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MICROCOMPUTER APPLICATIONS IN EDUCATION AND TRAINING FOR DEVELOPING COUNTRIES

AWAY VIEW SPECIAL STUDIES
IN SCIENCE, TECHNOLOGY, AND PUBLIC POLICY

PN-ABC-135

MICROCOMPUTER APPLICATIONS IN EDUCATION AND TRAINING FOR DEVELOPING COUNTRIES

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About the Book

Developing countries need to take an early and active role in the information revolution to narrow the gap between themselves and industrialized countries. The introduction of the microcomputer as an educational tool is an important step toward parity, but there are many obstacles to overcome when attempting to integrate computers and education in developing countries. Language barriers require cooperation between developed and developing countries in programming and translation of all materials. Software and hardware must be appropriate for the particular culture. Local school and community leaders must learn which material will best serve community needs. The national identity of the developing country must be respected, while the interests and experiences of the industrial country must also be carefully considered.

This book presents guidelines for integrating microcomputers into education in developing countries. In addition to a general overview, the contributors discuss training, software, primary and secondary education, special education, advanced education, and future developments. They offer specific recommendations for program design, detailing integration strategies and providing case studies of successful uses of microcomputers in Third World education.

This book was written by an ad hoc advisory panel of the Advisory Committee on Technology Innovation, Board on Science and Technology for International Development, Office of International Affairs, National Research Council.

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MICROCOMPUTER APPLICATIONS IN EDUCATION AND TRAINING FOR DEVELOPING COUNTRIES

Proceedings of
a Meeting
on the Use of
Microcomputers for
Developing Countries

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NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Foreword

The introduction of microcomputers into primary and secondary education is an immediate goal in a growing number of countries. Among the industrialized nations, Great Britain, France, Italy, Japan, and the Soviet Union have nationwide computer-literacy policies. Although there is no national plan in the United States, more than half of the schools at all levels have at least one microcomputer, and according to the 1985 National Survey of Microcomputers carried out by H.J. Becker for the Johns Hopkins University, the average American secondary school has more than fifteen. Developing countries also recognize the importance of integrating computers into education in a way that carries out national goals. This new technology offers them an opportunity to start on an equal footing with the industrialized nations, an opportunity they decline only at the risk of falling further behind in development.

As the use of microcomputers and educational software increases, however, serious questions of cultural imperialism and dependency arise, especially when programs that may not reflect a country's values are brought into the pre-secondary education process. A number of developing countries have created mechanisms to guide the introduction of information technology. In Sri Lanka, the Computer and Information Technology Council (CINTEC) was organized to help formulate policy and to coordinate the work of various ministries, including the Ministry of Education, in implementing computer technology. In Brazil, a Special

Committee for Informatics in Education, created to oversee the development of microcomputers as a teaching aid, emphasized the importance of using the technology in concert with the country's own culture.

Questions of fairness and equity also arise when microcomputers are introduced into education. In many countries, microcomputers are already being used in private and other advantaged schools, raising questions of equal access and opportunity. The experiences in these schools can be used as models to facilitate the general introduction of microcomputers in the public schools. A cooperative attitude between schools within a country, and between countries in a region, can prove invaluable in the rapid introduction of microcomputers into the public school system.

Of perhaps even greater importance than the acquisition of computer hardware is the planning for the uses of computer hardware once it is installed. Experts in the field caution that neither instruction in programming nor repetitive drilling may be the best use of the microcomputer in the classroom. Judah Schwartz, codirector of Harvard's Educational Technology Center, suggests that teaching "real-life" applications such as word processing and database management may better prepare students for life in a technological society. Seymour Papert, creator of the Logo language, proposes that microcomputers be used to develop an entirely new way of teaching children. According to Papert, it does not go beyond what is common in today's schools; "It goes in the opposite direction."

BACKGROUND OF THE PROGRAM

In 1983, the Bureau for Science and Technology of the U.S. Agency for International Development (AID) asked the Board on Science and Technology for International Development (BOSTID) of the National Research Council (NRC) to organize a series of meetings to assess the implications of microcomputer technology for international development. This AID-funded program became known as "Microcomputer Applications for Developing Countries." The first of four planned meetings was held in Sri Lanka in 1984 and considered microcomputer applications in the areas of health, agriculture, and energy. At the concluding plenary session of that symposium, the participants agreed on a number of

policy recommendations for governments of developing countries and for donor agencies.

One major area of concern focused on education and training: education to provide computer literacy for the public and for policymakers; training to permit technical professionals to use application programs designed for fields such as health, energy, and agriculture; and high level technical training to create a corps of computer professionals. It was emphasized that both education and training must be carried out in the developing country context and must involve people with sectoral expertise rather than be confined to computer specialists.

