and tutor, what to say to the student, and how to say it. Several possible strategies can be applied ranging from intrusive tutoring (eg. by commenting immediately after errors) to more liberal coaching (eg. by allowing exploration).

The communication module provides the actual interface to the student. The natural language interface has been emphasized in some ITSs. Another form of interface is to present the student with an 'audit trail' of his problem solving behaviour earlier in the session. The trail in a visualized tree form can be useful in certain domains, for example, mathematics tutors.

Several ITSs have been built over the years. They usually concentrate on one or two of the four components described above. du Boulay & Ross (1988) divide the application areas for ITS into four areas : programming, mathematics, science and engineering, and language. The majority of the systems built falls in the first two areas. Most ITSs are research prototypes, but a few have been in use in industry or in teaching environments at schools and universities.

Real-World Applications

Twenty years have passed since the earliest attempts, but unfortunately few classroom level applications or empirically verified improvements have materialized. Traditional computer-aided instruction (CAI) has gained strength from the recent advances in hardware and software such as bit-mapped mouse-based interfaces, hypermedia and multimedia. Thus the claim for applying AI to education as a panacea to engender more effective and efficient learning seems more equivocal now. On the other hand, some researchers hold the view that AI in education still shows promise even if their time is not ripe yet. They perceive that the model of instruction in traditional CAI has not worked and it will not work, even if we add multimedia to the instruction being delivered (Soloway, 1991).

Recently, some progress made in introducing AI-based educational applications to industry has been reported. Several systems were described which achieved the two-sigma effect (Bloom, 1984) which is the same improvement in learning that results from one-to-one tutoring over classroom tutoring. Success stories include (Woolf et al, 1991) :

1 Students working with an Air Force electronics troubleshooting tutor for only 20 hours gained a proficiency equivalent to that of trainees with 40 months on-the-job training.
2 Students using a Lisp tutor at Carnegie-Mellon University completed programming exercises in 30% less time than those receiving traditional classroom instruction and scored 43% higher on the final exam.
3 Students using a microworld environment learned general scientific inquiry skills and principles of basic economics in half of the time required by students in a classroom setting.

Given these results, these questions were asked: why are tutors not more used and why are existing systems not more effective? Some reasons are:

1 Industry has not widely adopted these systems because of the lack of tutoring-specific AI development tools. For example, expert systems have caught on in industry because of the proliferation of expert system shells and environments. AI tools can be used to facilitate large-scale development.
2 The task of reducing cognitive task analysis and current theories of teaching and learning to computational methods and engineering practice is a difficult one.
3 The development time of educational systems is excessively long.

As for the state-of-the-art in applying AI to education research, the following has been considered as solved problems according to Woolf (1988b) from an American perspective:

1 Knowledge and reasoning have been codified in several domains (eg. geometry, algebra, Lisp, Pascal).
2 AI techniques are now being learned by a large community of educators and cognitive scientists.
3 Hardware is becoming more cheaper, easier to use, and more powerful.

The Future

Woolf in 1988 noted some of problems still remaining to be solved in AI-based educational applications. Many of items on that list are still problematic to this date and they include the following:

- Not enough is known about student models, machine learning, or multimedia use of knowledge-based systems.
- Unsolved educational and social issues, such as lack of access to machines for dissemination.
- A generation of entrenched and unusable computers in the classroom.
- The need to integrate computer tutors into existing curriculum and educational system.

In order for AI to play an important role in the future of educational technology, we need to:

- have intensive cooperation between specialists in educational technology, the subject domain, pedagogy, and psychology,
- offer a principled approach to the design of AI-based educational software,
- build authoring systems and tools for ITSs,
- produce good small example programs across the curriculum and not just toy problems, in order to get more support and more dissemination of the ideas,
- conduct systematic and controlled large-scale evaluations of AI-based educational software.

The application of AI techniques to education introduces interesting yet almost insurmountable challenges, but at the same time offers some fascinating opportunities for future education.

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VIRGINIA CHENG

Information Technology and its impact on schools - The CTSS Experience

Information technology has made an enormous impact on education through technological advances, particularly in the area of computers. As schools are responsible for providing pupils with skills which will help them face the complexities of life and facilitate the transition from the school environment to that of the workplace and the world, it is imperative that schools provide pupils with skills to utilise technology to retrieve, analyze and use information to solve problems.

Schools must incorporate computers into their programmes as appropriate and with the same careful planning and preparation given any major instructional or administrative change. This naturally involves planning, the acquisition of computers, the training of staff and the applications of computers within the school.

The CTSS Experience

The school policy of Clementi Town Secondary School (CTSS) reflects the school philosophy and its motto *Aspire and Grow*. It embodies the setting of high aims to enable all pupils to grow fully in all aspects in a challenging yet caring environment.

To this end a computer system was initiated in 1987 with the setting up of a computer laboratory of IBM compatibles. To keep abreast with the rapid changes in technology many software packages were purchased. In 1990, a commercial company presented the school with a Macintosh Laboratory consisting of Macintosh computers and other peripherals.

With these facilities, computer education was formally launched with the formation of CREST (Computer Resource Education Support Team). This group of teachers is responsible for the training of pupils in general, Computer Appreciation Club members in particular and other members of the staff. In addition they provide support by assisting teachers who need customised help according to their department's needs as well as the school administration.

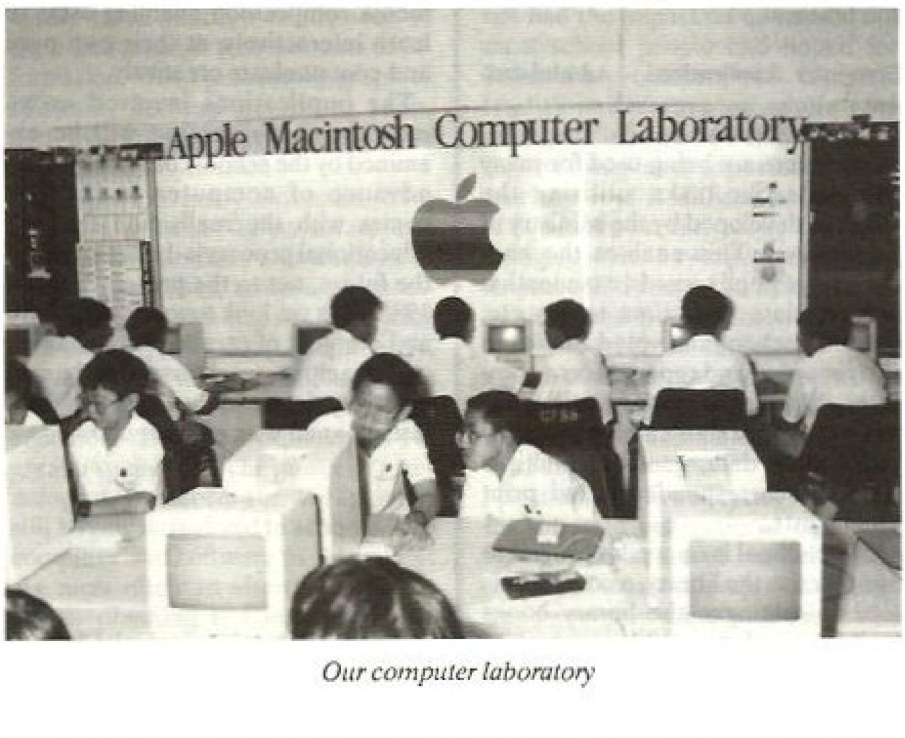
Computer Applications - Instructional

From 1990 all secondary one pupils were taught computer skills in the use of Macintosh and IBM computers. The objectives of this Computer Awareness Course, Module 1, include

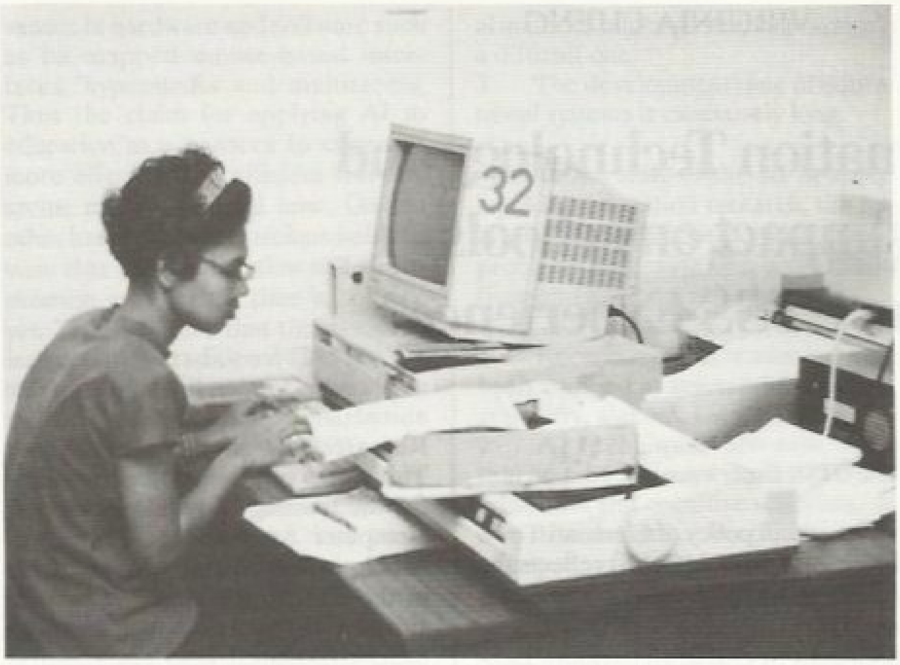
- the use of a word processing programme for basic word processing tasks
- the use of a graphic software and some graphicpackages
- the use of a spreadsheet programme for simple calculations and analysis
- operating computer hardware and peripherals
- understanding computer basics
- understanding simple programming concepts
- -using the tools for assignments and projects

A sample of the course outline is given below:

Week 1 : Introduction to Macintosh
Introduction to Microsoft Word



Our computer laboratory



Computers in school administration

Week 2 : Using M S Word

Week 3 : Using Superpaint

This year, the course content has been modified and improved to suit the needs of secondary one pupils. This enrichment programme is scheduled over a period of 15 weeks outside curriculum time.

Computer Appreciation Club (CAC) members are trained at a higher level and may choose to specialise in a particular programme. From these members, pupils are also selected to participate in national software competitions. To enhance the skills learnt, CAC members are expected to share their knowledge by training other pupils who are non-club members.

All secondary two pupils acquire skills of word processing by applying them during their English language lessons while secondary three, four and five pupils are offered computer electives as part of their enrichment programme.

Many in-house workshops have been conducted by the CREST team to train staff in the use of application packages to enhance their teaching and in the preparation of teaching materials. Teachers learn typesetting, word processing, graphics, spreadsheets and are introduced to Hypercards. Currently Chinese language teachers are involved in item banking with some schools in the same zone. All workshops conducted are scheduled with "hands on" sessions to ensure that teachers gain confidence and enthusiasm to utilise computers effectively. As Papert, creator of LOGO, appropriately stated "It's the feeling of, 'Gee, I can master that, I can get the computer to do something.'"

In CTSS, the computer is viewed as a tools to expand learner capabilities and enhance learning both for pupils and teachers.

Computer Applications - Administrative

Computers are being used for many administrative tasks, utilising the software developed by the Ministry of Education. This enables the easy retrieval of pupil records, examination results, class lists, time tables etc. Usage of school and voted funds are also recorded and reported on a computer. Word processing functions enhance the office staff's ability to record and update data, generate multiple copies of correspondence and print mailing lists.

As the school is on a pilot project to computerise the library, a computer is used to catalogue the library books available and to enable control of library circulation. As pupils and teachers helped in the cataloguing and barcoding of books, the computerisation exercise was completed well within a year. Pupils and teachers can now borrow and return books with ease.

Whenever a computer can free human energy for more productive activities, the opportunity will be seized (Patterson & Patterson, 1983). Hence the library and Media Department is currently taking steps to computerise the loan of media equipment as well as the inventory of items available.

Multi-Media Applications

The school has just embarked on another pilot project, "The SMART Classroom" project, in conjunction with the Curriculum Development Institute of Singapore. Module 1 incorporates the use of television and laser discs in the presentation of History, Geography and Chinese language lessons. Every secondary one and two classroom is equipped with a television set and a laser disc player and teachers involved are provided with their own copy of laser discs. In Module 2, computers will be used together with the equipment in Module 1.

One area being explored is the use of computer-based multi-media systems which will allow users to create and present information in a sophisticated way. The integration of sounds, visuals and text will create multimedia composition enabling users to learn interactively, at their own pace and communicate creatively.

The implications involved as we move in this direction will be examined by the school community. The advance of computer technology comes with the realisation that the educational process is dynamic and "in the future, not to the present." (Bork, 1985). As we look towards the future and our goal of excellence in learning and teaching we know that human creativity is the only limit to future instructional uses of computers.

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VICKI HANCOCK

Curriculum Reform Through Technology Integration

Technology can provide teachers with the means to transform teaching and learning

Technology has transformed the workplace significantly. Not only do workers have different kinds of jobs, but they view their tasks (the problems they solve) differently with the accessibility, speed, and magnitude that technology provides. Computers and spreadsheet software have simplified project planning. Telecommunications and online database services have made information access instantaneous. Large-capacity optical media have enabled institutions to store and manage vast amounts of information. Word processors, graphics software, desktop publishing tools, and hypermedia have streamlined written communication.

Schools, like many industries, have acquired a variety of hardware and software for teachers and students to use. In most cases, however, technology use in schools has not kept pace with changes in business and industry. Teachers tend to use technology to do the same jobs they've always done, except more vividly, more quickly, and in greater quantities. The power of technology to transform the workplace is still largely unrealized in schools. The computer and software in classrooms are most often an afterthought once lesson planning is complete, or an add-on that increases the preparation required for teachers to survive the day. Just as technology has transformed the business workplace, technology has the same potential to increase productivity in schools. Transformation will not occur unless technology is permitted to change the way teachers teach and the way students learn.

Technology's Underuse

For several reasons, technology has not had the impact on education that most school people had hoped for. First, many teachers still favor the traditional lecture or whole-class method of information delivery. Lacking training and experience, such teachers find it difficult to imagine, much less plan for, using new technologies when they expect all students to proceed through the same content at the same pace. Moreover, many teachers work in settings in which valuable resources and support are lacking: funding, appropriate technologies, and community acceptance of change.

Second, in spite of cycles of support for different instructional styles, the lockstep structure of the school day prohibits many attempts at change. Teachers must cope with curriculum demands, standardized testing requirements, strictly defined blocks of instructional time, and large groups of students.

Finally, familiarity breeds complacency, and uncertainty produces anxiety. Teachers who have established reliable instructional routines may balk at the prospect of the radical changes technology integration would bring. Why exchange traditional methods for a more complex, largely untested alternative?

Such commentary is not meant to be an indictment of the existing educational system. It is meant to accentuate a discouraging situation which can be

Teachers tend to use technology to do the same jobs they've always done, except more vividly, more quickly, and in greater quantities.

remedied by careful planning.

Educators must confront at least four issues as they prepare to use technology for curricular reform: leadership, equipment and space, access and quality, and staff development.

Leadership

The integration of technology into instruction cannot proceed without rigorous, knowledgeable leaders in each school and enthusiastic support from the central office. At the district level, a technology committee identifies objectives for technology use, defines expectations for "literacy", delineates a scope-and-sequence plan for implementation, and generates financial and political support. The committee also coordinates hardware purchases and maintenance, software evaluation, and a centralized acquisition and lending service. Other tasks include coordinating inservice activities for teachers, administrators, and staff; maintaining communication and integration among elementary, middle, and high schools; and conducting periodic evaluations. A district-level technology coordinator directs the computer committee's activities and oversees technology coordinators at each school.

Effective school administrators provide the impetus for successful technology integration. They may be principals, vice principals, teacher leaders, media specialists, or technology coordinators. They function as liaisons between staff members and district administrators, and they perform several important roles in school reform efforts.

Planner and Manager. First, administrators must develop their own awareness of information technology. District-level inservice activity facilitates this awareness and provides opportunities for administrators to share resources. Second, they must develop understanding of how technology can be incorporated into the educational system or school and anticipate the changes that will result. Again, frequent interaction with the district technology committee builds this understanding. Third, they must act as models and cheerleaders to promote the use of technology among students, staff, and the community.

School leaders must act as models and cheerleaders to promote the use of technology among students, staff, and the community.

Finally, they must develop and manage a professional development plan for staff members, in cooperation with the school's technology team.

Facilitator. As a facilitator of technology integration, the administrator performs the following functions:

1 managing resources to meet the needs of the program;

2 ensuring that each student develops skills using technology as an instructional, personal, creative tool;

3 providing information about the project to the community;

4 facilitating the creation of a flexible learning environment that uses technology to make learning more active and interactive for each student;

5 facilitating the development of an integrated curriculum that takes advantage of technology; and

6 monitoring the inclusion of technology in program and curriculum outlines when appropriate.

Evaluation Coordinator. Assessment of technology integration cannot be limited to logging the amount of time spent by students and teachers using technology. An evaluation plan should include systematic, ongoing measures that explore content achievement, teacher-student interaction, and content-technology coordination.

Mentor/Coach. As mentors, administrators are responsible for maintaining a sufficient level of skill to allow them to communicate effectively about technology with staff members. As coaches, they guide teachers in setting objectives, establishing peer coaching relationships, creating opportunities for observation and professional activity, and providing feedback.

Administrators at the school level play a critical role in any effort at curricular reform. Their authority as policymakers and their frequent interactions with staff members create the environment in which innovation and change can either flourish or perish.

Equipment and Space

When given the prospect of planning for technology in the curriculum, many educators ask first: "What hardware should we get?" This could be an inquiry about the best brands, features of particular technologies, or quantities of equipment. Regardless, this should be the *last question* answered in any technology integration effort. Until district or school staff members decide what they want to accomplish in the curriculum with various technologies, they cannot constructively answer questions about hardware. What is most important is a thoughtful match between curricular goals and the technologies that can expedite those goals.

Space needs, on the other hand, should be considered early in the planning process. The location of technology hardware and software strongly influences who will use it and how it will be used. For example, Henry Becker's (1984) survey, *School Uses of Microcomputers*, includes an examination of the consequences of various computer locations within a building. In a rapidly changing computerized society, Becker's results still offer useful guidance:

1 Locating computers in individual classrooms is convenient for some teachers and students, but limits access to equipment by others.

2 Computers configured in a lab setting tend to be associated with programming activities.

3 Hardware located in a library or media center encourages a variety of applications, but inspires less enthusiasm from students than other locations.

4 Mobile computers provide more access, but have less impact on students and learning activities.

The location and configuration of any technology in a school building should reflect the needs outlined in a comprehensive curriculum plan for technology integration. Speaking specifically of computers, Pogrow (1983) suggests that at the elementary level, technology be configured into "centers" for discovery, graphics, and computer-assisted instruction. At the secondary level, the centers should be subject-specific, with one center assigned for general, drop-in use.

Access and Equity

Just as the location of hardware in a school will influence its usage, so will the general plan for technology integration. Gender and socioeconomic status are two primary sources of access and equity discrepancies in schools. Awareness and consideration of these issues throughout the planning process will allow technology to reduce rather than reinforce their effects. Collis (1988) discusses many ways to reduce inequities in school computer use. These suggestions are applicable to all technologies used for instruction:

- Develop a plan in which technology is used as a tool in the classroom in the context of regular instruction throughout the curriculum and the grades and with as many different teachers as possible. Integrate technology into language arts, social studies, and music curriculums, as well as science and mathematics.
- Make technology use relevant; use a computer for tasks it does well, such as word processing, graphing, information handling, performing tedious calculations, and printing graphics.
- Structure time with technology so that all students have a reason to use it relative to their different classes and no students are allowed to dominate the activity. For example, students should access the U.S. Census Bureau database because the information they retrieve will be relevant to a social studies lesson on population.
- Emphasize an association between communication, information, text, and the technology; put the association of technology and mathematics into a more balanced perspective. Technology, especially computer use, has been previously associated more with mathematics than with other subjects. Emphasize through conscious planning the applications of technology to other subjects as well.
- Instead of expecting students to make independent use of technology, develop activities that involve small groups or pairs of students. Having the equipment in the building does not ensure that students will use it. Plan activities that depend on technology for their successful completion, such as requiring that as part of a book report, record on videotape a scene from the book that illustrates the theme.
- Sensitize teachers and parents to inequities in computer use and to plan their long-range implications. Plan a faculty meeting to discuss computer inequity. Allow time for brainstorming activities to alleviate the problem, such as lending hardware to girls to take home, creating a buddy system for computer activities, and recruiting girls for computer classes. Introduce the school's technology plan to parents early in the school year as part of "parents' night" activities. Outline efforts to eliminate inequities while soliciting parents' support.

Staff Development

Any plan for curricular reform must include inservice education for the staff who will implement the reforms. With the district-level technology coordinator, the school administrator or leader shoulders the significant responsibility of planning staff inservice activities. Kinnaman (1990) describes five ways to ensure positive inservice experiences for teachers. First, design activities that will engage teachers in reflection about the benefits and limitations of teaching with technology. Second, provide technology-related professional development experiences that are ongoing and systematic. These sessions should allow teachers to develop their skill and comfort with technology rather than be overwhelmed by it. Sheingold and Hadley (1990) discovered that it takes five to six years

Computers permit greater individualization as well as more independent student work. This allows teachers to give greater attention to individual students.

What is most important is a thoughtful match between curricular goals and the technologies that can expedite those goals.

for teachers to master computer-based practices and approaches. Third, supplement large group workshops with peer coaching and modeling sessions, which allow teachers to benefit directly from their colleagues' expertise. Fourth, structure inservice activities within the curriculum for which teachers are responsible, not segregated from it. Fifth, ensure that staff development sessions provide hands-on, exploratory experiences with the technology; teachers should have time to reflect on and share the many solutions technology can provide to a given problem.

Effective inservice experiences will result in effective recruiting activities for former "technophobes." Remember, many teachers who are expected to integrate technology into their content subjects have been in the classroom longer than the technology has existed.

Curriculum Reform Patterns

Specialists in the curriculum reform movement, including Glatthorn (1987) and Mojkowski (1989), recognize a number of patterns that characterize reform efforts. First, there is a balance of attention to discipline-specific process skills (how to do it), as well as an essential knowledge base (what to know). As a result, students learn to demonstrate an ability to think, learn and perform in a given subject area. Second, learning and study skills are integrated into each discipline so that students can see their importance in all classes. Moreover, students become familiar with available technology while they learn to access and manipulate information sources to become independent learners. Third, students spend more time in each subject area learning problem-solving skills that later translate into generic thinking skills for learning. They learn how to learn. Finally, teachers expand their repertoire of techniques from lecture to seatwork to such practices as demonstration, discussion, guided practice, simulation, and brainstorming. In this way, students take more responsibility for their own learning, and teachers become facilitators and collaborators.

Requirements for Effective Planning

As districts and schools plan for curricular reform through technology integration, they should use the following requirements as guidelines:

1 Students are knowledge producers as well as consumers; they must participate in their own learning.

2 Students must learn to access and use a knowledge base outside of themselves and their immediately available instructional materials; use of a variety of technologies facilitates this process.

3 Learning activities must be problem oriented and project organized, focused on an integrated set of knowledge and skills outcomes (interdisciplinary approach).

4 Learning activities must require applications, as appropriate, of a variety of technology support tools (e.g. word processor, database, telecommunications).

5 Learning activities must develop social interaction; such activities include collaborative learning and peer coaching.

6 Learning activities must produce meaningful work intended for audiences beyond the teacher.

7 Curriculum units must relate to a K-12 curriculum or framework; knowledge and skills should be organized in a scope-and-sequence format.

Ideally, the district establishes a generalized curriculum framework integrated for all grades and disciplines. Then schools design their own unit plans into which technology resources are integrated. One example of a curriculum plan integrated with technology is *Make It Happen!* from the Educational Development Center, Inc. (in press). The plan uses a thinking skills instructional approach the developers call "I-Search", which builds on a report-writing task and incorporates technology as a natural, logical part of the process. (A comprehensive description of the development of the I-Search process will appear in the *ASCD Curriculum Hand-*

Careful planning of curricular reform is essential for success, and technology can contribute significantly to that success.

Integrating the computer turns a teacher-centered classroom into a student-centered one, with the teacher acting more as coach than as information dispenser.

book, to be released in the fall of 1991).

Results to Expect

Careful planning for curricular reform is essential for success, and technology can contribute significantly to that success. In a survey conducted by the Bank Street College of Education, Sheingold and Hadley (1990) report: "In the eyes of teachers, significant changes are taking place as they integrate computers into the curriculum. Fully 88% of the [608] teachers in the sample indicated that computers have made a positive difference in their teaching, the remainder being unsure or negative." Respondents reported three major changes:

1 Teachers expect more of their students and can present more complex material.

2 They can meet the needs of individual students better. The computers permit greater individualization, as well as more independent student work. Computers allow teachers to give greater attention to individual students.

3 Integrating the computer has turned a teacher-centered classroom into a student-centered one, with the teacher acting more as coach than as information dispenser, and with more collaboration and work in small groups going on among students and between student and teacher.

The International Society for Technology in Education (ISTE) funded by a grant from IBM, interviewed 150 leaders in education and business. In the resulting report, *VISION: TEST*, ISTE (1990) reports: "From examining the successful use of technology in educational environments, we know that the use of technology:

- permits teachers to assume new roles in the creation of learning opportunities for their students,
- encourages individualization of learning experiences to accommodate various learning styles,
- allows learning experiences far beyond anything available otherwise,
- provides strong motivation for students, and
- reduces time-consuming paperwork and allows teachers more time to take advantage of the opportunities of technology.

Using technology to reform the curriculum provides teachers with the resources they need to transform the work they do. They no longer teach the same things in new ways; they can change their views of the work they do, the ways they deliver instruction, and the ways students learn.

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ROBERT SYLWESTER

Expanding the Range, Dividing the Task: Educating the Human Brain in an Electronic Society

We need to create curriculums based on the complementary relationship between the human mind and the machines we develop to supplement our capabilities

Recent developments in both brain research and computer technology pose complex curricular issues. We are currently laboring hard to teach students many skills that small, readily available calculators and computers can process more efficiently and effectively. Rather than continue this traditional practice, we should base our curriculum decisions on an understanding of the brain's capabilities, limitations, and interests.

New technologies have always emerged out of the limitations and interests of the brain's sensory/motor and problem-solving mechanisms - narrowing the distance between what we can do and what we would like to do. Typewriters, telescopes, telephone books, and trigonometry are but four of the rich complex of technologies that we have developed to expand the brain's ability to gather/process/interpret/use information. Schools, though, lag far behind society in adopting new information technologies. For example, the typewriter has existed for well over a century, the word processor for about a quarter of a century. Although they've transformed written communication in our society, we've provided K-12 classrooms with few of them.

This article provides background information on five properties of the brain that are central to the issues of how best to divide educational tasks between minds and machines and how to create curriculums that will help students understand the complementary relationship between the brain and the supportive machines that

A curriculum that makes use of calculators for boring repetitive work increases the amount of time students can spend involved in tasks that are more stimulating and challenging.

human brains develop. I will argue that the curriculum should focus principally on knowledge/skills/values that (1) most characterize and enhance our brain's capabilities and (2) teach students how best to use appropriate technologies on tasks that characterize the brain's limitations.

To succinctly state the differences, the human brain is currently much better than computers at conceptualizing ambiguous problems - identifying definitive and value-laden elements that it can incorporate into an acceptable general solution. Conversely, computers are much better at rapidly, accurately, and effectively processing complex sequences of clearly defined facts and processes that would otherwise require a high level of sustained mental attention and precision.

Or to state it in classroom terms, teaching is generally a delightful experience when we focus on activities that student brains enjoy doing, and do well - such as exploring concepts, creating metaphors, estimating and predicting, cooperating on group tasks, and discussing moral/ethical issues. Conversely, teaching loses much of its luster when we force students to do things their brains don't enjoy doing, and do poorly - such as reading textbooks and compress content, writing and rewriting reports, completing repetitive worksheets and memorizing facts they consider irrelevant. Now let's examine five key capabilities and limitations of the brain and the computer.

Rigid sensory/motor controls underscore human brain activity. They limit input and output to narrow ranges; and they limit our ability to make fine discriminations within those ranges - but our curiosity has led us to vigorously explore the universe beyond these limitations.

Sensory limitations/expansions. The information that our brains' specialized sensory receptors receive from the surrounding environment is somewhat meaningless initially - variations in temperature, touch, and air pressure, reflected light rays, and the chemical composition of air, water and food. Further, our sense organs function within relatively narrow ranges (e.g. 10 octaves of sound, about 30 odor-producing molecules, the narrow band of visible light in the broad electromagnetic spectrum).

We've now developed a class of powerful portable electronic machines that rapidly do the things our brains don't want to do - and don't do well.

It doesn't seem like much, but those variations are the source of all the external information that our brains transform into cognitive representations of the world. An exceptional sense of taste and smell can provide a wine taster with a vocation, and psychedelic drugs can briefly expand our sensory range - but we normally function within a narrow, genetically determined sensory range.

It makes sense. Our brains couldn't possibly process all the information that the surrounding molecules and vibrations carry. However, we've always been curious about what exists beyond our sensory range, and so we've developed such technological extensions as microscopes and telescopes, and oscilloscopes that transduce unhearable sounds into visible patterns.

Computers have materially broadened our knowledge of the universe by expanding the range and precision of such sensory technology. The curriculum should help students understand and master this technology, but it should also examine the social value of information that exists beyond the brain's limitations. For example, a computerized camera can now identify the winner in a race by differences of hundredths of a second, when our visual systems and less precise brains would have called it a dead heat. The curriculum should encourage students to ask: How important is such expensive accuracy to the human spirit, when a race is but a game? Does precise information become important to an imprecise brain simply because it's technologically available?

Motor limitations/expansions. Conscious and unconscious brain mechanisms operate our jointed motor systems. This system is similarly limited in its range/speed/strength, but it can directly and technologically send information far beyond our immediate body ranges.

We've long engaged in competitions to discover the limits of our own movement capabilities. Some people devote their youth to such goals as trying to jump a fraction of an inch higher than anyone else. Further, mechanical and computerized technologies, such as cars and telephones, that materially increase the range and speed of human movement and communication seem almost to define our current culture and economy.

Our brain's motor system drives the communication skills that dominate the curriculum. Relatively complex brain mechanisms and muscle groups control the mouth and hand movements we use in interpersonal communication. Our voices are directed to hearing, and hand/finger movements primarily to vision (generally via paper). Both muscle groups are most efficient when they function automatically - when the conscious brain can focus on the content of the message rather than the vehicle of expression.

Thus, we have long taught cursive writing because its automatic flowing nature permits writing speeds between 15-30 words a minute. But with much less instructional time, elementary students can learn to touch-type well beyond that speed, and in the years ahead, word processors with spelling checkers and superb editing capabilities will be readily available for any extended writing students will do.

This information suggests that we should phase out cursive writing as our principal technique for extended automatic writing. Rather, we should teach elementary students to compose stories/reports/letters directly on word processors and to use manuscript or cursive writing primarily for shorter notes and forms. Composing on a keyboard, like writing with a pencil, is an acquired skill. Its speed and rhythm are often more tuned to the speed of our thought processes than is cursive writing. Indeed, writing composed directly on a word processor tends to become conversational in style.

Developments in oral communication technologies further complicate this issue. In our increasingly oral society, one could ask how important it is to write fast when the telephone is even faster. Further, voice input/output capability in computers is also developing rapidly. Its advent will be a curricular boon for handicapped students, but it will also create curricular adjustments for those with normal proficiency in language. For example, clear diction and correct syntax will become more important when we speak into computers that require them than when we talk to people, whose brains can easily adapt to errors in speech and syntax.

Our brain can quickly identify potentially important incoming information - separating foreground from background information - and it can briefly hold elements of the foreground information in its short-term memory.

The brain is designed to merely monitor most of the low contrast sensory information that flows into it (e.g. blank walls/single tones), but it automatically attends to high contrast information (e.g. lines, edges, movements, oscillating sounds, a blast of cold air). For example, your brain is currently aware of the paper that constitutes this page (background), but it focuses its attention on the high-contrast lines that make up these words (foreground). Long before brain researchers discovered that the information in lines is sent into the brain with more strength than the information in solid areas, we humans had exploited this property by creating written languages that used combinations of lines on paper to represent words.

This initial automatic separation of foreground from background at the point of contrast certainly simplifies the critically important analysis task that follows within our brains. Our limited short-term memory buffer can briefly hold potentially important information from the current sensory field while we decide whether to attend to it further and/or store it in long-term memory. But we must decide quickly because the continual influx of new information will delete anything not consciously held.

Since short-term memory space is limited to perhaps a half dozen units of information at any one time, we must rapidly combine related bits of foreground information into single units by identifying similarities, differences, and patterns that can simplify and consolidate an otherwise confusing sensory field. The need to respond quickly has enhanced our ability and willingness to estimate, certainly one of our brain's major strengths.

Our conscious brain thus monitors the total sensory field while it simultaneously searches for and focuses on familiar/interesting/important elements - separating foreground from background. Even an infant can easily outperform an advanced computer in quickly recognizing its parents in a group of people. Extensive experience in a field develops these rapid editing skills to the expert level. Thus, the curriculum enhances this remarkable brain capability when it focuses on the development of classification and language skills that force students to quickly identify the most important elements in a larger unit of information.

The strong appeal of computerized video games may well lie in their lack of explicit directions to the players, who suddenly find themselves in complex electronic environments that challenge them to quickly identify and act on the important elements. Failure sends the player back to the beginning, and success brings a more complex (albeit attractive) challenge in the next electronic environment.

I watch with amazement as my 5 year-old grandson zips through the complexities of the electronic world that the Super Mario Brothers inhabit, and I wonder how eagerly he'll respond to the paper worksheets he'll shortly confront in kindergarten. Their directions will be clearly stated; their information will be static and uncomplicated; and, alas, their level of mental stimulation will generally be much lower.

We can't always mentally keep up with the rapid flow of information. Class notes and tape recorders testify to the limitations of our short-term memories to delay and hold the flow of complex experiences. Good class notes are active and selective and thus enhance the development of critically important rapid synthesizing skills. Conversely, a tape recorder passively stores everything the microphone picks up, and so it can reduce the stimulating mental pressure the listener would otherwise feel during the presentation to identify and write down the important elements immediately (without the security of instant replay via tape recorder).

Students need many opportunities to develop their short-term memory capabilities through experiences such as debates and games that require them to rapidly analyze complex information and briefly hold it. When textbooks and teachers highlight all the important information and software is too user-friendly, learning becomes more efficient, perhaps, but students also experience a reduction in the necessary challenge and enjoyment they get from continuously separating foreground information from background.

Our brains have a limited interest and attention span. We tend to focus on novel and intense information because of their strong contrast and emotional content, and we are stimulated by the successful completion of challenging tasks. Thus, the lack of contrast in routine and repetitive tasks bores us, and we do them inefficiently and ineffectively.

We have turned many of these tasks into low-paying service jobs and/or developed computerized machines to do them for us - and we can expect this trend to continue. For example, supermarket checkers who formerly responded mentally and rapidly to a cart full of groceries now merely run the items across a visual scanner. Many fast-food checkers now use cash registers that have replaced numbers with pictures of hamburgers/french fries/soft drinks on programmed price keys. Telephone operators who used to talk to the people who needed their help now activate voice synthesizers that provide computerized responses to common questions.

The long-term curricular and occupational implications of this development in computer technology will be disquieting unless we develop alternate challenging activities that enhance the estimating and pattern-recognizing skills that contribute heavily to an effective short-term memory.

Our brains can store potentially useful information at multiple levels of long-term memory representation that successively reduce the role of emotion, context, and the conscious regulation of recall.

When important and potentially recurring events occur, our brains may develop representations of the object or experience within long-term memory assemblies, which are specialized networks of neurons that our brains alter to function as a unit during recognition or recall.

It's possible that sleep and relaxation enhance the physical altering of these synaptic connection, since they are periods of less potential interference from sensory/motor and problem-solving activity (think of detours during road repair). Some powerful emotion-laden memories develop almost immediately after a single event, while other (often less effective) memories may require much effort over many trials.

Since a memory is a neural representation of an object and/or event, it is often tied to the context in which it occurred, and emotionally important contexts create powerful memories. Objects and events that registered in several sensory modalities can be stored in several interrelated memory assemblies, and such memories become more accessible and powerful, since each sensory memory checks and extends the others.

Recognition is easier than recall, since recognition often occurs in the original (or similar) context of the memory. If the emotional setting in which a memory originally occurred is tied to the memory, recreating the original emotional setting enhances the recall of the memory and related memories (e.g. family arguments tend to spark memories of prior related disagreements). Thus, emotional multisensory school activities such as games/role playing/simulations/arts experiences can create powerful memories.

Our brains process several interrelated types of memory systems. For example, *declarative long-term memories* are factual label-and-location memories - knowing the name of my computer, where it's located. They define named categories, and so are verbal/conscious. *Episodic* declarative memories are very personal - intimately tied to a specific episode or context (my first attempt to run my computer, my joy at discovering how it simplified writing). *Semantic* declarative memories are more abstract - symbolic and context-free. They can be used in many different settings and so are important in teaching for transfer (knowing how to use function keys and software). My semantic understanding of the typewriter and its keyboard simplified my moves from manual typewriter to word processor.

Initial skill learning, such as learning to type, is often episodic - the memories contain both foreground and background elements of the experience. When I learned to type, my teacher/classroom/typewriter provided an important, easily remembered emotional context during the initial learning period. It would have been inefficient for me to continue to recall all of these background elements whenever I typed, however, and so my teacher used class/home drills and different typewriters to help me eliminate the context of the learning (background) from the execution of the skill (foreground).

My typing knowledge and skill had thus become semantic - more abstract, but also more useful in a wide variety of keyboard settings and tasks (background). In effect, my brain erased the background information from my memory by reducing its frequency and significance, and thus strengthened the foreground information by focusing on it.

My typing speed was limited, however, by my continued simultaneous conscious spelling of words and activation of keys, and so I also had to eliminate this conscious behavior through a transfer of skills from semantic declarative memory to procedural memory - to master automatic touch typing.

Students should not be overwhelmed by the power of computerized machines simply because the machines are fast and efficient. They need to realize that being able to do something efficiently isn't the same as knowing whether or not it should be done.

Procedural long-term memories are automatic skill sequences - knowing how to touch type. They do not rely on conscious verbal recall (except to initiate/monitor/stop the extended movement sequence), and so they are fast and efficient. They are difficult to master and to forget. They are best developed through observation of experts, frequent practice, and continual feedback. As a skill develops, the number of actions processed as a single behavioral unit increases, and prerequisite skills are integrated into advanced skills.

Thus, when I was learning to type, I knew where all the keys were, and I was slow. Today, I don't consciously know where any of the keys are, and I'm a fast, efficient typist. My fingers have now become an automatic extension of my brain's language mechanisms.

Our brain is most efficient at recalling and using episodic memories that have important personal meanings. It is much less efficient at mastering the important context-free semantic and procedural memories. That's why the curriculum has to spend so much time/energy on worksheet-type facts and skills that are isolated from specific contexts. Conversely, computers, reference books, and so on are very reliable with facts and procedures, but they lack the emotional contexts that make our value-laden episodic memories so rich.

This knowledge suggests that we should teach students how to solve problems by combining their brains' subjective episodic strengths and emotional integrity with the objective semantic and procedural strengths of the new information technologies. For example, my decision to develop this article evolved principally out of the rich context of my personal studies and experiences, but my writing of the article also drew heavily on the university library, my own reference library, my ability to select the ideas that best fit the focus of the article and to write them clearly, and on the superior letter-formation and technical editing capabilities of my word processor/printer.

Students should not be overwhelmed by the power of computerized machines simply because the machines are fast and efficient. They need to realize that being able to do something efficiently isn't the same as knowing whether or not it should be done. Our generation has tended to reduce the discussion of the importance of a problem when we've developed an efficient technical solution to it. The curriculum must help the next generation to move beyond that tendency.

Our brains can solve problems at multiple decision points, but we seem oriented toward making early decisions with limited information.

The brain's problem-solving mechanisms appear to be located principally in the frontal lobes, the part of the brain that matures last. We have more frontal lobe capacity than we normally need to survive, because our brain's problem-solving mechanisms must be sufficient for crisis conditions (just as furnaces must be able to function effectively on the coldest day of the year).

Since our survival doesn't require our problem-solving mechanisms to operate at capacity most of the time, we've invented social and cultural problems to keep them continually stimulated and alert. Games, the arts, and social organizations provide pleasant metaphoric settings that help to develop and maintain our brain's problem-solving mechanisms. They are not trivial activities, in life or in the curriculum. Jean Piaget's suggestion that play is the serious business of childhood attests to the important developmental and maintenance roles that such activities play in problem solving.

Our brain can rapidly process ambiguities/metaphors/abstractions/patterns/changes. It can quickly categorize 100 leaves as maple leaves even though no two of the leaves are identical, and it can recognize a classmate at a 25th reunion despite all the changes that have occurred. This capacity permits us to succeed in a world in which most of the problems we confront require a quick general response rather than detailed accuracy. Thus, we quickly classify objects into general categories and estimate general solutions to our problems. We then adapt our preliminary decisions to any new information we might gather and use reference materials and machines to achieve further levels of precision, if they are necessary.

Our brains are better, therefore, at discovering conceptual relationships than at processing the accurate details that computers handle so well. We call it intuition, common sense - and we depend on it for much of what we do. It can lead to mistakes and to the overgeneralizations of stereotyping and prejudicial behavior - and also to music, art, drama, invention and a host of other human experiences that open us to the broad exploration of our complex world.

Language itself evolved out of these capabilities/limitations. It's a response to our need to develop a simple sequential coding system that can rapidly represent a complex information system and thus simplify problem solving and the need to communicate that often accompanies it. Our language uses only about 50 sounds and 50 visual symbols (letters/punctuation marks/digits/math symbols) to create its vocabulary of half a million words. It does this by coding meaning into precise letter sequences and word lengths (do/dog/god/good) and not into the 100 sounds and symbols themselves. Verbal language is thus similar to our genetic language, whose DNA coding system also uses sequence and length to assemble combinations of 20 different amino acids into the vast number of protein molecules that join to form a living organism - a solved problem.

Thus, our imprecise brains have adapted the basic structure of an existing internal genetic code into a precise external verbal code (although Mark Twain once suggested that only an uncreative person can think of only one way to spell a word). Our language has become so complex because we continually add words all across the general-to-precise continuum - from the general term *car* to the more precise *sports coupe*, from *man* to *Robert Alfred Sylwester*.

We can anticipate that computer technology will further expand the basic properties of genetic/verbal languages into new forms of technological language. The curriculum should therefore expand from its current focus on merely teaching students how to use language correctly to a broader extent that also teaches them the fundamental nature of information and language.

The rapid development of precise computerized information suggests another change in curricular focus. We should concentrate more on developing students' ability to quickly locate/estimate/organize/interpret information and we should teach them how to use the superior speed and accuracy of available information technologies whenever a complex problem requires an accurate solution. Hypercards, spread sheets, statistical programs, and spelling checkers are only a few examples of the rapidly developing software literature that can assist our imprecise brains to solve problems and communicate ideas with detailed accuracy.

Because these software programs eliminate problem-solving steps we formerly did mentally, we have a legitimate concern that students who learn how to solve a class of problems via such software won't understand important steps in the solution. It isn't enough to suggest that many people who drive cars don't understand the internal combustion engine. We must develop curriculums that effectively explain the complete solution process while teaching the student how to use a computer to solve the problem.

Most of the brain's development is adapted to the challenges of the environment in which we live, and a stimulating environment that includes much social interaction enhances this development.

The brain's principal activity is to change itself. Early brain development focuses on the stable, preprogrammed, automatic mechanisms and processes that are dedicated to biological survival and to the smooth operation of the body and its movements (circulation/respiration/walking).

Childhood and adolescent development focus on environmentally dependent and adaptable neural networks that are dedicated to the learned exploration of the inner self and the external environment (language/memory/problem solving/socialization skills). Most children are born capable of easily mastering any of the world's 3,000 languages, and American children must learn an average of almost a dozen new words a day to reach the normal vocabulary of a high school graduate.