These recommendations served as background for the Symposium on Microcomputer Applications for Education and Training in Developing Countries, the second symposium in BOSTID's program. This was held in Cuernavaca, Mexico, November 4–7, 1985, and was co-sponsored by the Academia Nacional de Ingenieria (ANIAC) of Mexico. Participants came from Argentina, Brazil, Chile, Colombia, Kenya, Pakistan, Panama, Peru, Trinidad and Tobago, and Uruguay, as well as the United States and Mexico. After an initial plenary session, the symposium was structured into three concurrent working groups on (1) training of teachers, (2) microcomputers and software for education at pre-university levels, and (3) microcomputers and software as aids to learning and research at the professional level. The participants then came together to present their conclusions and make recommendations based on their discussions.

ORGANIZATION OF THE PROCEEDINGS

This volume includes papers presented at the Cuernavaca symposium and the recommendations made by the participants. It begins with the papers that are concerned with the overall question of education in relation to information technology. The next chapters follow the general structural organization of the symposium, dividing papers in each area into overview papers and those reporting on specific projects. Finally, the report summarizes the conclusions and recommendations of the participants.

It became clear early on that participants from many countries shared similar concerns. Many emphasized the need for the educational community as well as other users of microcomputer

technology and policymakers to take the opportunity to put computers to work to serve their individual and national goals (see Brathwaite, page 59). In many cases, microcomputers are seen as an imported technology; however, their flexibility provides a unique opportunity for users in developing countries to mold them to their own needs. Many participants considered it important that software reflect each country's individual culture, especially in pre-university education (see Apel, page 151). This diversity would require that software be individually programmed for each cultural group. At the same time, the participants emphasized the importance of cooperation, both within Latin America and with the countries of the industrialized North (see Murray-Lasso, page 3, and Hughes, page 295).

The information presented in this volume is intended to provide background material for education policymakers in developing countries. The specific project reports, in particular, offer insights into problems that may arise and suggest tested methods for implementing microcomputer technology in educational systems.

William J. Lawless, Jr.
Chairman, Panel on Microcomputer
Applications for Developing Countries

Acknowledgments

The success or failure of international events hinges on planning, and on the competence of management and staff in particular. To ensure the success of the symposia conducted as part of this project on the use of microcomputers in developing countries, the panel sought local cosponsors who represent the scientific and technological interests of their countries.

The Academia Nacional de Ingeneria of Mexico embodies these concerns. We are grateful for their effort, their leadership, and their vision. Without the guidance and generous assistance of its current president, Oscar Gonzalez Cuevo, its past president, Marco Murray-Lasso, and Alejandro Lopez Toledo, this symposium would not have been possible. Special thanks are also due Enrique Sensores and Alfonso Toledo Casales of the Solar Energy Research Center in Cuernavaca of the Universidad Nacional Autonoma de Mexico.

We also wish to thank the staff of the U.S. Agency for International Development in Mexico, and, in particular, Samuel Taylor and Sidney Hamolski who have been especially helpful in organizing the symposium.

This symposium exemplified the opportunities that exist for creative cooperation in science and technology between Mexico and the United States. Future activities of this kind that strengthen and expand scientific exchange can benefit both countries and lead to greater understanding of mutual concerns.

Board on Science and
Technology for International
Development

MICROCOMPUTER APPLICATIONS IN EDUCATION AND TRAINING FOR DEVELOPING COUNTRIES

Section 1
An Overview

1

The Use of Microcomputers for Education and Training in Latin America

MARCO ANTONIO MURRAY-LASSO

A HISTORICAL EXAMPLE: THE CASE OF MEXICO

The use of computers in education has been a subject of discussion in Latin American countries for some time. The first computer in Mexico was installed in 1957 at the National University of Mexico. Many people (including researchers and academic administrators in the Department of Mathematics) opposed its installation, arguing that it was an esoteric technology that would soon disappear and that a poor country like Mexico should not be squandering its scarce resources just to conform to a fashion (Beltran, 1983). That computer became the core of the university's computer center. By 1970, the computer center had so much work that several departments and research institutes began pressing the administration of the university for computer centers of their own. This was roughly the same time as minicomputers were gaining in popularity, and their wishes were granted. This constituted the first step in decentralization of computing at the university.