A stimulating social environment enhances this later development, since our brains develop and alter many of their mechanisms in response to environmental challenges. Children reared or educated in a limited and boring environment will not develop the efficient broad-based brain mechanisms they'll need for effective behavior within a complex social environment. Interactions with other people seem to stimulate use more than anything else - and we have a marvelous capacity for love and commitment to one another.

Our mass culture cries out for cooperative learning and doing. Computers always function within human information networks, and so they can enhance or diminish our potential for cooperative behavior. Teachers can enhance this potential by asking students to collaborate on activities that incorporate computers, by discussing social issues that emerge out of computer use, and by emphasizing human values when information is processed electronically.

An interesting development has emerged in the schools's use of word processors. When students use a paper and pencil or a typewriter, classroom writing is essentially a solitary act because the writing can't be easily read by anyone other than the writer. With their upright brightly lit screens, word processors make writing more of a public act in a classroom. That other students read/discuss/edit the text can enhance the collaborative activities that add context to acquired knowledge.

What is an appropriate stimulating environment for the developing brain of a contemporary child? Electronic information technologies can now create high-resolution graphic representations of real and imaginary worlds far beyond the traditional verbal and visual representations, but they distort time, space, and reality in the process. Still, such things as instant replay, special effects, and computer joy sticks have become such an integral distortion of the real world that they are probably a necessary element in the education of students - whether we like it or not.

Our Curricular and Staff Development Challenges

We won't return to an earlier simpler world in which our brains had to do almost everything within themselves - with the sometime assistance of information stored in the increasingly complex and cumbersome print-oriented collection our society had amassed. We've now developed a class of powerful portable electronic machines that rapidly do the things our brains don't want to do -and don't do well. These technologies move our brain well beyond its normal range/speed/power. In doing so, they create a new set of problems about the value of the gain in relation to the effort and cost that our schools haven't faced before. Are things worth doing simply because we can do them?

Stress- and drug-related illnesses are part of the personal and social costs of educational and technological efforts to force our brains to function well beyond their normal capabilities - whether that be to require students to use paper and pencil to solve math problems they don't understand and consider irrelevant or to use an equally incomprehensible computer program.

Our profession must seriously examine the dramatic developments in cognitive science and computer technology. Doing so will enable us to identify and redesign the obsolete elements of our generation's version of The Saber-Tooth Curriculum, which, because it had evolved into such an effective curriculum, continued to teach tiger-killing skills after all the tigers had been killed (Benjamin, 1939).

This article has suggested a general approach - and explored it through five brain capabilities/limitations that relate to emerging curricular issues. Use this general introduction to focus your own thinking and to initiate discussions with colleagues that focus on your specific professional assignments. If our profession is going to move toward broadly accepted curricular policies and practices, however, we must engage in vigorous study that will move a critical mass of educators to a reasonable understanding of educationally significant developments in the cognitive sciences and to a hands-on understanding of new developments in computer technology. Join that critical mass.

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CHRISTOPHER DEDE

The Evolution of Information Technology: Implications for Curriculum

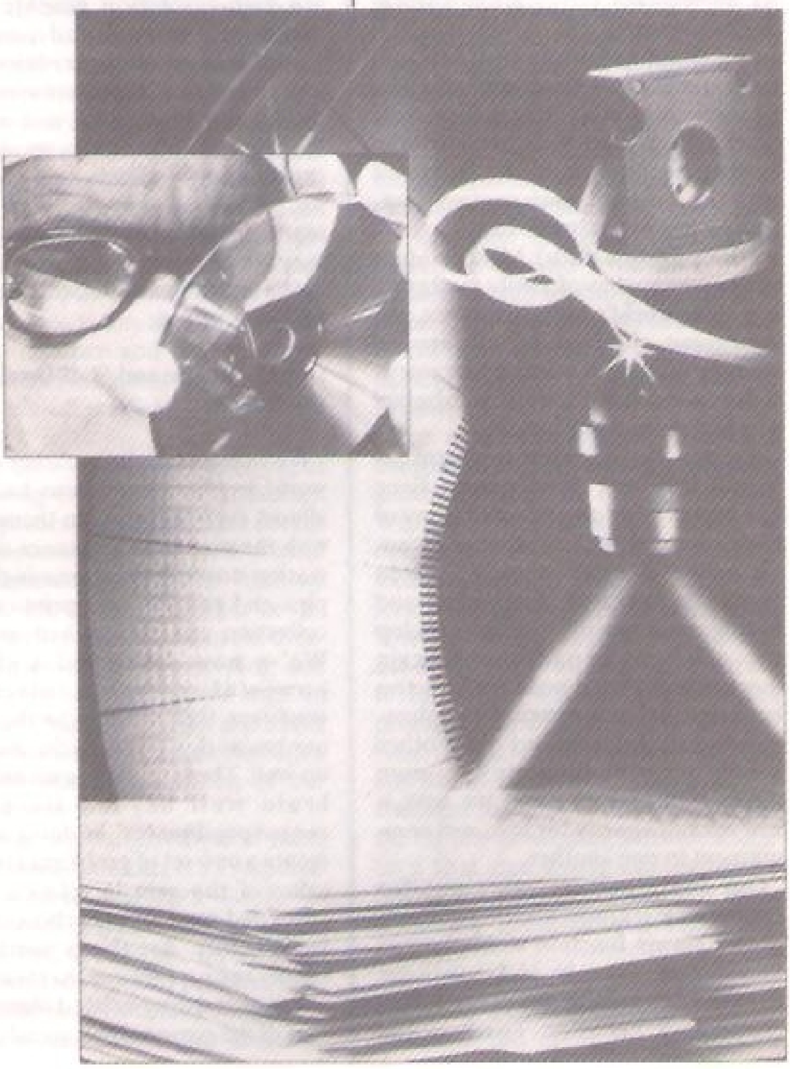
Schools must change their curriculums to reflect the changes technology is making in the workplace.

During the next two decades, major changes in the technological base of American society will alter the knowledge, skills, and values we need to be capable workers and citizens. Evolving information technologies will transform the nature of work, and this transformation will in turn affect the design and content of the school curriculum. As jobs change, schools must shift in response.

Technological Evolution

Since World War II, the performance capabilities of computers and telecommunications have been doubling every few years at constant cost. For example, a decade ago $3,500 could buy a new Apple II microcomputer. Today, $6,800 - the same amount of purchasing power (adjusted for 10 years of inflation) - can buy a new Macintosh II microcomputer. The Macintosh handles 4 times the information at 16 times the speed, preprogrammed and reprogrammable memory are both about 20 times larger, disk storage is about 90 times larger, and the display has 7 times the resolution and 16 times the number of colours. Comparable figures could be cited for other brands of machines. Equally impressive, users' demands for this power have increased as rapidly as it has become available.

Over the next two decades, data processing and information systems will probably be replaced by sophisticated devices for knowledge creation, capture, transfer, and use. A similar evolution can be forecast for telecommunications: personal videorecorders, optical fiber networks, intelligent telephones, information utilities



such as videotex, and digital discs will change the nature of media.

Cognition Enhancers

The concept of "cognition enhancers" can help us understand how we can use these emerging technologies (Dede 1987b). A cognition enhancer combines the complementary strengths of a person and an information technology. Two categories of cognition enhancers will have considerable impact on the workplace: empowering environments and hypermedia.

Empowering Environments

Empowering environments enhance human accomplishment by a division of labor: the machine handles the routine mechanics of a task, while the person is immersed in its higher-order meanings. For example, I once took an oil painting course. My goal was to transfer my mental images to canvas so that viewers could share my experiences and emotions. However, rather than pondering form and composition and aesthetics, I had to spend my time trying to mix colors that remotely resembled my visualizations, trying to keep the paint from running all over the canvas, trying to keep the turpentine out of my hair. Now, I can use a graphics construction set to choose from a huge palette of colors; to alter, pixel by pixel, the contour of an image; to instantly "undo" my mistakes. Now I am involved with the creative aspects of art, while the empowering environment handles the mechanics. (However, my accomplishments as an artist are still ultimately limited by my own talents and knowledge.)

The workplace is adopting many empowering environments: databases for information management, spreadsheets for modeling, computer-aided design systems for manufacturing. And word processors with embedded spelling checkers, thesauruses, outliners, text analyzers, and graphic tools are driving the evolution of a new field: desktop publishing.

Hypermedia

Even with a sophisticated empowering environment for desktop publishing, I can still get writer's block. I can know everything I want to write yet not have my ideas in the linear "stream" required for written or oral communication. I need an "idea processor," a way of creating an external structure that mirrors the concepts and links in my memory. I need a second type of cognition enhancer: hypermedia.

Nations with technological expertise, an advanced industrial base, and an educated citizenry are developing economies that use sophisticated workers and information tools to create products tailored to individual consumer needs

Hypermedia is a framework for creating an interconnected, web-like representation of symbols (text, graphics, images, software codes) in the computer. This representation is similar to human long-term memory: people store information in networks of symbolic, temporal, and visual images related by association. For example, in my memory the word *apple* conjures up religious, corporate, computational, botanic, and gustatory associations.

With my knowledge externalized in a hypermedia system, I can traverse this network along alternative paths through nodes and links, seeking the right sequential stream for my intended content, audience, and goals. The computer allows me to avoid overload in transferring long-term to short-term memory. Also, my access to long-term memory may be enhanced by the process of building and using hypermedia.

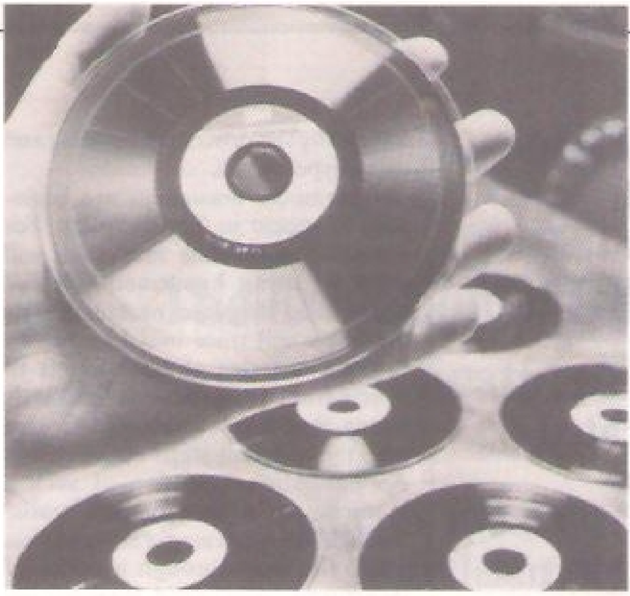
Hypermedia documents are beginning to appear in the workplace. For example, automobile mechanics will soon be using hypermedia repair manuals to diagnose problems. The mechanic will trace initial symptoms through a series of linked tests to reach final judgement on what is wrong, then follow a web of nodes that map the different steps of the repair. An educational version of such a manual would incorporate "trails" through the hypermedia network that guide the user through a series of structured, sequenced learning experiences.

The emergence of primitive hypermedia systems on personal computers is inspiring new ideas for their use. For example, a hypermedia version of this paper would place each fundamental concept in a separate node; links would tie related concepts together. Chunking and juxtaposing ideas in this way increases comprehension over the forced linearity of textual presentations. Perhaps different styles of remembering and learning will evolve!

Using cognition enhancers, however, requires more than learning how to activate the machine and issue commands; the style of working must change. For example, as a result of using a word processor, I can no longer write well with a paper and pencil. I used to compose a sentence by thinking for a couple of minutes and then setting down a near-final version, because making changes meant cutting and pasting; now, I think for half a minute and type in a sentence, think for another 15 seconds and make a change, make another change a few seconds later, and so on. Now I can concentrate on revision and polishing, without the pressure of having to create a finished product. However, when I try to write with a pencil using this new superior style - disaster! The eraser wears out long before the pencil needs sharpening. Most people who use cognition enhancers experience the same unconscious shift in style.

Shifts in Occupational Skills

In a world of empowering environments, the ways we accomplish tasks will alter. The global marketplace will drive this evolution; in this new



New technologies, like these erasable optical data disks, are changing the way we work and learn.

economic "ecology", each nation is seeking a specialized niche based on its financial, human, and natural resources. Developed countries, which no longer have easily available natural resources and cheap labor, cannot compete with developing nations in manufacturing industrial commodities (President's Commission on Industrial Competitiveness 1985). Instead, nations with technological expertise, an advanced industrial base, and an educated citizenry are developing economies that use sophisticated workers and information tools to create products tailored to individual consumer needs (Reich 1988). For example, we now try to match our stylistic preferences and the shape of our feet to the prepackaged shoes in a store; in a decade, a shoe store may have lasers to measure our feet, videodisc images from which to select styles and colors, and assembly machines to make customized shoes while we wait.

One way of understanding the impact of these changes on occupational skills is to contrast how information technology has changed the job roles of the supermarket checker and the typist. Many supermarkets now have bar code readers; rather than finding the price of each item and punching it into the register, the checker need only pass the good over the scanner. Efficiency and productivity have increased, and the job requires fewer skills.

In contrast, substituting a word processor/information network device for a typewriter completely alters a secretary's function. To use the information tool to its full capacity, the clerical role must shift from "keyboarding" to using database, desktop publishing, communications, and graphics applications. The job now demands higher-order cognitive skills to extract and tailor knowledge from the huge information capacity of the tool, and the occupational role shifts to the new profession of "information manager."

As workstations become more intelligent through embedded coaches and expert decision-aids, the thinking skills required of the human role in the partnership become more sophisticated. Creativity and flexibility become vital, because the standardized aspects of problem-solving skills are absorbed by the machine. However, technology is no panacea; over-automation and excessive reliance on assembly-line metaphors can deskill work and produce job dissatisfaction (Kraft 1987). Moreover, as the routine parts of the work are automated, a greater proportion of decisions will require stressful ethical choices.

Computers and people have complementary intellectual strengths; each can supply what the other lacks. However, the possible future described above is not meant to imply that this transformation of work will be inevitable or universal. On the contrary, advanced technology eliminates jobs as well as creating them; and, in an automated workplace, many of the occupations that survive may require only low-level skills (Rumberger 1987). In every developed nation, significant uncertainty exists about fundamental questions such as:

- How many jobs will be available in the early part of the next century?
- What will be the mix of skilled and unskilled positions?
- Will sufficient "middle class" occupations be available to prevent a polarization of wealth in society, or will most such jobs be deskilled by intelligent machines?
- How will these technological and economic shifts affect equity?

A reasonable assumption is that, during the next decade, developed countries' economies will evolve so as to generate some knowledge-added occupational roles and many lower-skill jobs. Eventually, however, if the majority of the population is to have interesting, well-paid work roles, educators must help shape the needs of the emerging workplace rather than merely respond to present trends (Levin and Rumberger 1987).

Implications for Curriculum Design and Content

As the American workplace begins to use intelligent devices, the goals, content, and the clients of education will alter (Office of Technology Assessment 1988a). The impact of knowledge bases on the content and design of the school curriculum will be profound. To illustrate, here are some potential effects of the widespread use

Three New NSBA Reports Available

Three new reports from the National School Boards Association may help educators make greater use of technology. Planning for Telecommunications: A School Leader's Primer gives an overview of technology used for "distance learning" in schools. On Line, Financing Strategies for Educational Technology explains ways that school districts can obtain funds to purchase and implement technology. Thinking about Technology in Schools: A 1988 Snapshot reports on a survey of 773 of the nation's largest school districts regarding their attitudes and experiences with technology. Single copies of the first two reports are $12; single copies of Thinking about Technology in Schools are $35. Available from NSBA's Institute for the Transfer of Technology to Education, 1680 Duke St., Alexandria, VA 22314.

As the workplace shifts to an emphasis on group task performance and problem solving, collaborative learning will become more important.

of cognition enhancers (Dede 1988b):

> Human strengths in partnerships between people and cognition enhancers include skills such as creativity, flexibility, decision making with incomplete data, complex pattern recognition, information evaluation/synthesis, and holistic thinking. These higher-order mental attributes might become our new definition of human intelligence, as basic cognitive skills increasingly shift to the tool's portion of the partnership.

- Methods of assessment will alter from measuring mastery of descriptive knowledge to evaluating attainment of higher-order skills. Developing technological methods for collecting and analyzing detailed performance data could greatly improve the assessment of individual learning needs (Office of Technology Assessment 1988b). For example, we could easily collect the exact hesitation time a student took before each problem-solving step in learning subtraction; this could be valuable diagnostic information.

- "Learning-while-doing" will become a more significant component of occupational education, as combined computer and telecommunications technologies allow delivery of instructional services in a decentralized manner. To allow credit for job-based learning, workers' tools may include intelligent devices that act as job performance aids while simultaneously collecting a cognitive audit trail of user skill improvements. For example, a student in a technical writing course could write all week at work on a word processor, then bring a record of his or her performance to class. The instructor could monitor how the student was writing by scanning his or her actions (deletions, revisions, resequencing), looking for patterns of suboptimal performance and evaluating the learner's writing process.[1]

- As the workplace shifts to an emphasis on group task performance and problem solving, collaborative learning will become more important. Information technology tools may increasingly be designed for use by teams rather than individuals working in isolation (Gorry et al. 1988), and new types of interpersonal skills will be needed for occupational roles in which computer-mediated communications is important (Kiesler et al. 1984). In such an economic environment, adults who lack sophisticated experiences in shared machine-enhanced interaction may be at a disadvantage (Reder and Schwab 1988). Students in conventional classroom settings have few opportunities to build skills of cooperation, compromise, and group decision making; shifts in teaching must occur so that computer-supported collaborative learning becomes a major type of student interaction.

Interlinked "educational information utilities" that supply access to a variety of data, tools, and training might emerge (Dede 1985). For example, a device may soon be marketed that combines the attributes of the telephone, radio, television, videotape, computer, copier, and printing press. If I heard an item of interest while watching the nightly news, pushing a function key could output articles on that topic from major newspapers. Scanning these might produce keywords of interest; another keystroke would trigger a knowledge base search. From the list of articles that resulted, I might identify the name of a researcher active in this field; yet another command could dial that person's work number. If no one answered, a final keystroke could send an electronic mail message. All this integration may seem merely a gain in speed, but from that perspective the airplane is "just" a faster version of the automobile. Such a device could be inexpensively accessible to a wide range of users, altering the curriculum by shifting emphasis from acquiring data to discussing and synthesizing ideas.

As discussed earlier, hypermedia would enable a long-standing instructional goal: an integrated curriculum. In a hypertextbook series, the math "book" would contain links to materials in social studies, biology, history, language arts, and physical education. The important interrelationships among different subject areas could be explicitly represented through concept maps; students could modify these webs of linkages to help them learn (Yankelovitch et al. 1985). The curriculum could shift from a subject-centred, disciplinary emphasis to a focus on real-world problem solving using perspectives and tools from multiple fields.

Using Tools Wisely

Some claim that technological advances are driving the emergence of a new era: industrial society is being replaced by a civilization based on

Computers and people have complementary intellectual strengths; each can supply what the other lacks.

knowledge processing. Others disagree that the industrial economy is ending but do see many occupational shifts as people implement new information technologies to aid in their work.

The implications for the school curriculum and instructional practice could be profound: a new definition of human intelligence, more sophisticated methods of assessment, decentralization of teaching into workplace settings, a greater emphasis on collaborative learning, a curricular shift from presenting data to evaluating and synthesizing ideas, a focus on solving real-world problems using concepts and skills from multiple subject areas. The most important barriers to this evolution will not be technical or economic but conceptual and organizational; and, unless controlled, the outcome of these changes may be undesirable. We must begin shaping the use of these emerging tools now if we are to have a bright educational future.

"Learning-while-doing" will become a more significant component of occupational education, as combined computer and telecommunications technologies allow delivery of instructional services in a decentralized manner.

[1]For the interested reader, I have written detailed, annotated scenarios of sophisticated "learning-while-doing" task performance aids: an intelligent tutor and coach (Dede 1987a) and a computer-supported cooperative learning environment (Dede 1988b).

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DAVID J. S. IBSEN

Cooperation and Education - Keys to Improving Access to Computerized Information

Abstracts in the ERIC database are a rich source of educational information. Improving access to ERIC and other sources of information in computer format can potentially increase educators productivity.

Cooperation and Education are key factors among several identified by Ibsen (1991) which affect access to information stored in computer format. In this article, these factors are discussed in relationship to improving access for Ngee Ann Polytechnic (NP) lecturers to the ERIC (Educational Resources Information Center in the USA) database.

The ERIC database has been chosen as the initial source of information in computer format because it contains a broad range of educational information which can easily be made available to lecturers at NP. The ERIC database "contains nearly 700,000 abstracts of documents and journal articles on educational research and practice" (ERIC, undated).

Before discussing how Cooperation and Education can improve access to ERIC, other factors mentioned by Ibsen will be considered briefly.

Other Factors

The following factors have a minor role in improving access to ERIC compared to Cooperation and Education (for a more extensive coverage of these factors as they relate to China, see Ibsen, 1991).

Physical conditions. Other than the installation of a campus wide computer network there is little or no need to improve physical conditions to improve access to ERIC.

Access to resources. NP lecturers can gain access to a computer and the ERIC database on CDROM in the library. Primary documents (full text) can be obtained through the NP library, inter-library loan, or ordered from the ERIC document reproduction service.

Language. Since NP lecturers speak and write English, they should have minimal natural language difficulty in accessing ERIC. They also have the ability to learn computer languages (software) needed to improve access to ERIC.

Change. Ngee Ann lecturers have been sufficiently exposed to technological and social change to be able to make the changes needed to improve access to ERIC.

Social organization. The basic social structures are in place at NP to facilitate the development of cooperative structures to improve access to ERIC.

Cooperation

Although pilot tests of the cooperative approach for improving access to ERIC have successfully been conducted in Canada and China, further development is needed before proposing widespread use of this approach. In this section, the development of the cooperative approach is discussed in relationship to the Educational Development Centre (EDC) facilitating improved access by NP lecturers to a narrow range topics contained in ERIC.

For the cooperative approach to be most effective, both formal and informal cooperation are needed. At NP there is an interest in sharing information on CBT (Computer Based Training) (informal cooperation). To facilitate this interest, cooperative structures need to be set up with the departments involved (formal cooperation). To initiate formal cooperation, the EDC in conjunction with the library would develop comprehensive search strategies on topics related to CBT. These strategies would be made available to departments and individual lecturers as a basis for their searches. Once a search has been analyzed, primary documents need to be found for selected items of interest. The Singapore online library system would be used to determine where documents could be found in Singapore or if they needed to be ordered from abroad.

To illustrate the cooperative approach to searching ERIC, let us assume that various groups would be interested in different aspects of a search on CBT as follows:

- The EDC would be interested in instructional strategies.

- The CBT Center would be interested in tools and techniques.
- The Mathematics and Sciences Center would be interested in math related uses.
- The library would be interested in software for student use.

Using search terms from a comprehensive search for information related to the use of computers in mathematics education, a cooperative search to meet the needs of the groups mentioned above would be conducted. Different parts of the search would be distributed to various members of the group for their analysis. Once analyses are completed, primary documents for selected abstracts would be obtained. As new information becomes available, updates to the search could be distributed to interested persons for analysis.

The cooperative approach for searching ERIC has the following advantages:

- One search serves the needs of several people.
- A more comprehensive coverage of a topic is possible through several people sharing in the analysis of a large search.
- People who would not normally search ERIC could be encouraged to join a cooperative search group.
- Duplication of effort, especially in searching and locating primary documents is reduced.

There are also disadvantages:

- Setting up and maintaining cooperative search networks takes time, effort, and coordination.
- Comprehensive cooperative searches are more difficult to conduct than individual searches.

The advantages of the cooperative approach to accessing information will be realized through education.

Education

In order to provide improved access to ERIC, both facilitators (librarians) and end users (lecturers) need further education and training. Librarians and other facilitators need to learn how to develop cooperative networks and conduct comprehensive searches. End users need to learn how to analyze information they receive and how to obtain primary documents for selected records. End users also need to become aware of the advantages of cooperative searching and learn to provide feedback to facilitators so that searches and cooperative systems can be improved to provide information which is most relevant to both the group and individuals within the group.

Educating facilitators and end users should pay dividends in improving access to information, which in turn should improve both group and individual productivity.

Conclusion

In considering the potential results of the cooperative approach to improving access to educational information, one needs to consider that cooperative networks developed to access the ERIC database can be expanded to improve access to information from other sources.

As mentioned earlier in this article, further development is needed before the cooperative approach to accessing ERIC can become a wide spread common practice. This development will be facilitated by Cooperation and Education.

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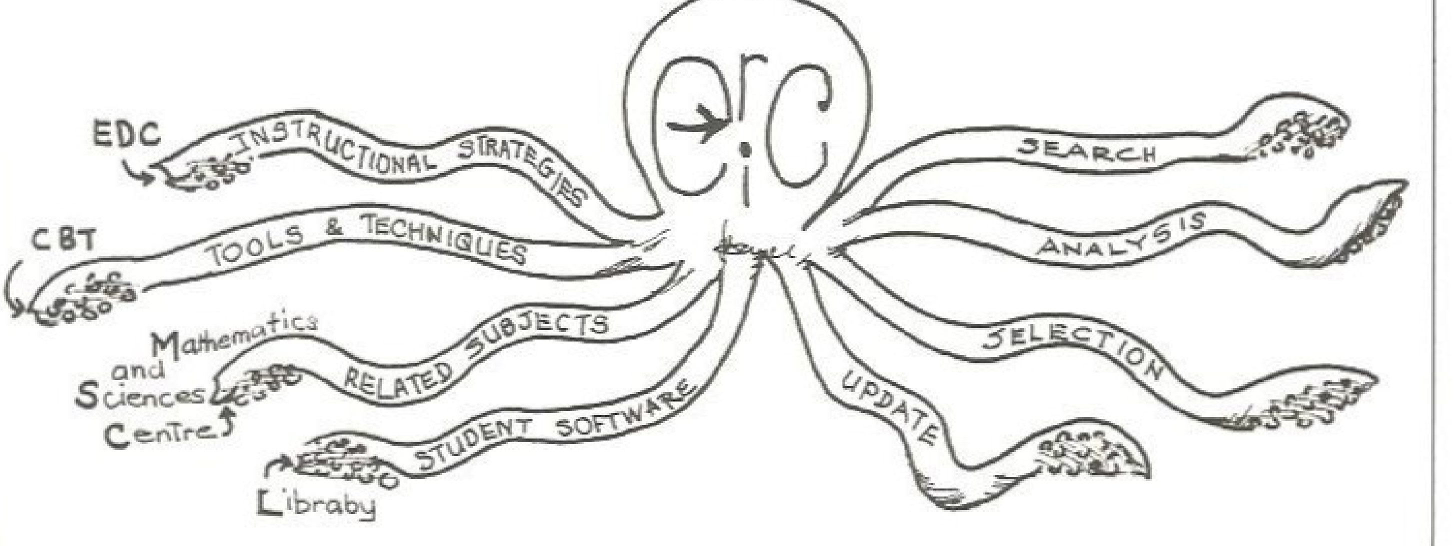

MARY LIM CHO KOEN

Information Technology - the Mayflower Way

In July 1990, Mayflower Primary School set up a computer laboratory with 12 Macintosh computers, donated mainly by the Singapore Totalisator Board (75%) and partly by the School Advisory Committee Fund (25%).

Staff participation features prominently in this set-up. The obvious reason is that they are the ones who will use the computers to teach our pupils. Hence, they tried out different models, chose the ones they considered most user-friendly and participated eagerly in courses and computer camps organised by the Ministry of Education.

The small group of teachers shared their expertise and learnt along with their equally small groups of enthusiastic pupils. Soon the number of teachers using computers to teach pupils increased rapidly - from 2 to 4 and then to 18. They taught their pupils word-processing and Hypercard. Another 19 teachers taught pupils *Hanyu Pinyin* using "Chinese Talk", a Chinese word-processing package.

Among pupils who benefitted were 13 Primary Five and Six camp leaders who were taught to log their thoughts and feelings about the 1990 School Camp using Hypercard, a software which could incorporate script, design and even scanned photographs. The professional touch lent to their finished product thrilled and stimulated other pupils to seek the same resource for their class and school publications.

Twelve computers did not quite measure up to the interest shown by 1686 pupils, all raring to go and use them. Fortunately the school won a 22-computer Apple MacLab on August 25, 1990 in a national competition. Primary 5 and 6 teachers made full use of this expanded facility to teach their pupils process writing to produce class and end-of-year school bulletins. The Chinese and Malay cultural club members used computers to publish their own "Cultures and Festivals of Singapore" and the rest of the teachers wasted no time to learn along with these pupils and their colleagues.

By January 1991, half a year after acquiring the computers, nearly all 62 teachers have had some training on the use of computer software (e.g. word processing, Hypercard) and about 20 knew how to use "Chinese Talk" to teach *Hanyu Pinyin*. However, the latter group of teachers, led by 3 pioneers, were not satisfied with how their Primary One and Two pupils were learning *Hanyu Pinyin* vocabulary in the class - typing them on the keyboard and matching them with the correct Chinese characters. They were impatient with the slow process and were frustrated by the number of pupils requiring assistance or a nod of approval for correct responses. They wanted more - how to excite and maintain their pupils' interest, to make them more independent, to enable the slower as well as the faster learners to benefit equally from a program that allows each child to learn at his/her own pace. As luck would have it, blessings came in the form of two computer salespersons who willingly gave some teachers a few free lessons on computer programming. However, as they were not professionally trained in computer programming, the teachers found the going tough. The next good samaritan came from the Institute of Systems Science of the National University of Singapore. This software engineer was looking around for a school to help, primarily to do research on how teachers and pupils acquire computer literacy. Mr Raymund Chan fitted snugly in our own search for computer programming skills. From March to June 1991, about 10-18 teachers spent long Saturday afternoons and most of the June vacation with him, learning programming and how to design simple computer games to teach pupils English, Mathematics and Chinese.

At the same time, 3 new Institute of Education (IE) graduates, led by their lecturer, Dr Philip Wong, also responded to our call for help. They had scored earlier successes in producing computer games for teaching as their IE projects. Armed with this knowledge, they collaborated with our teachers and produced 4 computer games to teach Primary One and Two pupils *Hanyu Pinyin* in an exciting, challenging and fun way. This collaborative effort took them only one June vacation to accomplish - a feat my teachers dared not dream of.

After 3 months of exploring and searching, our teachers have produced some tangible results they can be proud of - a Malay vocabulary computer game, 2 *Hanyu Pinyin* games they can call their own, an English vocabulary game and a mathematics number game. Though small in achievement, this feat will surely act as a stimulant for teachers to explore further information technology and to continue their search for solutions. This augurs well for both staff and pupils a Mayflower Primary prepares itself for the next decade.

Mary Lim Cho Koen is principal, Mayflower Primary School, Singapore.

KANNAPPA IYNKARAN

Using Computers to Enhance Learning

Thermodynamics and thermofluids are not easy subjects to understand and learn. Hence, to help students at the Mechanical Engineering Department of Ngee Ann Polytechnic learn these subjects, a team of Mechanical Engineering lecturers decided to include a computer-based component into their course.

The team devised a series of multiple-choice questions related to the syllabus and used this as a form of self-test for the students. Each student could book the use of a computer in the computer laboratories and, using the prescribed textbook, would work through the questions in the computer program. Some of the questions involved short computations whereas others were related to laboratory work. For example, the students were asked about safety aspects, measuring techniques and sources of errors, and they had to plot graphs and draw conclusions from simulated experiments.

Advantages

Students today enjoy working with computers and a computer-based program is student-centred. Computer-based programs enable the student to work individually at his/her own time and pace.

The computer program designed to teach thermodynamics and thermofluids has helped to reinforce the learning that takes place in the classroom, lecture theatres and laboratories. From the evaluation that was made of this new method of teaching the subject, student learning has definitely improved. The students are interested and they enjoy using the program. They find it challenging and this stimulates them to learn.

Developing the computer-based program

Perhaps the most important step in developing an efficient and effective program is the formulation of good questions. Designing objective-type questions is no easy task. The questions should require the students to think and not to merely regurgitate an answer. Of the four options provided, only one is the right answer. The three other options are incorrect. To make the program more effective, the team decided to include in these incorrect options, errors commonly made by students. Such a practice depends on the experience of the staff and the interactions they have had with the students. An experienced lecturer would be more familiar with the misconceptions of students and could suggest an appropriate response or remark to correct these misconceptions.

Provide feedback

When a student chooses a correct answer, the computer program should offer more than an acknowledgement that the answer is correct. It should provide additional comments designed to reinforce the student's understanding of the particular topic. Similarly, when the student chooses an incorrect option, there should be helpful comments indicating the nature of the error. The comments should also guide the student to work towards the correct solution.

If the questions are designed in such a way that the student can make easy reference to the prescribed textbook, this would further enhance the learning that takes place. The student acquires confidence as he/she is able to relate to the material which he/she is expected to study.

Help Screens

Some form of ready help must be made available to the students when they are working through the questions. Information might be presented on the help screens. However, caution must be taken in the design and use of these screens to ensure that the computer is not used as an electronic textbook. The help screens must be designed to enhance the understanding of the topic and colour, graphics and animation should be included, if and when necessary.

Conclusion

As students become more familiar with computers they will prefer to work on such programs. If computer-based testing could be implemented, teachers will be relieved of the tedium of marking of test papers. Such a program would benefit both teachers and students.

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ALAN M. LESGOLD

Preparing Children for A Computer-Rich World

Computer-literate students will be able to distinguish between the routine tasks from which computers can release them and more sophisticated capabilities - framing and solving problems, communicating visually and verbally - that are least likely to be automated.

Which computer should we buy? Which software should we buy? How can we incorporate the computer into the curriculum? These questions, and many more detailed questions about different brands of computers, printers, hard disks, and other pieces of hardware, keep arising whenever I talk to people who know that I am an instructional psychologist who also is heavily involved with computers. The same basic questions pop up whether I am talking to a principal or school superintendent planning for next year, a teacher wanting to be more creative and productive, a ministry of education official planning to introduce computers into the schools of an entire country, or my brother, who is worried about whether his daughter will be a full member of our increasingly computerized society. When I try to answer such questions, I think about three things:

- how massive use of computers will change the occupational roles available in our society,
- what that implies in terms of changes in the curriculum, and
- how the computer can be used to help bring about such changes.

How the Computer is Changing Society

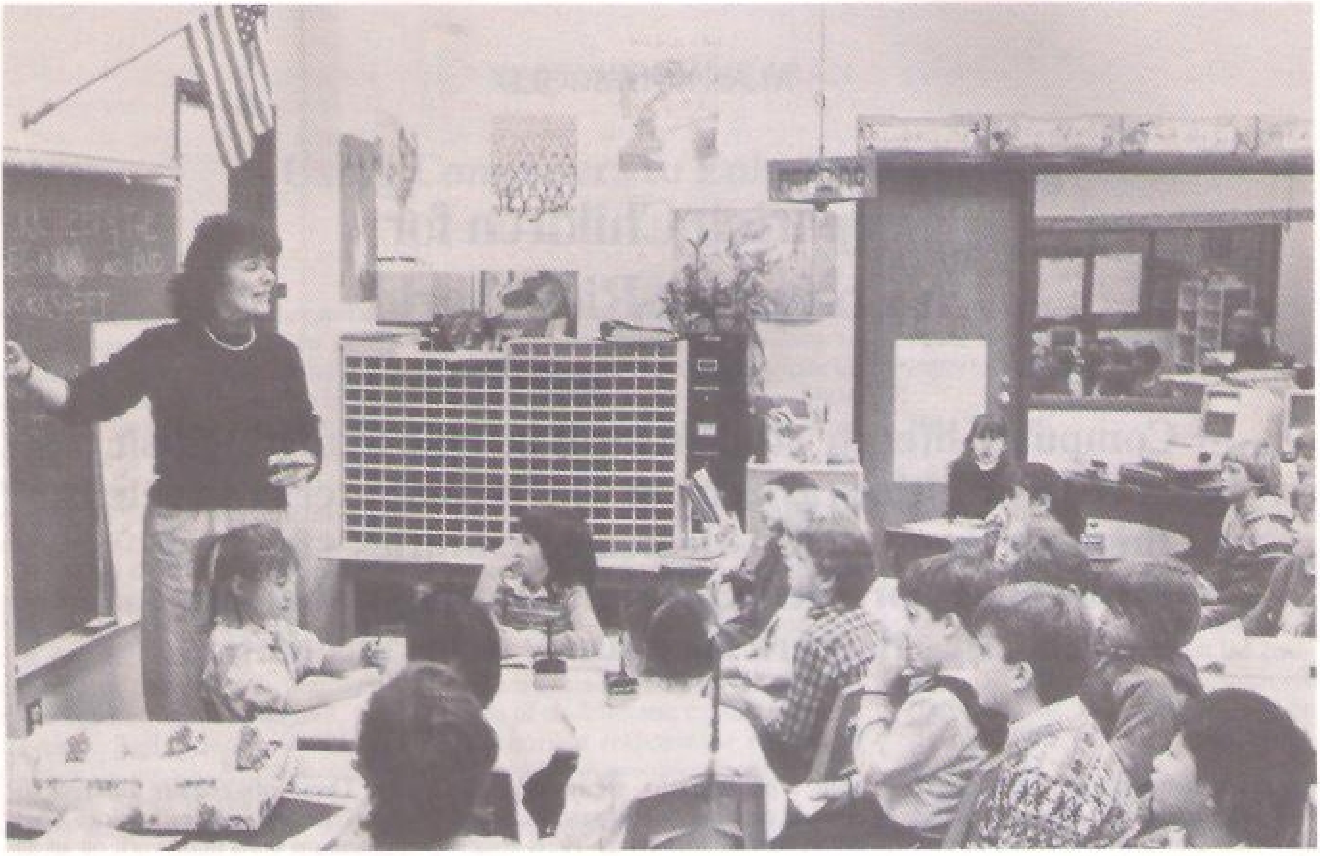
We have had major technological changes before. The invention of movable type and the steam engine brought changes as profound as those the computer will bring. Their long-term impact was to change the relative value of different skills. The key to surviving the transition from handwritten to printed books was not having the ability to read printed rather than handwritten words. Nor was the key to doing well in the Age of Steam the result of having played with a steam engine. Rather, doing well required having the skills to use the new technology to extend one's capability. To take advantage of cheaper books, one needed to be able to read with greater facility, since a book was no longer a rare object worthy of days of contemplation. To use steam engines, one had to understand mechanics, but it was much safer and easier to acquire that understanding from experimentation other than playing with steam engines.

Similarly, we can be pretty sure that certain skills will become more important in a computer-rich, automated society and others, less valuable. So far, the pattern has been to replace routine mental work with computers, enabling people to engage in more creative intellectual activity, including design and problem solving in many technical areas. An indirect effect is that automation is displacing more of the labor force from manufacturing jobs and moving them into service jobs. These jobs require different social skills and generally more communication skills than work on an assembly line requires.

Implications for New Curriculum

A cruel but useful caricature is that of the role the assembly line assigned to schools. Schools were supposed to

"Computer literacy" has little if anything to do with handling computers. It is, rather, a set of broad cognitive capabilities that allow one to think deeply, creatively, and efficiently and to communicate the results of that thinking.



At the University of Pittsburgh's Falk School, Leslie Thyberg leads students in discussions that precede their developing writing projects, using IBM PCjr's.

teach children to be on time, work according to a fixed schedule, obey orders, read and follow simple directions, and do simple arithmetic. In contrast, the computer era requires more complex schooling - good verbal and graphic communication skills and the ability to formally characterize and solve problems. This means that written composition skills are more important, along with the hard part of math and science, understanding and solving problems. While specific technical knowledge is needed in a computerized society, the specific facts and skills acquired today will be less important tomorrow. Thus, the curriculum must teach children to learn new information and skills efficiently. We can be pretty sure that the world of the future will be dominated by the person who is a "quick study".

The school day is already used up; some think it is too short for the existing curriculum, and it seems inappropriate to add new items to it. We do not want to exchange 20 minutes of reading for 20 minutes of learning skills. Instead, we must teach, in the context of existing subjects, learning and problem-solving skills, the skills of communication, and certain social skills. In a sense, "computer literacy" has little if anything to do with handling computers. It is, rather, a set of broad cognitive capabilities that allow one to think deeply, creatively, and efficiently and to communicate the results of that thinking.

Tools That Extend Thinking

Computers have two important roles in the classroom. First, they can be useful in teaching some of the skills needed for the computer era. They can provide instructional microworlds and minilaboratories within which students can carry out experiments. Second, they can help students tackle problems that are too big to be handled within the limits of human thinking. The best is yet to come in these areas, as artificial intelligence techniques start to be used, but in this article I am focusing on what is possible now.

Because schools use so many different kinds of computers and have so little money for software, few good programs are tailored to school needs. We can, however, consider the potential educational uses of software developed for the business market. The most pervasive use of personal computers, for example, is probably for word processing. A second major use is with spreadsheet programs, which help people explore alternative mathematical models easily. A third common use is probably with graph and chart programs that facilitate communication. In contrast to educational software, which is in its infancy, word processing, spreadsheet, and graphic programs are well developed, readily available, and cost-effective. All three types of software can be used in the schoolroom.

Word processing. Although we would like our children to be able to write better, many obstacles stand in the way of teaching effective writing. Teachers have too little time to read the scrawls of many students, and writing is so physically slow and tedious for some students that they are not able to generate texts substantial enough to build good writing skills. For the same reason, they are unlikely to revise what they have written, or even edit for typographic and syntactic errors. The total effort involved when a child

"The artificial intelligence tools we are developing ... will coach students in systematic learning skills that they can practice in microworld environments."

writes a composition and a teacher reads it is so high that facile interaction between teacher and student is difficult. The teacher's comments both on editing and content problems can swamp the student with too much simultaneous feedback. Having put forth so much effort to produce the composition, the student has little tolerance for correction.

Ready access to word processing, however, could give students much more practice in a skill that requires considerable practice. Teachers could read essays more quickly and thus be more productive. They could also respond to one or two issues at a time, and the student could then deal with the identified problem and print another copy of the text. Standard programs that highlight differences between the first and second computer file could be used to point out the student's changes and enable the teacher to reread the student's paper more quickly.

Even so, teaching writing skills remains a labor-intensive proposition. But tools now being developed can ease the teacher's problems considerably. One such tool is the spelling corrector, common in the business world. Students could use the spelling corrector as a tool, so that by the time they turned in a paper, it would have no spelling errors or typos. The teacher who wants students to become better at spelling, however, may prefer that spelling correction not be automatic.

It is possible to write software that simply points to lines in which spelling errors have been found, leaving part of the detection and editing to the student. We have developed such a capability (written in C for a VAX computer) for use in University of Pittsburgh remedial writing courses. Initially, it directs the student to two or three lines within which a spelling error has been detected. If the student cannot find the error, the program points to the specific line in which it is located. If necessary, it can highlight the misspelled word.

It is possible to go one step further and detect syntactical errors also. For this, schools need special software different from that of the business world. Employers assume that workers understand English grammar and can correct an error once it is pointed out. For many school children who do not understand all of English grammar, pointing out an error is not enough. They need special software that describes syntactical errors in language they can understand.

For example, a common error in student writing is the comma splice. In it, two independent clauses are connected with only a comma: *I got to school early, nobody was there.* Simply pointing out comma splice errors may not improve a student's performance, if the student does not seem to be forgetting to use a conjunction. When students are asked why they write sentences such as the one above, they usually answer that they were told that a sentence expresses a complete idea. They keep writing until they have put down the entire idea they had in mind. The comma may be put down because of another incorrect rule (or bug): "Insert a comma at those points in the sentence where you would pause if reading it." The most helpful feedback to the student would be to isolate the two clauses, point out that each of them is a complete idea, and talk about strategies for combining them grammatically. Simply saying that the *and* is missing may not help much.

This kind of responsiveness requires a form of syntactic analysis very different from grammar correction for the business world. The program must be smart enough to have a model of how a student generates such a sentence in the first place. This capability is becoming possible for the most common errors in remedial writing classes, but a complete system that can deal with all syntactical errors will not be ready for some time.