At about this time, a master's program in computer science was initiated at the university, and many computers were installed throughout the country, with a heavy concentration in Mexico City. A few years later, microcomputers appeared on the scene, coinciding with the initiation of an undergraduate program in

computer engineering. In a few years, many other universities and technological schools had started undergraduate programs, and by 1983 we had more than 114 programs in Mexico (including 23 graduate, 74 undergraduate, and 17 for technicians) in 66 educational institutions (Instituto Nacional de Estadistica, 1984). Now, no one questions the advisability of using computers in university education, whether for administration, education, or research. As for the choice between large and small computers, few still support the idea of a large central computer with many terminals. Many people think that most of the needs of the university could be fulfilled by stand-alone microcomputers. For some research and administration problems, microcomputers connected to larger computers forming one or several networks should suffice. Some institutions of higher learning in Mexico, such as the Instituto Tecnológico de Monterrey, have gone a long way toward solving their computing problems with microcomputers.

Although the use of microcomputers in college education is well accepted and in some instances well established, the same is not true of elementary and high school education and training. There is still considerable debate about the introduction of computers in public schools at the lower levels. An important push in this direction was given by President de la Madrid's announcement that microcomputer prototypes, adequate for the needs of students at the junior and senior high school and college levels, had been developed (De la Madrid Hurtado, 1985).

THE ISSUES

There are at least two types of issues surrounding the discussion of the use of microcomputers in education. One set of issues is common to all those countries considering extensive use of microcomputers in education. The other set deals with issues pertaining to Third World countries, including Latin America.

The first set of issues, which has been amply discussed in the U.S. literature for the U.S. scenario, has to do with such questions as: What is computer literacy? How many students ought to share a microcomputer? At what age should computers be introduced? What should be taught with a computer? How many hours a day should students spend in front of the computer? How should the curriculum change because of the presence of the computer? Should the use of computers be of the programmed instruction

type or of the menu-driven environment type? How should the educational software be evaluated? How do we go about training teachers for the use of computers in education? What should be the roles of computer clubs and camps? How should computers and software be financed? How can equality of opportunity for access to computers be ensured for those of different races, social levels, and regions of the country?

The Latin American issues include all those previously mentioned, as well as others. For example, given the extreme lack of resources, is computer-aided education really worth the sacrifice? That is, can a country with many children attending school without having had breakfast afford to spend money on computers rather than on free breakfasts for school children? Where should the computers for education come from? Should the country try to manufacture them or import them—generally at lower prices? Should a country try to develop its own educational software, or should it use software developed in advanced countries, perhaps adapted to those cases in which there are important differences, such as language? Should the Latin American countries develop hardware and software cooperatively—and if so, in the case of software, on what topics, and in the case of hardware, what kind of machines? Should the hardware used in Latin America include the latest technology, or should 8-bit machines that can be obtained inexpensively be used? Is normative legislation helpful, or should decisions be left to market forces? Would legislation designed to promote the use of computers in education be helpful? What portion of their gross national products should Latin American countries allocate for computers in education? How can the advanced countries help the Latin American countries introduce computers in education?

Discussion of the Issues

It is not my intention to delve deeply into the discussion of the issues, as that is the main purpose of the symposium. My intent is only to point out the fact that this discussion is of a different nature than that occurring in the United States. Perhaps some of the issues may be easily resolved, such as collaboration between Latin American countries to develop software that can be used throughout the region. Although a common ground would

have to be reached relative to topics, points of view, quality standards, and hardware with which to operate the software, I suspect that few would oppose such an idea. Moreover, the savings of resources could be quite substantial. On the other hand, some of the issues are apt to cause heated discussion. One, for instance, is the normative legislation on the use of computers in education. Here we are referring to national policy, which may forbid importing microcomputers and software for educational purposes. The arguments could range from the industrial protection of local microcomputer manufacturers and software developers to the protection of the national cultural heritage of the country. It is widely accepted that the United States has "culturally colonized" Latin American countries through its movies, publications (particularly technical literature), television, wire service, and music industries. The latest form of colonization has to do with information stored in data banks and microcomputer software. Regarding the latter, one often hears criticism that the popular packages, such as spreadsheets, database managers, word processors, and languages have most of their manuals, error comments, and other facilities in English, in spite of the fact that they are marketed in many Spanish-speaking countries. I recently heard a talk in which a teacher from the city of Puebla bitterly complained about an elementary software package for teaching the alphabet that he had ordered from a store in Mexico City. The package had received rave reviews in several microcomputer magazines, such as *Creative Computing* and *Byte*. Great was his disappointment when he found that when he pressed the letter "A," beautiful red apples appeared on the screen, despite the fact that the Spanish word for "apple" is "*manzana*." In my own experience, I have had to struggle with word processors sold in Mexico in order to be able to include accents and other Spanish characters.