The hardest part of writing is getting a good set of ideas in the first place. Products (e.g. *Thinktank*) that facilitate outline construction are already available. These can be very useful. Some people might object that an outline can be written on a piece of paper as easily as on a computer. This is true only if you already know what you want to write about. If you are still formulating ideas, you may need to insert new entries between existing ones and move whole sections from one part of the outline to another. The special advantages of an outline processor are automatic numbering of entries, automatic indenting, and the ability to reprint the outline with or without different levels of detail. While these are all useful features, they are not essential. Children can use existing word processing equipment to develop outlines and plan essays.

As a college professor, I read quite a few student papers. I am struck by the number of students who have mastered spelling and syntax but who have not yet learned how to develop an argument clearly. It could be very useful to give students exercises in developing ideas for an essay using word processing software as a tool. Since some of my students have computers at home, I give them suggestions for developing essay assignments, such as those in Table 1. These can work quite well regardless of their word processing program. Simple text editors, *Bank Street Writer*, *WORD*, and *Wordstar* can all be used.

Of course, even better idea-development software will be available in the future. Researchers at the Xerox Palo Alto Center have already developed a product called *Notecards* that allows both word processing and graphics to be used on many small pieces of text, computer-screen equivalents of the note cards we sometimes use to prepare an article. Further it can indicate relationships between part of one note and another separate note. For example, one could indicate the evidence for an assertion by showing a relationship between that assertion on one note card and the evidence for it on another. One could even show relationships between text and graphics. For example, one can have a map of Florida on one card and show a relationship between a description of the Okefenokee Swamp on another card and the location of the swamp on the map. *Notecards* will even turn a set of notes into a first draft. Unfortunately, it will be a few years before most schools can afford the more powerful computers needed to run *Notebooks*.

Table 1: Suggestions for Preparing Written Assignments

- Start with an outline in which you list your main points.
- Under each main point, list arguments for and against that point.
- Evaluate the arguments for and against each main point and make a decision about whether to modify your point.
- Restate your evidence for and against each point to take account of any modifications.
- Reorder your points taking account of the evidence for and against each. Put points that rely on related evidence close together. Put points in a coherent order.
- Write the center of your essay, in which you present your assertions, present evidence for and against them, and critique them in light of the evidence.
- Write a conclusion that summarizes the supported thread of your argument.
- Write an introduction that states the issue being discussed and the kinds of points you make in the main part of your essay.

Spreadsheet and graphing programs. The spreadsheet is a system that allows data to be represented as a matrix. Various operations can be performed on selected columns of the data matrix to yield new figures. For example, if each row of the matrix represents sale figures for one month and the columns represent gross receipts and costs, the costs column can be subtracted from the receipts column to produce profit figures. Spreadsheet programs can compute summary statistics on columns, make correlations between columns, and graphically display single columns and inter-column relations.

A spreadsheet program can be very useful in science courses in which children conduct experiments, manipulate certain parameters to produce measurable outcomes. If the data are systematically kept in matrix form using a spreadsheet program, the student can examine and manipulate them. Consider a simple balance beam experiment. Suppose the student hangs different weights at different distances from the fulcrum and records all relevant data from every arrangement that balances. This means that each balanced situation will be represented by a row in the matrix, and the columns will correspond to the mass of the left weight, its distance from the fulcrum, the mass of the right weight, and its distance from the fulcrum. Once these figures are accumulated, the teacher can guide the student through some experimentation with the spreadsheet program. Do the two mass columns correlate? Do they produce an interesting scatterplot? What about the distance measures? What about comparing mass plus distance on the left with mass plus distance on the right? If there is still no clear pattern, you may want to add some of your own data to that gathered by the student. Finally, the student can be asked to compare the product of distance times mass on the left with the product of distance times mass from the right. This shows a clear pattern that makes sense when plotted.

In our own work at the Learning Research and Development Center, we are adding spreadsheet capability to a variety of exploratory microworlds, computer programs that simulate experiments such as that just described with the balance beam. For example, Valerie Shute has developed an economics microworld in which the student can vary income, preferences, price, and other parameters to project the effects on supply and demand. In Peter Reimann's optics world, the student can vary refraction index and lens curvature to observe their effect on a refracted light beam. The spreadsheets in these microworlds supply a "lab notebook" that supports systematic experimentation. The simulation microworlds themselves can probably be implemented for the larger computers already found in schools. The artificial intelligence tools we are developing (which require more powerful computers that schools won't have for another few years) will coach students in systematic learning skills that they can practice in microworld environments.

Programming. The simple low-level programming courses taught in schools today will not help students secure places in the work force. In the future, routine programming will be done automatically by the computers themselves. Already, several large corporations are eliminating their data processing departments in favour of massive database systems that can respond to questions in a form comparable to standard English. Consequently, if programming is to be taught in our schools, it must be for purposes other than vocational training.

The most important reason to be able to program is to put the computer to work for oneself. Thus, the products of programming exercises should probably be software that students will use later as tools in another course. Students use this approach at Stevens Institute of Technology. In their first year at Stevens students accumulate a tool kit of programs that they use in

Using the Computer to Prepare Future Teachers

In Ed302, Curriculum and Instruction at Allentown College of St. Francis de Sales, future teachers receive pragmatic instruction in using computers as an object of instruction, a manager of instruction, and an aid to instruction. The course, which focuses on lesson planning, teaching methodology, and micro-teaching, is designed to help future teachers learn in relatively short time how to use computers to produce highly useful teaching tools.

The Computer as Object of Instruction

Future teachers are introduced to the three most popular brands of computers being used in schools, the TRS-80, Apple, and IBM PC or PC compatible. Their first goal is to accomplish an ordinary task, the recording of grades and generation of report cards. Students are asked to create and print out a list of ten student names, ten grades, and an average for each. They receive a clear set of written instructions on how to perform each required step, beginning with turning the computer on and putting in disks. During the class period, each student sits at a separate terminal and follows along with the instructor, who explains exactly what to do.

The Computer as Manager of Instruction

In this section, students are introduced to **VisiCalc**, the electronic spreadsheet, which enables them to create a rollbook. They label the columns on the spreadsheet for recording grades for tests, class participation, and so on. Once the grades have been typed in, averages can be automatically calculated for each class member. The students' homework assignment is to give a relative weight for each grade, for instance, quizzes equal 20 percent of the final grade, essays 20 percent, tests 30 percent, and so on. The formula is edited to include separate multipliers for each column and can be used again by simply changing names and grades.

The Computer as Aid to Instruction

In this segment of the course, the future teachers learn how to generate written material using IBM's word processing package, **Writing Assistant.** With this software, students learn to center; check spelling; search, replace and move paragraphs. Again, they are given concise written instructions for completing each step. Their home assignment is to produce a one-page, multiple choice, short essay quiz that is then typed on a ditto master using a conventional typewriter and reproduced for each class member. Considering the difficulty of producing a letter-perfect ditto master, especially if one is not an ace typist, the object of this assignment is for students to see that a computer and printer are excellent aids for correcting and re-running ditto masters.

Students are also introduced to an authoring system using Radio Shack's **Quick Quiz,** which provides programmed test formats. Once all test questions and correct answers have been typed in, **Quick Quiz** produces an answer key.

As an aid in their own teaching training, the students are required to run tests on the effectiveness of selected teaching strategies, which they try out on their college peers in 15-minute teaching sessions. They first identify a few specific behavioral objectives to be addressed and prepare pretests and posttests using items criterion-referenced to these objectives. Following their teaching session, the test scores are tallied for each of the future teachers' "students," and grades are calculated for each objective. A hand analysis is then done to find significant differences in pre- and posttest scores for each objective. Finally, they again use **Visicalc** to perform the same analysis on the computer. Thus, these student teachers learn not only how to do a statistical analysis of their own performance, but they also learn firsthand the benefits of using a computer to carry out the same task.

- By Andrew Robert McGilvray, assistant professor and chair, Department of Education, Allentown College of St. Francis de Sales, Center Valley, PA 18034.

engineering courses, science courses and advanced mathematics courses. By structuring the curriculum this way, Stevens has ensured that students learn not only how to program but also when to program and why. Further, when they have to use the software they wrote a year earlier, students learn that, rather than just being a stodgy requirement of the instructor, good programming style benefits them.

The same approach could readily be taken in high school, with teams of students writing graphing and plotting programs, sorting programs, and data accumulation programs for use in later courses. As teachers become more facile with computers, they may use this approach outside mathematics and science to enable students to create outline development programs, word search programs, and programs to help study foreign language vocabulary. What is critical is not the exact program content but its usefulness to the student, providing a better rationale for computer use in the first place.

Developing Higher-Level Thinking and Learning

Standard computer software can help children become better at acquiring knowledge, solving problems, and communicating their ideas. Computers should be used as assistants to facilitate and extend learning and problem solving. When used this way, computers will certainly help children prepare for a high technology future by assisting them to develop those higher-level thinking and learning processes that are least likely to be automated into obsolescence and most likely to benefit from computers that extend human capabilities.

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HARLAN CLEVELAND

Educating Citizens and Leaders for an Information-Based Society

If schools are to help students process knowledge in a rapidly changing world, they must teach for breadth, values and a global perspective.

Education is the drivewheel of an informed society. Information, processed into knowledge and wisdom, has become our dominant resource in the United States. Consequently, the quality of our leadership both at home and abroad depends more than ever on our educational systems - on how demanding and relevant and continuous and broad and wise our learning is. The people and nations that don't learn to participate in an information-based society will be its peasants.

Yet, our formal systems of education haven't assimilated the new fact that more than half of all work is information work and that, as a consequence, the nature of the work for which we educate students is changing faster than ever. Such information work requires integrative thinking and a global perspective, precisely the kind of brainwork-in-breadth that most of our schools and colleges aren't yet set up to encourage.

A Skeptic's Predictions

The content of many, perhaps most, jobs a generation hence is unknowable today, as were the job descriptions for astronauts, nuclear physicists, ecologists, computer programmers, and data base managers a generation ago. But even a decade ago, the U.S. Department of Labor projected that two-thirds of 1974's kindergarten students would eventually fill jobs that did not then exist.

In earlier writings I have expressed skepticism of our ability to forecast the market for work. Do not, then suspend your own skepticism as I try, with an impressionist's broad brush, to picture the kinds of work that are bound to be especially valued in a future knowledge-rich society.

There will be more information and service and less production work. Farming, mining, and manufacturing already account for a good deal less than a quarter of the U.S. economy, and a lot of what is still counted as working with things is actually work on symbols, which is to say information work. The mechanized application of more and better and faster information, so greatly accelerated by the explosive marriage of computers and telecommunications, will keep on eating up routine and repetitive tasks. The jobs left for people to do will require more brainwork and skill in people-to-people relations, the uniquely human functions that machines can't handle. Work, and therefore education for work, will have to become less competitive and more organized around cooperation.

The market for education as a non-polluting leisure-time "consumer good" will grow. Already some union contracts grant workers time off for education; Italian metal workers, for example, are entitled by contract to 150 hours of education a year.

"Recurring education," the 1980's in-word for adult or continuing education, will create a growing proportion of the demand for higher education. Education for leadership in varying forms will be a growth industry, because the proportion of people who perform some leadership functions will continue to grow. Despite tenure systems and retirement benefits, people will move around even more than they do now - from place to place, function to function, and career to career.

More and more people will work at managing forms of international interdependence. International travel for work and leisure, along with the expansion of global telecommunications, will continue to spread, swelling the demand for people with training in cross-cultural communication.

First at Thinking Up New Things to Do

Will there be enough jobs to go around? No one knows with certainty, but there is no reason to doubt a continuation of the cheerful precedent Howard Bowen reported in the 1970s. "Two centuries of history have revealed no secular trend toward greater unemployment as technology advances." There is no finite amount of work that must be parceled out to a given number of workers. Work, along with capital, expands with our capacity to use new devices in new ways for new purposes. The United States did not get to be a great nation merely by improving the previous generation's practices. We got there, and can only stay there, by being the first to think up new things to do, such as linking computers to telecommunications. The numbers and quality of jobs will continue to be a function of men's and women's imaginative capacity to solve problems.

Real Problems are Interdisciplinary

Liberating human imagination for creative solutions to human problems has hardly been the strong suit of the U.S. educational system. Both students and school critics can sense that the vertical academic disciplines, built around clusters of related research methods, are not very helpful in solving most problems. Few, if any, real-world problems fit into the jurisdiction of any single academic department. As every urban resident knows, we have a great deal of specialized information about the city, but we seldom get it all together to make the city livable, efficient, safe, and clean. In agriculture, by contrast, university-based science combined with its delivery to the farms in every county created the miracle of U.S. food production.

Many of the university's interdisciplinary approaches in the past have been disappointing. A course on environmental issues may be taught by an evangelist less eager to train analysts than to recruit zealots. A workshop on a "problem" may ask a research contract for a government or corporate client who knows the answer and is looking for an academic rubber stamp. Even so, many students prefer courses that promise to cut across the vertical structures of method and help them construct homemade ways of thinking about the situation as a whole.

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The students' intuition may not be wrong. Yet they face a phalanx of opposition to their instinct that the vertical disciplines should be stirred together in problem-solving, purpose-related combinations. Access to authorship in academic journals, professional repute, and promotion and tenure are not achieved by having lunch with colleagues from other departments. For once, education's external critics and the academics agree: if the division and knowledge into manageable compartments enabled graduates to develop self-esteem and a decent living, why does the curriculum have to be changing, complicated, and controversial?

Doesn't the *new* knowledge environment place a higher premium on integrative thought? Won't we have to take a new look at systems that award higher credentials for wisdom than for mastering the narrowest slices of knowledge?

A Heavy Bias against Breadth

I suspect that a newborn baby knows from the start, by instinct, that everything is related to everything else. We are born with naturally integrative minds. Before a child is exposed to formal education, its curiosity is all-embracing. The child hasn't yet been told about the parts, so is interested in the whole.

Ironically, the more the child learns, the less her or his learning is tied together. Most holistic learning comes in grades K-4 when the teacher often has to be able to answer the question "Why?" Farther up the ladder of formal schooling, we manage to persuade most children that the really important questions start with "When?" and "Where?" and "How?" and especially "How much?" Fortunately for the nation and the world, some young citizens persist in asking "Why?"

Jasmina Wellinghoff, a Twin Cities scientist and writer, writes about her 1st grader.

> When my six-year-old learns that we heat the house with forced air, she immediately wants to know who is forcing the air, where natural gas comes from, and how it got stuck underground. After I have done my best to explain all this, comes the next question: "If we didn't have natural gas, would we die in the winter?" There you have it. Geology, engineering, physics and biology, all together in a hierarchy of concepts and facts. However, a few years from now, my daughter will be studying the structure of the earth's crust, combustion, hydraulics, and the classification of living things - all in different years and quarters, neatly separated, tested and graded.

Everyone seems to know that in the real world, all the major problems are interdisciplinary and all the solutions are interdepartmental, interprofessional, interdependent, and international. Yet our institutions cling to a heavy bias against breadth, for at times they have found the bias useful: the secret of success in the scientific revolution was not breadth but specialized depth. Chopping up the study of physical reality into vertically sliced puzzles, each to be deciphered separately by a different analytical chain of reasoning (as a discipline), made possible the division of specialization and of labor.

These simplifications have led to complexity, just as E.B. White thought they would when he asked,"Have you ever considered how complicated things can get, what with one thing leading to another?" The resulting complexity now makes it imperative that these differing analytical systems be cross-related in interdisciplinary thinking and coordinated action, and to do that, leaders must get used to thinking integratively.

The trouble is that our whole educational system is geared more to categorizing and analyzing patches of knowledge than to threading them together. It would be nice if, having noticed this problem, we could discover a simple solution. The clashes between training and education, between honing the mind and nourishing the soul that divide outside critics also divide professional educators; they even divide students.

Just now, our favorite way to avoid having to make difficult choices is to delegate them to individual students. We "maximize the student's options"

What we need now is a theory of general education that is relevant to life and to work based on the new information resource.

by creating a bewildering proliferation of courses and programs of study, a cafeteria of the intellect using what the food service people call the "scramble system." For the limited numbers of students who know just what they want and why, the freedom doesn't work badly, but most students expect some guidance in creating an intellectually complete array of reading, discussion, writing, computing, and work experience.

My guess is that if U.S. schools and colleges continue to proliferate courses, external pressure groups and state and federal governments will sooner or later impose social and economic, even political, criteria for curriculum-building. If our ultimate curricular principle is abdication-by-providing-maximum-options, the outsiders will, in the end, tell the academics what to teach and the students what they can learn at the public's expense.

Neither Horn, Thank you

The curriculum debate, as usual, will not be settled by choosing one or the other of a dilemma's horns. Honing the mind and nourishing the soul are equally important. What we need now is a theory of general education that is relevant to life and to work based on the new information resource. Perhaps, in the alternating current of general and job-oriented education, it is time for a new synthesis, a new "core curriculum," a central idea about what every educated person should know, and have, and try to be.

Such a core is not going to have much to do with learning facts. Most of the facts that children learn in schools are unlikely to be true for as long as they can remember them. (The last time I took physics, I was told that the atom couldn't be split - a fact that has not served me well in the nuclear era.) What students need above all is general theory with which they can process the shifting facts they will encounter over a lifetime.

If we think hard about what the new knowledge environment requires, and consult the instincts and perceptions of our own future-oriented students, I think we could construct a new core curriculum for American citizenship from goals such as these.

Integrative brainwork - the capacity to synthesize the analytical methods and insights of conventional academic disciplines so as to solve real-world problems. Exposure to basic science and mathematics, to elementary systems analysis, and to what a computer can and cannot do are part, but only a part, of this education.

Social knowledge - education about public purposes, the costs and benefits of openness, and the ethics of citizenship. Such knowledge should enable the educated person to answer two questions: "Apart from the fact that I am expected to do this, is this an action I would choose?" and "Does the validity of this action depend on its secrecy?"

A capacity for self-analysis - the achievement of some fluency in answering the question "Who am I?" through the study of ethnic heritage, religion and philosophy, art, and literature.

Practice in real-world negotiation, in the psychology of consultation, and the nature of leadership.

A global perspective - an attitude of personal responsibility for general outcomes, in an interdependent world.

I would like to conclude with a few words about the last of these new imperatives for American citizenship. In the mid-1970s "global perspectives in education" was novel enough to sound radical, but change has become so rapid in our society that by the mid-1980s, the idea has flowed into the mainstream of a powerful public school reform movement.

I do not mean that the elementary school teacher, that very model of a modern generalist, should teach about everything at once. I am not neurotic about global perspectives, merely insistent. I do believe that young children can learn to think in systems. They live with interdependence every day - in families, home rooms, and in the local public park. The ambience of mutual dependence, the ambiguities of personal relations, the conflicting ambitions of groups, are the stuff of socialization from their earliest years.

Once they know how to think about value questions in their everyday life, they are more than halfway to coping with complex planetary puzzles, such as food production, climate change, energy use, population planning, development strategy, environmental protection, ocean law, trade, investment, and money.

In short, once the child can follow cause and effect around the corner, the child-grown-up should be able to follow cause and effect around the world. And with that kind of education for wisdom, the child-become-adult-leader can tackle with less diffidence the Cheshire cat's first question: "Where do you want to get to?"

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ALEX MOLNAR

Common Sense About Information and Information Technology

Before we become slaves of the Information Age and its complex technology, we need to ask ourselves not how much information we can generate and absorb, but what information is of most worth and for what purposes.

In his book, *The Knowledge Executive,* Harlan Cleveland (1985) quotes Gertrude Stein: "Everybody gets so much information all day long that they lose their common sense." Stein has put her finger on the heart of an increasingly difficult problem for educators: how to make sense of and respond to the increasing volume of information available to them. This problem has both policy and curriculum and instruction aspects.

Schools are subject to laws and regulations governing the information they may gather, the people about whom they may collect information, the circumstances under which information of various types may be gathered, and who may have access to that information. The increased attention given to the information institutions may gather and who may see it reflects a growing recognition that in modern mass society information may shape destiny, both individual and social, more than at any other time in human history. Social power is often created or affirmed by the nature of the information possessed by an institution or an individual. Although few educators would be likely to quarrel with the dictum that "knowledge is power," many might be uncomfortable taking a hard look at how schools as institutions establish and maintain institutional power relationships by controlling information. To an important degree, the difference between a teacher and a principal, a superintendent and a curriculum coordinator, a student and a teacher, a school psychologist and a parent is the difference in *which* information they are given and *when* they are allowed to have it. Schools, as other institutions, maintain the status quo in part by maintaining a particular pattern of information exchange. Any change in that pattern threatens the status quo. The Buckley Amendment, for example, which granted students and parents access to information that might previously have been kept from them, disrupted the standard patterns of information exchange in and outside of schools and precipitated serious reconsideration of the nature of information that schools should collect.

Internally, the collection of some information (e.g. anecdotal records of student behavior) and not other information (e.g. the teaching styles each teacher uses to greatest effect) helps to shape the nature and direction of the school's educational program and both shapes and reflects the school's instructional priorities. Decisions about which information is offered to parents, or has to be requested reveal a school's definition of the nature of its relationship with parents and the school's conception of their proper role in school affairs. The mechanisms through which the various units of a school or school system and the community receive information from and about each other reveal a good deal about the assumptions and power relationships that shape that school system. It is in the nature of information gathering, processing, and disseminating that decisions reflect the functional value orientation of the school system.

Given the importance of the topic, a principal research task facing educators is the analysis of what information educational institutions gather, how it is gathered, and what is done with it after it is gathered. The data derived from such investigations could then be used by schools and school systems to help formulate specific information policies based on explicit values.

The Sociology of Information

Information and information technology pose two types of curriculum and instruction problems. The first type of problem concerns what might be described as the sociology of information. This refers to the role of information, information technology, and the use of information in society. Curricular topics in the study of the sociology of information would include the role of government and private institutions in creating, processing, and disseminating information; the political and social implications of alternative information policies; and the merits of different information policies. The sociology of information is an important area to study because the information policy issues involve scientific, social welfare and foreign policy matters as well as the fundamental relationship of the government to the governed. For example, the question of whether a given policy encourages the concentration of information in the hands of a few or makes information widely available is of primary importance to democratic governance.

The laws and policies regulating information will increasingly affect the lives of all citizens. There are plenty of important questions to be answered. Should the Internal Revenue Service be able to share the information in its computers with other governmental agencies? Does the First Amendment protect the right of scholars to present their findings at international scientific meetings? Do citizens have the right to know all of the information gathered about them, the purpose for which it was gathered, and who has access to it? It seems reasonable to argue that schools should attempt to graduate students reasonably familiar with the public policy issues posed by information and information technologies.

The Technology of Information

Schools have been primarily concerned with a second area: computers as an important technological phenomenon that students should know about and have the skills to use, computers as an instructional aid in various content areas, and computers as a mechanism for structuring instruction and curriculum. However, after an initial burst of enthusiasm, educators have begun to awake to the difficulty of meaningfully integrating computers into a school curriculum and instruction program. Not all software is good. Computers do many things less well than teachers. Some students can be bored by computer literacy classes as they are with social science or science. Educators have, on occasion, even been known to refer to microcomputers as a technology in search of an application. Clearly the blush is off the rose.

After an initial burst of enthusiasm, educators have begun to awake to the difficulty of meaningfully integrating computers into a school curriculum and instruction program.

Educators can formulate a number of curriculum and instruction questions to think critically about the place of information technology in their school programs. For example:

1. As a result of participating in this program, will students have a critical understanding of the potential political, economic, and social significance of information policy decisions?
2. Is the curriculum designed to help students evaluate both the technical adequacy of computer programs and the value of what the programs are designed to do?
3. Does the program include an analysis of the vocational developments in information technology; for example, what jobs have been created, in what numbers, and at what status and salary?

It would be a missed opportunity if school programs contributed little more than an appreciation for the dazzle of technology without helping students learn to take it in hand and make it their own. Surely few would want the computers to go the way of the television set, an artifact of a magnificent technology that is largely used for banal and uncritical purposes.

If computers don't go the way of the TV set, are they likely to go the way of the language laboratory instead? Probably not. They play an increasingly fundamental role in too many aspects of society. It does seem clear, however, that with regard to information technology, as with every other aspect of the school curriculum, educators who fail to design curriculum that is meaningful and useful to their students are likely to face apathy or rebellion. In assessing how to treat information technology in the curriculum, therefore, the first question to raise is not,"Can it be done?" but instead, "Is it worth doing?" Although the technology may be new, the fundamental question is not.

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LOW GUAT TIN

Education in the year 2000

Let's take a peep at the school of the future

What will schools in Singapore be like in the year 2000? What will classrooms look like then? How will teachers conduct their lessons in the year 2000? Indeed, what constitutes schooling in the year 2000? There were a few of the questions we had in mind when students in the Further Professional Diploma of Education class sent out a delphi survey to members of the public, asking panel members to select the most probable trends in a specified areas of education in the year 2000. Returns from the survey offer interesting insights into the future of schooling. Get into a time machine with me and transport ourselves to the year 2000.

A Peep into a Classroom

Students go to subject resource rooms which are filled with all the latest equipment. Each resource room has a smart lectern through which the teacher orchestrates graphics, animation and sound to produce life-life images. A PC attached to the lectern enables the teacher to conduct lessons and communicate with his students through an electronic blackboard and an intelligent audio-visual system. This system also enables students who are absent (e.g. due to illness) to key in to the lesson at home.

Every school is equipped with interactive multi-media systems and students communicate with one another via the inter-classroom video. Classes are crammed not only with computer terminals for computer-based learning but also features like a key pad for students to communicate with teachers.

The hub of the school is the nerve centre - a place to access information, to consult, plan, teach and learn. The nerve centre provides the intellectual and physical access to materials in a variety of formats, instruction and resources. There are computers, a large screen monitor for viewing instructional videos as wll as laser disc players to allow instantaneous selection of research information. This centre extends the teaching and learning environment beyond the walls of the school. The world is brought into the classroom to broaden the scope of the students' intellectual, spiritual and social development. This is made possible through satellite antennas which enable students to tap into educational resources worldwide. In the year 2000, this is a necessity, not a luxury, for students need this instantaneous exchange of information to keep up with the rapid developments occuring in the world.

Schools

Schools are linked to educational institutions in other parts of the world through all kinds of network. By keying in their ID numbers, students can communicate with peers elsewhere. This international computer link-up enables students to access the latest information and to communicate with peers on issues that matter

to them. Indeed, through this link-up, students become part of a global classroom; each student is an international student with 'teachers' from many parts of the world. For example, students could watch and listen to a teacher in Kenya talking about wildlife. At the next, they could discuss with American students on the protection of wildlife or with Hong Kong students on how to stamp out the ivory trade.

Libraries are no longer stacked with books - instead, there are thousands of diskettes, video discs and computer terminals to access information. Electronic networks enable students and teachers to tap into huge databases located in different parts of the world.

Students no longer carry backpacks or heavy school bags. They come to school carrying a notebook PC - the size of an A4 sheet of paper - which is then plugged into the school's network. From the network, they can access learning materials which have been stored electronically. A few strokes of the keyboard allow students to search for learning materials using appropriate keywords. The learning materials are not just text, but include video clips, sound, slides and films. School work is done entirely on diskettes, with expert systems marking and grading the students' work. The student's progress is automatically recorded in his personal electronic file, accessible by parents and teachers. With the automation of most of the mundane tasks, teachers can now concentrate on facilitating learning and identifying students who need help. One-to-one tutoring has finally arrived!

Schooling in the year 2000 is both exciting and challenging ... and we must seriously reconsider our present curriculum and ask ourselves whether or not we are equipping students for such a world.

Home

With the latest Home Education Centre, homes is now extensively linked to a vast array of computer resources. Parents can now monitor their children's progress in school as the School Link extends to a Home Link network. Part of the learning can now be done in the comfort of the home. Students can communicate to their academic mentors (not necessarily their school teachers) by videophones. Homework is sent to teachers and academic mentors electronically, graded and returned, also electronically. With the rapid obsolescence of knowledge, even adults will need to keep on learning new things and skills. Schooling is totally different from that of the early 90s. A vast array of courses - ranging from academic pursuits to skills training - is available on the Home Education Centre through the Electronic University. With the constant demand for new knowledge and skills by employers, everyone strives to upgrade himself continuously. No longer is a university degree sufficient to see one through his career.

Conclusion

This is a scenario of what the future could hold for us and our students given the rapid pace at which technology is advancing. Schooling in the year 2000 is both exciting and challenging, and as teachers, we must be prepared for it. We must seriously reconsider our present curriculum and ask ourselves whether or not we are equipping students for such a world. Can we inculcate skills that can endure the rapid technological changes? That is a challenge to teachers as we approach the year 2000.

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LEONG WING FATT

When Leadership becomes Transformational

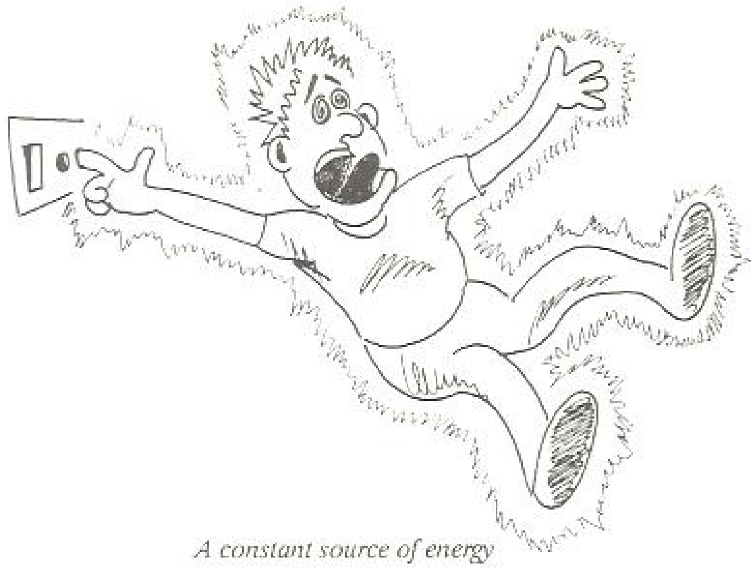
The central role that school leadership plays in making a school exemplary is no longer in serious dispute. What is still not so certain is how an effective or exemplary school benefits from the kind of leadership that it has. What may be the nature of the kind of leadership that contributes toward making a school excellent? Personal characteristics of the principal and/or the way she behaves toward the staff are factors that have been known to make a difference, and indeed have been used as important dimensions for guiding theory, practice and assessment in the field of leadership. While these various factors certainly do have merit in enhancing the quality of leadership, it is now believed that a more important factor is probably what Burns (1978) had referred to as a *transforming relationship* between a leader and her followers. Leadership that is based on a transforming relationship has been called by different names such as, transforming leadership (Burns 1979), transformative leadership (Bennis, 1984), transformational leadership (Bass, 1985), and value-added leadership (Sergiovanni, 1990).

Leading and Managing

Transformational leadership can best be understood by first making a distinction between *leading* and what is usually regarded as *managing*. Selznic (1957, 24) had drawn attention to the observation that leadership "may or may not be engaged in by those who are formally in positions of authority". Since a school principal is occupying a position of authority, she too may or may not be engaged in leading, even as she is expected to manage. To help in understanding the

manager-leader distinction better, Zaleznik (1977) stressed that leaders attract strong feelings of identity, love and even hate whereas managers maintain the balance of operations. In an organisation, the designated leader may just exercise headship by simply serving a representative function. In a study of eighty chief executive officers, Bennis (1984) reported that the successful, "innovative" leaders among them saw themselves as leaders and not managers in which the former was concerned with "doing the right thing" and the latter with "doing things right". Finally, Burn's (1978) eloquent essay on leadership urged that if we can distinguish leaders from mere power holders, then we can hope to have a sound understanding of leadership.

This distinction between leading and managing is not merely academic but can be observed in practice where in most organisations, it is true to say that there is more managing going on than leading. For example speaking of US industries, Kotter(1990,103) pointed out that "Most US corporations today are overmanaged and underled". The same can possibly be said of school leadership. Given such a situation, it is proposed that transforming leadership is associated more with leading and less, if any, with managing. Managing, in fact, might more closely be associated with what Burns(1987,4) also identified as *transactional leadership*. According to Burns, "The relations of most leaders and followers are transactional". Bass(1985,229) perhaps put it most succinctly when he pointed out that "managers displayed transactional leadership...leaders, transformational leadership". Essentially then, school principals who are formally in a position of authority, may be expected to behave more commonly as managers and less commonly as leaders, except perhaps those who can be both transformational as well as transactional. There is actually some evidence now that some of the more effective school principals in Singapore do engage in both transactional as well as transformational leader behaviours. A research report being written at the Institute of Education contains some preliminary result of a study into the nature of transactional and transformational leadership behaviour of school principals in effective schools.



A constant source of energy

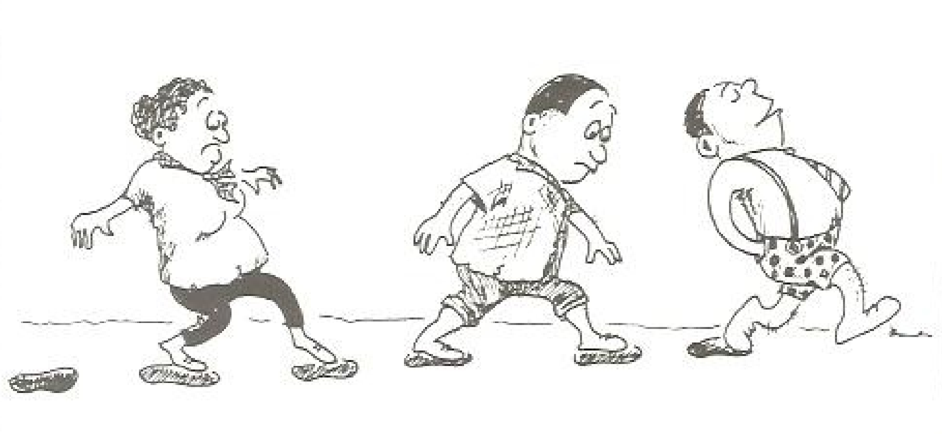
The Nature of Transformational Leadership

Bennis(1984,70) summed up the nature of transformational leadership when he said that "it is the ability of the leader to reach the souls of others in a fashion which raises human consciousness, builds meanings, and inspires human intent...". Where transformational leadership exists there will be a shared sense of purpose among organisational members. There will be an enmeshing of the goals and values of both the leader and her followers. They share common norms and have linked power bases that serve as mutual support for their common purposes.

A transformational leader generates excitement in the workplace and is a constant source of energy for others. She attracts strong feelings from her followers forming deep emotional attachment and identity. The followers are proud to be associated with such a leader whom they trust and who serves as their symbol of success and achievement.

Under a transformational leader, followers feel elevated by the leader-follower relationship, resulting in heightened effort from them. Actually the relationship is one of mutual stimulation and elevation that lead to higher order changes and "ultimately becomes *moral* in that it raises the level of human conduct and ethical aspiration of both leader and led". (Burns 1978,20).

We speak of followers instead of subordinates whenever people become transformed and are motivated to do more than they originally expected to do. Additional effort becomes evident as there is developed in the followers an upward shift in their level of need



toward self-direction and self-actualization. An important characteristic of such followers is that they are capable of transcending their own immediate self-interests for the good of the organization. They will consider taking greater risks as their interest grows in developing themselves to reach for higher standards and higher level goals. Instead of adjusting to situational constraints, this kind of leadership is capable of changing situations and creating new circumstances if necessary. Transformational leaders are perfectly capable of "turning around failing situations...and turning ordinary situations into extraordinary ones" (Sergiovanni 1990,3). A transformed organisation results from this kind of leadership which through complete involvement and the meanings and images that it provides, inspires and creates followers who are also leaders.

The Nature of Transactional Leadership

It has been traditional to see leadership in terms of getting subordinates to meet job demands through the use of rewards and punishments. Leadership here is seen as an exchange process, "a transaction in which followers' needs are met if their performance measures up to their explicit or implicit contracts with their 'leader'" (Bass 1985,27). A transactional leader clarifies with her subordinates what is expected of them and what they will receive in exchange for satisfying expectations. The relationship between the leader and subordinates is "characterized by bargaining and consensus about benefits in exchange for compliance. Subordinates are motivated by an exchange of valued things and managers approach subordinates with an eye to trade one thing for another. Such transactions eventually consist of mutual promises, obligations and expectations, augmented by reciprocal support and rewards.

There is much focus on processes as opposed to substance. Much time is devoted to the "nuts and bolts" of the enterprise, and much concern is given to "doing things right". Managers are bent on bringing a degree of order and consistency to the key areas of the organisation. So they concentrate on what will clearly work and do what seems to be most efficient and free of risk. Keeping to time constraints and ever mindful of all other organisational limitations, they focus on how best to maintain and keep the system running. Transactional leaders will react to problems and modify conditions only as needed.

By paying attention to maintaining and achieving results that are expected or contracted, transactional leadership can only hope to obtain marginal increase in subordinate performance and job satisfaction. What is obtained is immediate, short-term satisfaction and not long-term positive effectiveness. By concentrating on current needs and self-interests, lower level changes result and a purely transactional leader does no more than maximizing short-term gains and bringing about lower level changes in the organisation.

Both Types Are Needed

Although we have made a distinction here between transactional and transformational leadership, an organisation really needs both types of leadership and a leader can indeed be both. It is useful to think about transactional leadership and transformational leadership as two different *levels* of engagement between persons in a leader-follower relationship. Leadership that is transactional may be viewed as functioning at a lower level of motivation and subordinate performance while leadership that is transforming may be associated with higher levels of motivation and followership. The idea similar to one suggested by Sergiovanni is that first transactional leadership must be present before any "value" can be added to it to get transformational leadership. This view also corresponds with observations that transactional type behaviours make up the bulk of a manager's attempt at leading. When on occasion leadership that is transformational emerges, "motives, values, and goals of leader and led have merged" (Burns 1978,21) to mutually stimulate and elevate one another to higher order achievement. Avolio and Bass (1988,7) emphasized the importance of using transactional leadership as a base "with the truly effective leader using transformative leadership on top of transactional leadership". Specifically when the focus shifts from largely extrinsic motives and needs to higher level intrinsic motives and needs, a transactional leader whom we earlier referred to as a "manager" will become transformative. In fact, by becoming transformative, leadership itself is transformed to a higher *level* of the "social influence process", with its concerns for task and relationships, that characterizes what we normally understand as "leadership". Leadership then "transcends" instead of just "directs".

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GRANT WIGGINS

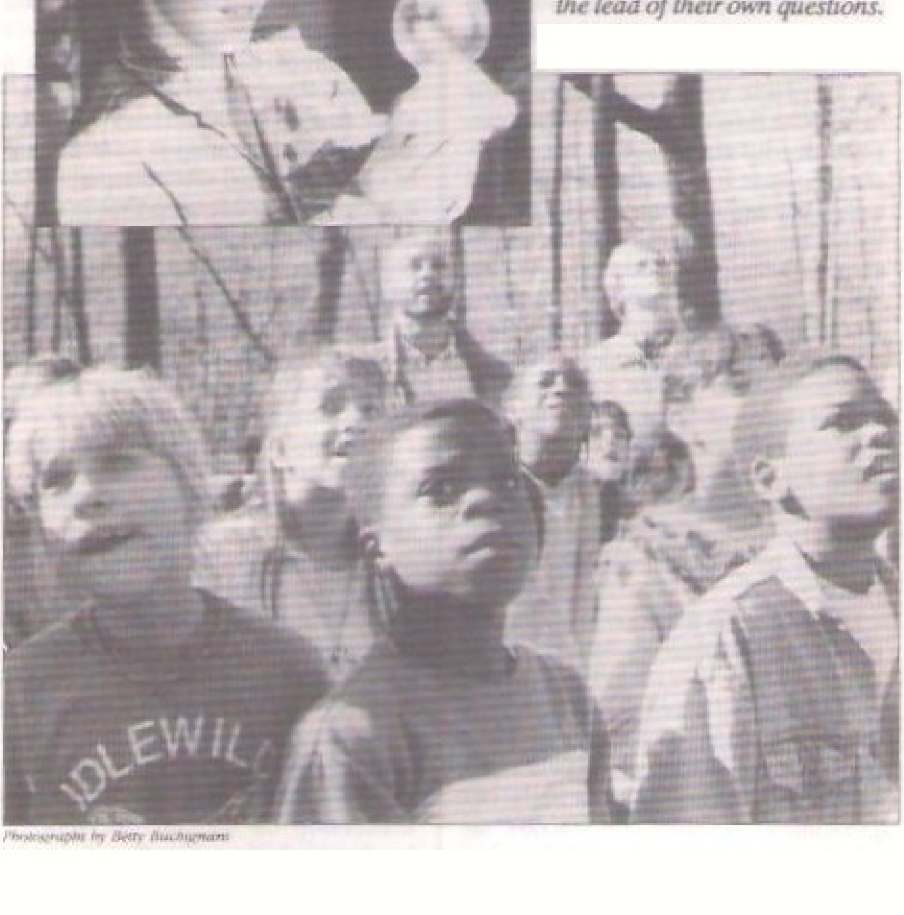
The Futility of Trying to Teach Everything of Importance

Students cannot possibly learn everything of value by the time they leave school, but we can instill in them the desire to keep questioning throughout their lives.

The aim of precollegiate education is not to eliminate ignorance. The view that everything of importance can be thoughtfully learned by the 12th grade - notice I did not say "taught" - is a delusion. Those who would treat schooling as designed to educate students on all important subjects are doomed to encounter the futility that faced Sisyphus: the boulder of "essential content" can only come thundering down the (growing) hill of knowledge.

By now, you may have read the articles in this issue (*Educational Leadership, Nov 1989*) describing the many things students should know but do not know. I, too, have been dismayed that some students don't know where Mexico is or how to read a timetable, never mind solve an algebra problem with two variables. But, oh, how we forget our earlier and current ignorance[1]. How easy it is to feel indignant when some student doesn't know what *we* know. But somewhere out there, in this highly specialized world, is a well-educated adult who also neither knows it nor deems it essential.

Developing in students a love of discovery - whether alone observing a radiometer or in a group following the flight of a hawk - should be our aim. To do so, however, teachers and students must have the intellectual freedom to follow the lead of their own questions.



Photographs by Betty [illegible]

From a Medieval View of Curriculum

The irony of the fuss about student ignorance is that the *causes* of such ignorance are never adequately explored. To gain insight into the causes, we need only look at any textbook. Teaching has been reduced to the written equivalent of TV news sound bites - in part, because so many groups lobby hard for inclusion of *their* pet ideas. Moreover, much of what they wish to be taught *is* now taught; the problem is that it isn't learned - can't easily be, given the inert and glib quality of the text. Content is reducible to sound bites only when curricular lobbyists (and an alarming number of educators) believe that learning occurs merely by hearing or seeing the "truth". The problem of student ignorance is thus really about *adult* ignorance as to how thoughtful and long-lasting understanding is achieved.

The inescapable dilemma at the heart of curriculum and instruction must, once and for all, be made clear: either teaching everything of importance reduces it to trivial, forgettable verbalisms or lists; or schooling is a *necessarily* inadequate apprenticeship, where "preparation" means something quite humble: learning to know and do a few important things well and leaving out much of importance. The negotiation of the dilemma hinges on enabling students to learn about their ignorance, to gain control over the resources available for making modest dents in it, and to take pleasure in learning so that the quest is lifelong.

An authentic education will therefore consist of developing the *habits of mind and high standards of craftsmanship* necessary in the face of one's (inevitable) ignorance. Until we accept the sometimes tragic, sometimes comic, view that students, *by definition*, are ill-equipped at the end of their tutelage for all that their professions and intellectual lives will require, we will keep miseducating them. Curriculum design could then finally be liberated from the sham of typical scope and sequence whereby it is assumed that a logical outline of all adult knowledge is translatable into complete lessons, and where a fact or theory encountered once in the 8th grade as a spoken truism is somehow to be recalled and intelligently used in the 11th.

Our attempts to avoid the dilemma reveal our naivete or *hubris* -so much at the heart of Greek myths like that of Sisyphus. Given the pain of necessary curricular deletion, critics retreat to rigid ideology to ensure someone *else's* canon is cut. The traditionalists demand complete cultural literacy; the progressives deify "thinking" and multiple points of view. The former see themselves as the guardians of rigor, standards, and disciplinary knowledge; the latter see such views as elitist, narrowly pedantic, unmindful of nontraditional knowledge and modern epistemology. Alas, "literacy" somehow always get reduced to memorized lists or cultural hegemony, and "perspective" ends up being *my* perspective, that is, egocentrism.

The problem of student ignorance is really about adult ignorance as to how thoughtful and long-lasting understanding is achieved.

Both views end up making the same mistake. In trying to "cover content" or in treating facts as equivalent fodder for some vague set of skills called "critical thinking," both sides ironically reduce essential knowledge to Trivial Pursuit. In *neither* case do students understand that some ideas are indeed more important than others. In *neither* case are students equipped to see for themselves, as a direct outgrowth of schoolwork, that some skills and ideas offer touchstones of such power that our own worldviews must change as a result of encountering them. On the contrary, the typical lesson becomes important only because the teacher says so. (Worse, "This is important" often reduces to "Take notes because this is going to be on the test.")

To subscribe to the myth that everything of importance can be learned through didactic teaching amounts to a pre-modern view of learning. The pejorative simile of the school as factory could only have taken hold in a culture which already believed that knowledge is facts passively received. The view that learning is nonproblematic and inactive reflecting upon knowledge is the persistent residue of a medieval, static, sectarian tradition. The substance of education is "truth"; the number of essential truths is limited; there is a catechism and a sacred text providing sanctioned, effective ways of explaining all phenomena; the means of knowing are nonempirical; understanding is essentially passive, dependent upon the self-evident truth of doctrine or through contemplation of it. The lecture - once necessary in a world without ready access to books - survives as a dominant technology despite our technological advances and recognition of diverse learning styles.

Toward a Modern View of Curriculum

We will not escape our essentially medieval view of curriculum, premised on the finite and static quality of knowledge, until education learns the lessons of modern intellectual inquiry. Today's curriculum design should thus have as its motto that of the 17th century Royal Society: *Nullius in Verba*. The best translation, as Boorstin (1985) has noted, is "Take nobody's word for it; see for yourself." Only by apprenticing in the hands-on work of knowledge production can students learn to turn inchoate feeling and received opinions into unforgettable, vibrant, and systematized knowledge[2].

Given the Sisyphean task of teaching so that all important ideas are thoughtfully learned, the only wise goal is to reframe the problem. Our aim should be to develop in students a thirst for inquiry and a disgust for thoughtless, superficial, and shoddy academic work, irrespective of how "little" they know. Students must be educated to feel what all wise people know: the more you learn, the more you are aware of your ignorance. They must be shown that there is a perpetual *need* to think and that *all* "official" knowledge (including that in the textbook) is thinking fashioned into facts by rigorous, sustained but personalized work.

Such epiphanies are possible only when we treat every "fact" as the result

of inquiry and not as a given, finished thing produced *ex nibilo*. Conventional curriculums reinforce the idea that knowledge is uncontroversial or self-evident, when the opposite is often true. The test for a modern curriculum is whether it enables students, at any level, to see how knowledge grows out of, resolves, and produces questions. Rather than the TV-view that by the end of a class or school career all the "answers" have been taught is tied together in a happy ending, closure would consist of taking stock of the current state of the boundary between one's knowledge and ignorance, and gauging the depth of one's grasp of the questions.

In short, the aim of curriculum is to awaken, not "stock" or "train" the mind. That goal makes the basic unit of a modern curriculum the *question*. Given the intimidating, easily trivialized mass of knowledge, what the modern student needs is the ability to see how questions both produce and point beyond knowledge (whether one's own or the expert's). Educational progress would thus be measured as the ability to deepen and broaden one's command of essential questions by marshaling knowledge and arguments to address them.

Note, therefore, that questioning is not a context-less skill any more than knowledge is inert content. One learns the power of the question only by seeing, for oneself, that important "facts" were once myths, arguments, and questions. And one therefore learns self-confidence as a student only by seeing that one's questions, not one's current store of knowledge, always determine whether one becomes truly educated.

Freedom to Go Where Questions Lead

Curriculums should therefore be organized around essential questions to which content selection would represent (necessarily incomplete and always provocative) "answers."[3] What is an adequate proof? What is a "great" book? Does art imitate life or vice versa? Are there really heroes and villains? Can one medium of discourse or art adequately translate into others? Is there a fixed and universal human nature? Is "history" the same as "progress"? These more general questions would have subsets of specific questions under which content would be organized.

The task is to *reorganize* curriculums more than to add or subtract from them. The aim is to establish clear inquiry priorities within a course, around which facts are learned - the method of athletics and the technical and performing arts, by the way. To demonstrate such a curriculum is feasible, let us look at the essential concepts of science cited in the AAAS report, *Project 2061: Science for All Americans.*[4] The following "Common Themes" are stressed: systems, models, constancy, patterns of change, evolution. Now, turn them into questions under which content would be organized: Is nature "systematic"? In what senses is the body a "system"? What are the strengths and weaknesses of the "model" of light as a wave or of atoms as planetary systems? Does scientific knowledge change by gradual evolution or by revolution? All student inquiry, specific labs and assignments, and final exams would be used to ascertain *the degree to which the student understands the question.*

The modern educational task is thus to put students in the habit of thoughtful inquiry, mimicking the work of professionals. That naturally implies that essential questions must also derive from students: the best questions in my classes invariably came from engaged students. Sometimes all a teacher need do is ask students to design the questions and tasks composing the final exam, based on their

Like the music or athletic coach, the classroom teacher's job is to help the student "play the game" of the expert.

Photograph by Jay Thompson

knowledge of the "essentials." (In theory, one should assess students on their ability to anticipate the essential questions. In fact, in my teaching and that of many others, the students growth in question-asking over the course of the class is assessed.)

The implication for curriculum design in all of this is profound: if the students' questions partially determine the direction of the course, it will no longer be possible to write scope and sequence lesson plans in advance. The teacher and the students must have the intellectual freedom to go where the essential questions lead, within bounds set by the general questions, themes, and concepts of the syllabus. The teacher must have access to material that offers a variety of specific inquiries to pursue, with suggestions on how to deepen student responses and to use the text as a more effective resource. *The textbook, instead of being the syllabus outline and content, would be a reference book for student and teacher questions as they naturally arise.* Like the music or athletic coach and the vocational education teacher, the classroom teacher's job is to help the student "play the game" of the expert, *using* content-knowledge, as contextually appropriate, to recognize, pose and solve authentic knowledge problems. Most important, the teacher-as-coach would use the curriculum to help students develop the habits and high standards of the expert (as opposed to thinking of content mastery as a superficial and desiccated version of all professional knowledge). We have learned this lesson in the arts and in writing, thanks to the work of the national and regional Writing Projects in the latter case. But we have yet to translate it into the learning of history, mathematics, foreign language and literature.

The reference to "high standards" may well be lost or misconstrued here. The "standard" was originally the flag that soldiers rallied around, the source of self-orientation and loyalty; it represented what mattered, what one was willing to fight for. To speak of high standards is to invoke images of pride in one's work, a loving attention to detail, an infusion of thoughtfulness, whether one is learned or not. What is sadly visible in so many American classrooms, even in the "best" schools, is that there is so little evident student craftsmanship in academic work - a far cry from what one witnesses on the athletic field, on stages, and in vocational wings, by the way. The cause? Seeing facts as the remedy of ignorance and accurate recall as the only sign of knowledge.

Standards are intellectual virtues - habits of mind. In workshops I ask teachers, "What 'bad habit' gets in the way of students' learning what is essential?" They quickly offer many good ones: inability to delay gratification, inability to listen, no concern for thoroughness or discipline in proofreading, and so on. When one then asks them to imagine the solving of each problem as the changing of a habit, there is a noticeable set of sobered faces. Didactic lessons obviously cannot work. Days of reinforcing actions are not required. What then often follows is the more painful realization that *teacher* habits unwittingly reinforce the student habits deemed undesirable, especially the teacher habit of "coverage" and the short-answer tests.

But it is not only that skills are habits. An *idea* is a habit of mind. Only with repeated use, and by investigating it from various points of view, do we learn to understand a new idea - whether it be F = ma or irony in literature. To imagine that one verbal exposure to such ideas or a few mindless uses of them (as if they were plug-in algorithms not requiring judgement) is sufficient for students to understand them is as naive as Sisyphus' thinking that *this* time he has the tools to make it.

The Ability to Keep Questioning

What students need to experience, firsthand, is what *makes* an idea or book "great" - something hard to do well, but possible with students of all ages if teachers grasp the need for cycles of Question-Answer-Question instead of merely Question-Answer. The issue is ultimately not which great book you read but whether any book or idea is taught in a way that deadens or awakens the mind, whether the student is habituated to reading books thoughtfully, and whether the student comes to appreciate the value of warranted knowledge (as opposed to merely beliefs called "facts" by someone else).

One irony in the fuss over *Cultural Literacy* is that Hirsch has written a classic liberal argument: the point of cultural literacy is to enter the Great Conversation as a coequal. But Hirsch made a fatal (and revealing) error in his prescription of a shared base of essential information[5]. The capacity to understand is only partially dependent on facts; rarely do we need to know the same things that our fellow conversants know. It is far more important for a novice to possess intellectual virtues (moral habits of mind, if you will); one must:

- know how to listen to someone who knows something one does not know,
- perceive which questions to ask for clarifying an idea's meaning or value,
- be open and respectful enough to imagine that a new and strange idea is worth attending to,
- be *inclined* to ask questions about pat statements hiding assumptions or confusions.

So-called "liberals" in education have been myopic in thinking that one can evade the question about what facts, ideas, or books are worth spending *limited* time on. There is no "critical thinking" without substantive ideas and criteria for distinguishing between exemplary and slipshod work, no matter what the age or experience of students. But didactically teaching sanctioned bits of knowledge from a silly list will promote only thoughtless mastery and the very ignorance we decry. "Knowledge" remains a forgettable patchwork of adult sayings in the absence of our own questioning and verifying. "Knowledge" must solve a problem or provoke inquiry for it to seem important.

Since it is impossible to teach everything we know to be of value, we must equip students with the ability to *keep* questioning. The value of an idea, when time is limited, stems from its ability to pass this test: does it sufficiently illuminate student experience and provoke new thought? If not, it clutters up the curriculum.

A truly liberal education is one that liberates us from the oppression of unexamined opinion and feeling - a far cry from letting students encounter only what they think relevant or fun. As the philosopher Gadamer put it, the enemy of the question is the dominant opinion, be it the loud voice of a textbook or one's student peers. The aim of the modern curriculum ought to be to use selected content as a vehicle for developing in students an unwillingness to accept glib, unwarranted answers from any source. They must leave school with the passion to question, without the fear of looking foolish, and with the knowledge to learn where and how the facts can be found.

The sign of a poor education, in short, is not ignorance. It is rationalization, the thoughtless habit of believing that one's unexamined, superficial, or parochial opinions and feelings *are* the truth; or the habits of timid silence when one does not understand what someone else is talking about. Most first-rate questions or comments I have heard from my high school students were inevitably preceded with "I know this sounds stupid, but ..." The principal sign of the failure of curriculum-as-content is that admitting ignorance becomes increasingly rare as students age: many of our best high school students will not openly express their ignorance, while younger students happily inquire regularly.

One therefore learns self-confidence as a student only by seeing that one's questions, not one's current store of knowledge, always determine whether one becomes truly educated.

Toward a Thoughtful Education

Curriculum must develop in students the habits of mind required for a lifetime of recognizing and exploring one's ignorance. The modern curriculum should thus: (1) equip students with the knowledge through careful questioning, (2) enable them to turn those questions into warranted, systematic knowledge, (3) develop in students high standards of craftsmanship in their work irrespective of how much or how little they "know," and (4) engage students so thoroughly in important questions that they learn to take pleasure in seeking important knowledge.

To enable students to be more thoughtful about what they do and do not know, the following aphorisms should be kept in mind in curriculum design:

1. *The most essential habit of mind we can provide students is the ability to suspend disbelief or belief as the situation may warrant.* Experts are so called not because they know everything of importance in their field but because they have developed the habit required to avoid believing the first thing they see, think, or hear from other so-called experts[6].

Ask yourself, then: how would we teach the same content from the perspective that students should feel the need and desire to be critical or empathic when most people, when encountering a would-be problem, are inclined in the opposite direction? At Central Park East Secondary School in East Harlem, for example, all courses are designed around the following five sets of questions:

- Whose voice am I hearing? From where is the statement or image coming? What's the point of view?
- What is the evidence? How do we or they know? How credible is the evidence.
- How do things fit together? What else do I know that fits with this?

- What if? Could it have been otherwise? Are there alternatives?
- What difference does it make? Who cares? Why should I care?

As these questions reveal, the criteria of good answers become more important than merely whether one possesses a seemingly adequate-but-really-superficial "right answer." When content is organized to address such questions, the student's (limited but growing) knowledge becomes a means to the end of mastering the *standards* - the discipline - of scholarship. Second, when the questions are continually asked, the students get *in the habit* of asking good questions unapologetically. (While visiting the school last year, I heard an 8th grader ask, after the teacher gave a history lecture, "From whose point of view were the facts in the talk from?" - leading to an exemplary inquiry of the *teacher's* sources.)

2. The deep acceptance of the painful realization that there are far more important ideas than we can ever know leads to a liberating curricular postulate: *all students need not learn the same things.* Why do we persist in requiring all students to take mathematics courses that are designed only for would-be professionals? Why do we require all students in an English class to read the same books? High standards matter, not whether we have all marched through the same "content."

The teacher should be an intellectual librarian, constantly making it possible for students to be challenged anew to pique their curiosity and raise their standards and expectations. Just as there are different learning styles, there are different equivalent books and tasks that will serve such purposes. And if different "essential questions" are tackled by groups of students drawing upon different books and experiences, the possibilities for *genuinely* cooperative learning are heightened.

3. *If everything taught is said by teachers to be important, then nothing will seem important to students.* Of all the "important" things students are learning, some are more important than others. This concept is one that few students are ever helped to grasp through their schooling experience. How do we help students grasp priorities within a course? "Importance" is only "learnable," not "teachable": the student must be helped to *directly* perceive and astutely judge an idea, fact, skill, model (or whatever) to be essential for understanding or uniting the other elements of a course. (The ultimate test: the student's ability to say "*This* is important," when the teacher is silent on the matter.)

A truly liberal education is one that liberates us from the oppression of unexamined opinion and feeling.

The only practical cure for our bloated curriculum, in which everything is important, is to stop thinking in terms of adult logic and specialized priorities. Rather than asking, "What will my course cover?" or "What are the important outcomes of this course?" teachers should ask:

- "What must my students actually demonstrate to reveal whether they have a thoughtful as opposed to thoughtless grasp of the essentials?"
- "What will 'successful' student understanding (with limited experience and background) actually look like?"

The only realistic way to deemphasize or reduce content to stress priorities in teaching is to align one's curriculum in the true sense: design final tests and scoring rubrics that reflect thoughtfulness as a curricular priority, and then teach to them. (And, as I have argued elsewhere, the operational sign of a school's priorities can be found in those things we take points off for on assignments and tests[7].) A sign of successful curriculum and instruction, where priorities are clear, can be found in the students' ability to anticipate the final examination in its entirety and provide accurate self-assessments of their finished work.

4. *Curriculum is inseparable from assessment:* the tests set standards of exemplary performance, as point number 3 implies. But as the notion of intellectual performance implies, competence can be shown in various sometimes idiosyncratic ways. Why must all students show what they know and can do in the same standardized way? *Craftsmanship and pride in one's work depend on "tests" that enable us to confront and personalize authentic tasks.*

School-given tests, whether bought from vendors or designed by teachers, are typically *inauthentic,* designed as they are to shake out a grade rather than allowing students to exhibit mastery of knowledge in a manner that suits their styles and interests and does justice to the complexity of knowledge. We must once again return to the idea of the public "exhibition" of knowledge, where the student's incentive to reveal high standards and competence is greatly increased through personalized "performance."[8]

5. *The "essentials" are not the "basics."* The laws of physics, the rules of grammar, the postulates of geometry, the difference between fact and opinion, or the shades of meaning and usage with respect to words are not unproblematic givens. They represent embedded and persistent problems within organized knowledge. Students are rarely taught to appreciate the fact that the logical foundations were typically discovered or invented *last* in the history of a discipline: they are the least obvious facts or truths and often represent stunning triumphs in problem resolution.

Put in terms of the classroom, essential ideas, like essential questions, should recur in different guises and levels of difficulty within each course[9]. That is the only way for students to perceive knowledge to be essential. Also implicit in such a view is that to enable students to understand the essentials of a discipline, we need not teach the basics first and proceed in "logical" order. Only experts have the discipline and perspective to grasp the importance of studying the basics, whether it be van Gogh learning about color for eight years or professional writers laboring over a few word-choice problems in a manuscript. We should teach the minimum basic content necessary to get right to essential questions, problems, and work - within and across disciplines. Pride in one's work leads to greater care for the basics; pride depends on authentic and engaging work, and a product "owned" by the student.

What Socrates Knew

The dilemmas of curriculum and instruction are real, the problems increasingly intractable. There is simply too much for any one of us to know, never mind teach to dozens of students in a crowded day. Such a tragic fact leads to a liberating realization: wisdom matters more than knowledge. However, as a wise Greek curriculum-basher pointed out 2,200 years ago, and who was killed for his trouble, few people know or admit this essential lesson about our own ignorance - none of us readily imagine ourselves to be unaware of things worth knowing. This was the one thing Socrates knew deeply and unequivocally. The ideal curriculum would use knowledge judiciously to further that insight. Maybe, therefore, the myth of Sisyphus *is* appropriate for curriculum work. As Camus suggested at the end of his essay on Sisyphus, given a deep awareness of the "absurd" plight of his task, "One can imagine Sisyphus as happy."

There is no "critical thinking" without substantive ideas and criteria for distinguishing between exemplary and slipshod work.

Notes

1. A personal example having never had a history course that went beyond World War I, it wasn't until I was 28, watching "The World at War" on PBS, that I discovered that Russia had been our ally in the second World War.
2. Readers of Dewey will hear an echo here of *How We Think* (1910/1933). There, Dewey argues that neither conservatives nor liberals understand the mind's native interest in thinking and the need to culminate, not begin with, one's work in a "logical" organization of subject matter.
3. See Wiggins (1987) for a further account of "essential questions." For examples of curriculums designed around such questions, see the June 1989 issue of *Horace*, the newsletter of the Coalition of Essential Schools, based at Brown University.
4. American Association for the Advancement of Science (1989), pp. 123-131.
5. He has also erred in his portrayal of Dewey's thinking. The caricature he presents of what he calls Dewey's "formalism" overlooks a massive corpus of writings that provide substantive guidelines on how to ensure that students truly understand academic ideas of value and substance.
6. Note, for example, the recent "cold fusion" controversy and how careful some scholars have been about *testing* the initial claims by Pons and Fleischman before responding one way or the other. Note, too, that many experienced chemists may have been (necessarily) ignorant of all they needed to know about nuclear physics to settle the matter.
7. See Wiggins (1988).
8. See Wiggins (1989a) and (1989b) for more on authentic forms of assessment.
9. Echoes, of course, of Bruner's (1960/1977) "spiral curriculum" in *The Process of Education* (which borrowed the phrase from Dewey's *Experience and Education*). But the point here is that students need to see knowledge "spiral" within each course, not just over the K-12 years.

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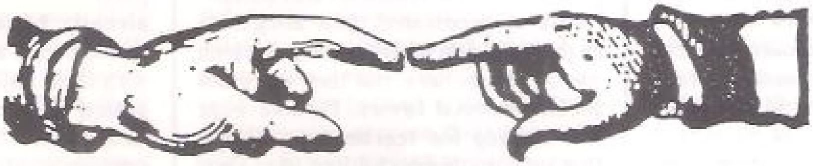
JANE C. LINDLE

What Do Parents Want from Principals and Teachers?

It's not "professionalism" that parents want but rather the "personal touch."



As a former principal, I cannot recall a single day in that office when I did not meet with at least four or five parents or help a teacher prepare to meet with a parent. Many of those interactions were pleasant, even delightful, but plenty were not. My fellow principals and I would often spend considerable amounts of professional development time with spontaneous recitations of the latest "unpleasantness" with a parent or group of parents. We - principals and teachers - all tried to help each other cope with parental demands by developing skills in focusing the conference on the issue (Fisher and Ury 1981) or through judicious repetition of the appropriate and clearly stated school or district policy (Canter and Canter 1976). Yet nearly all of us walked away from many of the conferences wondering, "What do parents want?'

Just what do parents want from principals and teachers? What do they say when we ask them?

Parent/School Communication Study

I am conducting an ongoing study at the University of Pittsburgh that is examining the relationship between schools and families in four school systems. By talking with school personnel and parents, we are identifying the mechanisms that schools provide to promote school and parent/family communications. We then ask parents (or guardians or any custodial adults) to evaluate their experiences and to suggest improvements. We also ask them to reflect on the worst and the best experiences they have had with my school.

School people are not likely to earn parents' respect by adhering to a cold, businesslike approach.

Personal interviews were used to collect the data. The interviews were conducted with parents, principals, and teachers. School documents on communications were also reviewed. The report here represents only a portion of this study. A complete report is forthcoming.

Although we interviewed school personnel from both public and private schools, this report focuses on the parents' responses. Other research has looked at the perceptions of school personnel (see, for example, Epstein and Becker 1982, Goldring 1986, Nasstrom 1981). The major limitation of this study is the regional nature of the population. Thus, caution must be exercised in generalizing these parents' responses to parents' perceptions nationally, but the stories they tell can provide school people everywhere insight into their own school/family relationships.

Historically, the research on parents and public policy focused primarily on families and schools facing crises concerning students. The findings concluded that socioeconomic status differences between teachers (or other school personnel) and the families-in-crisis increase the alienation of parents from schools (Lightfoot 1978, Schaefer 1983). However, the University of Pittsburgh research, thus far, refutes this conclusion. We are finding that all families, regardless of socio-economic status, have similar preferences about the nature and the conduct of school communications.

What Do Parents Want? Professionalism?

The responses we have collected indicate that existing school mechanisms can both enhance and detract from school and family relations. In a classic example of misunderstood cues, the reported preferences of parents are *not* what school personnel think they are. School personnel passionately believe that a professional, businesslike manner will win the respect and support of parents. The responses of parents to questions about their contacts with the school reveal that they view "professionalism" on the part of teachers, school psychologists, guidance counselors, or principals as *undesirable.* Parents mentioned their dissatisfaction with school people who are "too businesslike," "patronizing," or who "talk down to us."

When specific incidents that generated parental disapproval were checked with the school personnel involved, the school people reported they were trying to "do what is best for them [the students or parents]." One principal said that "sometimes people don't know what is best for them." Thus, the responses of school personnel generally supported what one father reported as a tendency to ignore or respond inappropriately to parents' questions or desires. Our findings in this area replicate Corwin and Wagenaar's (1976) conclusion that teacher-parent disagreements increased with the seniority, training, and formality of the teacher.

Patronage?

Parents reported a "personal touch" as the most enhancing factor in school relations. Teachers or principals who take a personal interest in the children will call parents to alert them to problems, both academic and social.

Parents reported a "personal touch" as the most enhancing factor in school relations.

Parents predicated their allegiance to the school on whether their children liked the teachers, but they were not seeking special favors. Parents were not looking for teachers or schools that only do things children like. They said that kids *need* discipline, but they genuinely appreciated teachers who provided it appropriately and with their knowledge. Parents who found out about student-teacher disagreements from the child without any information from the teacher, though, usually became very angry and were slow to forget. However, they acknowledged the need for teachers to handle situations as they arise - "Why wait eight hours until the kid gets home?" - but they appreciated teachers' keeping them informed of the incidents as soon as possible. In such instances, parents were not requesting special consideration, just timely information.

Partnership?

Parents spoke favorably of the activities that schools provided for them. Especially popular were programs that supported them as partners in fighting drugs or in understanding the development of their children.

Parents also valued schools that acknowledged working parents' needs. Parents' work schedules often interfered with their becoming more involved in the day-to-day activities of the school, including attendance at their children's plays or other performances. If the events are held only at one time, day or night, not all parents are able to attend. Parents suggested that schools schedule a day and a night performance, so that parents who work different shifts can attend.

The traditional school-parent communications device, the parent-teacher conference, received mixed reviews. The good news is that parents appreciate teachers who arrange conferencing times around their work schedules. On the down side, they rated negatively almost everything else about the conference. Some parents resented the formality of the conference and the limited time often allotted for it.

Dislike of the formality of the conference is probably directly related to the "professional-client" nature of the exchange. The degree to which parents dislike "professionalism" has already been mentioned. Parents would prefer a less formal relationship with their child's teachers. They suggested more regular, informal contacts by teachers through less time-consuming phone calls or notes (if students are reliable in delivering them). The message from parents about conferences was summed up by one father, who said, "Save the conferences for the *big* things."

Some parents viewed the limited

All families, regardless of socio-economic status, have similar preferences about the nature and the conduct of school communications.

conference time period (10 minutes in some cases) as a way teachers or other school professionals avoid finding out what the parent knows about the child. As one mother put it,"Ten minutes is ridiculous, especially when other parents are waiting right outside the door. I need time to tell the teacher about how my child is at home, too." The lack of interest in the parents' perspective on their children caused parents to view all that school people said with suspicion.

The Message from Parents

Parents respect school personnel who return that respect. School people are not likely to earn parents' respect by adhering to a cold, businesslike approach. Personal attention, which means timely information on an informal basis, is most likely to win parents' esteem. The parents we interviewed also want to be included in the dialogue about their children's education, to share important perceptions they have about their children with the people at school. They do not want a "professional-client" relationship with schools in the education of their children. Rather, they want to be equal partners with schools in the rearing of the children.

Parents do not want a "professional-client" relationship with schools in the education of their children. Rather, they want to be equal partners with schools in the rearing of the children.

The National PTA Talks to Parents:

How to Get the Best Education for Your Child

Published in September 1989, this valuable guide by Melitta J. Cutright advises parents how they can become more involved in their child's education. Topics addressed include helping your child learn at home and at school, obtaining assistance for a child with special needs, managing the out-of-school hours, keeping your child healthy, and making your voice heard at the local, state, and national levels. Contains many practical lists and tips, including: A Safety Checklist for Children Home Alone, 10 Things Teachers Wish Parents Would Do, Homework Tips for Parents, A Parent's Rights and Responsibilities, and Evaluating Drug Education in Your School.

Available from Bantam Doubleday Dell Publishing Group Inc., 666 Fifth Ave., New York, NY 10101; (212) 492-9793, 304 pp. $19.95 hardcover/$8.95 paperback.

Schools that demand parental support without reciprocating will be likely to experience increasing discord. Lessons from the parents in this study may help schools increase their successes with a diverse student population and with their families.

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BOO HONG KWEN

How Ought Science be Taught and Learnt?

To answer the question, "How ought science be taught and learnt?", we need first to ask ourselves, "What is science?"

Science is *not* merely a body of knowledge, that is, the current inter-connected set of principles, laws, concepts, theories, together with the vast array of systematic information about the material world. To define science as merely a body of knowledge is to subscribe to a dated and static view.

Science is a *human activity, a process of inquiry*, of acquiring and refining knowledge of the material world. (Fitzpatrick 1960, and Ryan and Ellis 1974). As a process of inquiry and a human activity, there are at least three facets of science, namely,

(i) the products of inquiry or the body of scientific knowledge, which includes facts, concepts, principles and laws, and theories, which is tentative and changing all the time.

(ii) the processes or methods of inquiry which include process skills such as observing, classifying, measuring and using apparatus and equipment, communicating, interpreting information and inferring from data, formulating hypotheses, planning investigations to test hypotheses. These are relatively stable.

(iii) the mental attitudes and values which are intrinsically involved, such as curiosity, humility, impartiality, integrity, inventiveness, open-mindedness, perseverance and a positive approach to failure, cooperation with others, and care and concern for the environment. These attitudes and values are even more important than the other two domains of knowledge and skills. This is because students who have imbibed the proper attitudes and values would naturally go on to acquire the relevant knowledge and skills. The reverse could not be said of students who have a good grasp of scientific knowledge and/or skills; such students may not necessarily have acquired positive scientific attitudes and values, and may never become scientifically literate!

Thus following from the above definition of science, science education in Singapore, as in elsewhere, has a minimum of three aims, focusing on each of the above-mentioned three facets of science. These aims are:

(i) to promote the acquisition of scientific knowledge

(ii) to develop the ability to inquire and problem-solve through the acquisition and practice of science process skills as well as decision-making and problem solving skills.

(iii) to develop attitudes and values such as those mentioned above, which are necessary for fruitful scientific pursuit.

In the past, the dated view of science as merely a body of knowledge was generally adopted by educators. Hence science teaching was narrowly focused on the aim of promoting the acquisition of scientific knowledge. Teaching thus tended to be didactic and emphasised telling students about science. Laboratory work tended to be "recipe-following" highly convergent practical activities, designed to illustrate a scientific concept or principle, and experimental results were foreknown to students.

However, today, with the broadening of the aims of science education to include the inculcation of process skills and attitudes and values, it must be clear to all concerned, that didactic methods alone do not suffice. Acquisition of process skills and proper scientific attitudes and values by students cannot be promoted through teacher exposition and routine "cookbook" type practical work alone. Since science is an activity and an inquiry process, students should not learn science by merely being told about the products of science. Just as we do not expect students to learn cycling or swimming or any other human activity by merely being told about such activity. Instead, students need to be actively involved in first-hand experiences with objects, events and phenomena in the natural world. They need to be involved in practising science, as real scientists do, in working cooperatively with others, in gathering facts, generalising, conceptualising, raising questions, hypothesising, hypotheses testing, interpreting data and constructing instruments, simple devices and physical models. In so doing, they would have opportunities for not only developing the skills of inquiry, but also for learning to exercise perseverance, inventiveness, cooperation, integrity and the other scientific attitudes. If students are to develop proper values and attitudes, opportunities would need to be provided for them to clarify, test and modify their values through activities such as discussions, debates and role play on topics such as environmental, social and moral issues in science. Further, if they are to develop a sense of care and concern for the environment, they would need to come into contact with the different components of the ecosystem and to appreciate the interdependence of all life forms on earth. Thus, it is obvious that today, a variety of teaching methods are needed in order to achieve even just the three minimum aims of science education. These methods would include:

- group as well as individual investigations,
- small group discussions and brainstorming,
- project work,

- field visits and outdoor practical work,
- debates,
- role play and simulations,
- pupil presentations and demonstration, as well as
- lecture and demonstration by the teacher and guest speakers.

Thus science classrooms and laboratories today will no longer be the fairly quiet and tame places they used to be, when students were expected to listen passively and take notes silently. Today science classrooms and laboratories will be bustling with hands-on and minds-on activities for students. There will be quite a high level of noise. However, this will be productive noise, which is generated as a result of expressing the thrills of discovery and in the process of exchange of ideas among students.

Where it is not possible for students to have first-hand experiences, such as where dangerous or harmful objects or materials are involved, or where objects, events and phenomena are not accessible within the constraints of time and place, a variety of media representations of these could be used. These could include slides and overhead transparencies, videotapes and audiotapes, computer disks, films and filmstrips, models and charts.

It is a pity that today, there are still some educators who are clinging to the dated view of science, and perpetuating the traditional mode of teaching. They see their main role as dispensers of knowledge. They treat students' minds as stores for scientific knowledge, instead of as potential generators of new knowledge. By so doing, they are in a sense dehumanising students, because human minds, unlike books, computer disks and microfilms, are meant for more than the mere storage of knowledge. By failing to equip students with the necessary skills, attitudes and values, they are rendering them dependent and ineffective as learners, and scientifically illiterate!

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WOO YOKE YOONG

Mini Conference by Dr Diane Berreth

Theme : Restructuring Schools For The Year 2000

Dr Diane Berreth

In conjunction with one of its most important events of the year - the Annual General Meeting - ASCD Singapore invited Dr Diane Berreth to conduct three talks on *Restructuring Schools*. As Deputy Executive Director of ASCD, USA, Dr Berreth had to set aside a busy schedule in America to share her extensive knowledge on policy issues and strategic planning with members of ASCD Singapore.

Restructuring involves a collection of processes of getting a better school. "At the heart of the Restructuring effort is the focus on Teaching *for* Learning," stressed Dr Berreth. She described three forms of Restructuring. Restructuring of Governance leads to changes in the management of decision making. In contrast, Restructuring of Organisation involves changes in the school's organisational components e.g. length of school year, teachers. The third form, Restructuring of Curriculum, aims to improve instructional strategies, assessment and other curriculum related matters.

In her second talk, Dr Berreth described the process of *Strategic Planning*. "Strategic Planning is a process of creating the best possible future for an organisation", she explained. It is essential to consider factors such as mission, strengths, weaknesses, opportunities and threats before planning strategies and carrying out programs that will bring success, to an institution.

Her final talk, "Developing a Mission for your School" stimulated the most discussion from the Conference participants. Everyone tried their hand at writing mission statements that incorporated Dr Berreth's 3A's - Audience, Action and Aim. "Mission is the emotion of excellence. Without it, we are mere employees. With it, we are crusaders," Dr Berreth concluded. It was an inspiring finale to ASCD's event of the year.

Woo Yoke Yoong is the Assistant Secretary of Singapore ASCD.

Participants having a go at writing mission statements.

WONG MEE MEE

Mathematics Festival Day '91

Serangoon Garden Technical injects fun into the learning of Mathematics

At our school, teachers often notice that pupils treat mathematics as a dull subject which requires a great deal of drill and practice. Pupils are pressed to complete exercises and teachers are often up to their necks with heavy marking loads. To make matters worse, pupils do not have a positive attitude towards the learning of mathematics. Due to the tight schedule of the examination syllabus, it is not often that teachers can conduct enrichment activities in the classroom.

The Mathematics Festival Day was planned with the idea of injecting some fun and movement into the learning and the experience of mathematics. The programme consists of five stations. At each station, pupils were given a specific task to complete within a limited time. Pupils work in teams of give. Altogether, about 150 pupils participated, forming 30 teams. Each team had to complete the circuit of five stations. Depending on their performance at each station, each team scores a number of points. To add some tangible meaning to the activities, the teams compete against one another.

At the first station, pupils play a computer game called "Columns". This game was selected because it tests a player's ability to plan and visualize the movement of blocks of objects. At another station, pupils were given "Tangram" sets to assemble. Here, pupils exercise their ability to visualize spatial objects, rotating and assembling each piece to form the required patterns. At the third station, "What's your guess", pupils have a hands-on lesson on estimation. They were given a list of things to estimate - how many metre rules are required to surround the basketball court, how many fluorescent lights are there in the classooms, how many 1-litre bottles are required to fill the tub etc. The next station was a puzzle corner where pupils were required to solve 20 puzzles questions. At the last station, pupils went on a shopping spree. They were given a worksheet on which was listed certain shoppinh items. These items were advertisement items displayed on charts. The prices of the items were listed, some with percentage discounts while others showed net prices. Pupils had to compute the cost of their purchases at this "Shopping Mall". As they were allowed to use calculators, even secondary one pupils were seen punching away at their calculators and through this experience must have certainly familiarised themselves with the use of calculators.

In a game-like fashion, pupils enjoyed the activities at each station. The competition between teams helped to spur them on to perform thier best. Through these activities, pupils also learnt to work as a group and making decisions as a group. Try it in your school.

Teamwork and Tangrams

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ROBERT SYLWESTER

An Educator's Guide to Books on the Brain

Fascinating books on the recent advances in our knowledge of the brain can provide educators with fresh insights into teaching and learning.

Recent dramatic advances in the neurosciences and in cognitive psychology are moving us toward a clearer understanding of the three-pound human brain that is the focus of our profession, and a number of excellent books outline these developments in terms the layperson can grasp.

The 32 informative (and at times controversial) books selected for this list provide functional explanations of brain mechanisms and processes and introduce the reader to the fascinating and competitive world of cognitive research. Written by respected scientists and science writers, all books have been published since 1983, many in paperback. Most include helpful illustrations.

General/Introductory Information

Several books provide excellent overviews of the cognitive sciences. Michael Gazzaniga's *Mind Matters: How the Mind and Brain Interact to Create Our Conscious Lives* (1988, Houghton Mifflin, available in paperback) is an excellent nontechnical introduction to the basic brain/mind questions that affect educators. The Diagram Group's *The Brain: A User's Manual* (1987, Putnam, available in paperback) and Robert Ornstein and R. Thompson's *The Amazing Brain* (1984, Houghton Mifflin, available in paperback) provide clearly written explanations of basic brain mechanisms/processes - with delightfully imaginative "Amazing Brain" illustrations by David Macaulay. Marion Diamond, A. Scheibel, and L. Elson's *The Human Brain Coloring Book* (1985, Harper and Row) uses the tactile experience of coloring diagrams to help non-neuroscientists grasp brain relationships. *The Science of Mind* (1989 MIT Press), by Kenneth Klivington, is a beautifully illustrated coffee-table-size book that synthesizes recent research.

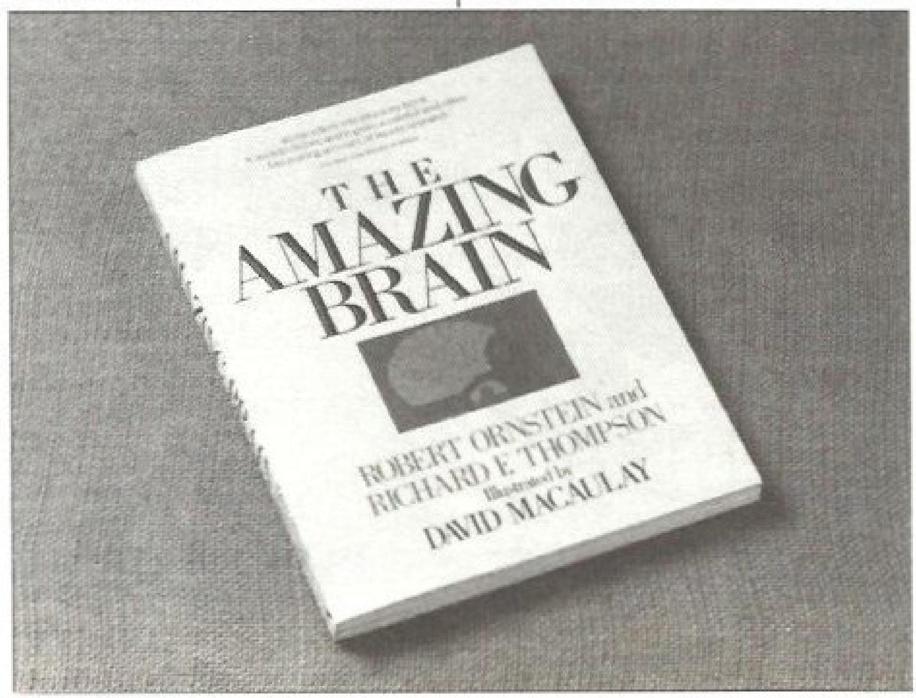
Three fine books emerged from the excellent PBS-TV series on the brain. Richard Restak's *The Brain* (1984, Bantam, available in paperback) and *The Mind* (1988, Bantam) contain easily read chapter discussions that expand upon the content of individual TV programs. Floyd Bloom, A. Larson, and L. Hofstadter's comprehensive *Brain, Mind, and Behavior* (1985, Freeman) is the more technical textbook accompanying the TV series.

Daniel Kimble's *Biological Psychology* (1988, Holt) is a basic college text on the brain, and its excellent organization and clear writing and illustrations also make it a fine reference work for educators.

Specific Research Areas

Several books focus on specific brain research developments (all have educational significance) and on the cooperative/competitive (and sometimes gossipy) human side of that area of research.

Susan Allport's *Explorers of the*



Black Box: The Search for the Cellular Basis of Memory (1986, Norton) discusses the extensive work on sea slugs that led to the discovery of what happens within individual neurons when learning occurs. Michael Gazzaniga's *The Social Brain: Discovering the Networks of the Mind* (1985, Basic Books, available in paperback) and Sally Springer and G. Deutsch's *Left Brain, Right Brain,* (1989, Freeman, available in paperback) discuss the history of the split-brain research and the discoveries that captivated educators, initiated the learning styles movement, and led to the currently dominant modular theory of brain organization and localized memory.

Howard Gardner develops this theory further for educators in *Frames of Mind: The Theory of Multiple Intelligences* (1983, Basic Books, available in paperback). Conversely, *The Invention of Memory: A New View of the Brain,* by Israel Rosenfeld (1988, Basic Books) and *Remembering and Forgetting: Inquiries into the Nature of Memory* by Edmund Bolles (1988, Walker) argue against the theory of modular memory storage, contending that the brain creatively generates memory out of experience. And so the argument on transfer, with all of its educational implications, continues.

William Allman's *Apprentices of Wonder: Inside the Neural Network Revolution* (1989, Bantam) moves the discussion further, into recent developments in brain/machine research.

Jon Franklin's *Molecules of the Mind: The Brave New World of Molecular Psychology* (1987, Atheneum) describes the discovery of endorphins, which led to our current understanding of the molecular basis of neural activity. Charles Levinthal's account of endorphin research, *Messengers of Paradise: Opiates and the Brain* (1988, Doubleday) relates the endorphin research to Paul MacLean's Triune Brain Model, a paradigm familiar to many educators.

Robert Julien's *A Primer of Drug Action* (1985, Freeman, available in paperback) and Solomon Snyder's *Drugs and the Brain* (1986, Scientific American Library) provide useful background information. Nancy Andreasen's *The Broken Brain: The Biological Revolution in Psychiatry* (1984, Harper and Row, available in paperback) is a fine nontechnical introduction to the new biological perspectives of mental illness and the use of drugs in its treatment.

Start reading somewhere in this list, continue as your time and interest dictate, and discover our profession's exciting future.

Jeremy Campbell's lively *Winston Churchill's Afternoon Nap: A Wide-Awake Inquiry into the Human Nature of Time* (1986, Simon and Schuster) and J.A. Hobson's *Sleep* (1989, Scientific American Library) describe recent research in body/brain rhythms and cycles that can affect educational performance, among many other aspects of human life. Richard Bergland's *The Fabric of Mind: A Radical New Understanding of the Brain and How It Works* (1985, Viking) describes the development of the new wet-brain theory, with its audacious proposal that the brain is essentially one of the endocrine glands. Robert Ornstein and D. Sobel's *The Healing Brain: Breakthrough Discoveries About How the Brain Keeps Us Healthy* (1987, Simon and Schuster, available in paperback), further explores relationships between our brain and our endocrine/immune systems.

Enriching Heredity: The Impact of the Environment on the Anatomy of the Brain by Marian Diamond (1988, Free Press) explains the educationally pertinent research on factors that affect post-birth brain development.

For Advanced Readers

The books listed below are intellectually demanding, but educators who venture into their pages will be rewarded with expanded professional vision.

Jean Pierre Changeux's *National Man: The Biology of Mind* (1985, Pantheon) presents a thought-provoking brain/mind synthesis. Humberto Maturana and F. Varela's *Tree of Knowledge: The Biological Roots of Human Understanding* (1987, New Science Library) offers an inspiring, unified scientific conception of mind/matter/life. Patricia Smith Churchland's *Neurophilosophy: Toward a Unified Science of Mind/Brain* (1986, The MIT Press) is a fine introduction to philosophy for those interested in neuroscience and a fine introduction to neuroscience for those interested in philosophy.

The Society of Mind by Marvin Minsky (1986, Simon and Schuster, available in paperback) combines what we know about brains and computers into a truly mind-boggling book organized by the author according to the model he proposes to represent the brain's organization.

Finally, Sarah Friedman, K. Klivington and R. Peterson's *The Brain, Cognition, and Education* (1986, Academic Press) moves us into issues in our own professional world. It is a sometimes technical but always thoughtful examination of the educational implications of research in the neurosciences and cognitive psychology. It's an excellent update to the pioneering 1978 National Society for the Study of Education Yearbook, *Education and the Brain.* It's exciting to note how much has been discovered during the past decade, sobering to realize how much more ground needs to be covered.

Start reading somewhere in this list, continue as your time and interest dictate, and discover our profession's exciting future. And if you don't understand something you read, look it up in *The Oxford Companion to the Mind* (1987, Oxford), edited by Richard Gregory. This is an excellent, comprehensive, and relatively inexpensive reference book for general readers.

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