Many educators feel that languages intended for the education of small children, such as Logo, should write their commands in Spanish so that children can more easily remember the commands and abbreviations. They argue that a command such as "LT," which is short for "left," means nothing to a Spanish-speaking child, since the Spanish equivalent of the English word "left" is "izquierda." It would be a simple matter to translate the commands of Logo into Spanish, but it would require some standardization of the words used, because even within the same

country, some groups use "adelante" for the English word "forward," whereas others use "avanza." There are those who favor the use of English because of the large amount of literature both in book and magazine form that contains Logo listings that could simply be typed into a computer; if the computer had a Spanish version, the programs would have to be translated, a laborious job in the case of large programs. The group favoring the Spanish version of Logo are quick to respond that small children seldom take programs from magazines, while the English Logo supporters counter by suggesting that as a child grows older he would have to learn the English version, though this contradicts Papert's well-publicized claim that Logo is a language with which a student can grow without having to "unlearn" anything as his needs increase (Papert, 1980).

There may therefore be a tendency for some Latin American countries to legislate that all educational software for elementary education be developed in the country and be approved by the educational authorities. One of the dangers of such legislation would be that excellent, culturally undamaging software developed outside the country might not be available to the children of that country, resulting in a loss of opportunity. Such might be the case with software for teaching mathematics, which is culturally transparent, generally speaking.

Another issue, teaching methodology, is common to the advanced and developing countries, but is treated differently by the two groups of countries. There are some in the United States who claim that programmed instruction as used in the teaching of basic skills (such as reading, arithmetic operations, and typing), is the only computerized teaching methodology supported by solid experimental results (Suppes, 1979). They argue that other methodologies, such as simulation and creative computer environments, have yet to be proven effective, adding that no solid evidence of their efficiency has been documented in research studies other than casual observations of individual students. In turn, the defenders of creative computer environments answer that creativity is such a complex concept that tools for measuring it have yet to be developed. Defenders of the two positions are evenly paired, and the discussion continues in the United States without either group clearly dominating the other.

In Latin America, however, the creative computer environment methodology seems to have the support of pedagogy theorists

and psychologists, whereas teachers tend to support programmed instruction. In Latin American countries, teachers tend to have less schooling than pedagogy theorists and psychologists, who usually have college degrees, while the former have diplomas from a normal school. Because of this, the creative computer environment group, who is most often in charge of planning, tends to dominate the field intellectually. Thus, we are in danger of observing the implementation of programs that completely ignore the benefits of computer-aided drill and practice, thereby throwing away years of experience and useful results, such as those of the Plato Project (CERL, 1977).

A second common issue between the advanced and developing countries is the question of whether it is really necessary to introduce computers in elementary education on a large scale. Judging from numbers and trends, the question seems to have been answered in the affirmative in the United States. Typical arguments point to the fact that computers are here to stay and therefore, should be introduced into the educational system as early as possible. I have no argument against this, although it should be pointed out that some past predictions about technological advances have been totally erroneous. In 1870, a high British government official commented that the recently invented telephone would probably be of some use in the colonies, but he could see little use for it in the United Kingdom because of an overabundance of messengers. In 1927, senior editors of *The New York Times*, after seeing a demonstration of television, wrote a story declaring it a fine scientific invention, but one with no commercial future. In 1947, several leading scientists were asked to forecast the number of computers that would be required in the United States. Their initial forecast was 12. It was subsequently revised to 50 (Dupont, 1985).

In the examples provided, the possibilities of a new technological device were underestimated. There are also examples of overestimation. The great use of television as a medium for improving education has gone largely unrealized. In many schools in both advanced and developing countries, many types of audiovisual aids and language laboratories are gathering dust after overly optimistic expectations. In the United States, many microcomputers are unused because they were introduced into schools before proper planning took place. Be that as it may, the popularization of computers in education has a positive effect in advanced countries that have a hardware and software industry, as it provides

jobs and economic growth. On the other hand, for developing countries with no such industry, the introduction of computers in education increases the deficit of foreign currency and promotes unrest among the grossly underpaid teachers, who accuse the government of spending precious, scarce resources on seeming luxury items rather than increasing their salaries.

CONCLUSION

Some of the issues surrounding the use of microcomputers in education in Latin America have been put forward. All the issues currently under discussion in the United States and other advanced countries have to be addressed, along with others that treat Latin America as a region made up of developing countries. A brief discussion of some of the issues has been presented to stress the fact that even the common issues have to be seen in a different light. Something we can all agree on is that collaboration between Latin American countries, many of which share a common language and have similar cultural backgrounds, is a step in the right direction. Undoubtedly, efforts will have to be made to reach a common ground. Likewise, cooperation with advanced countries which have considerable experience in the area, such as the United States, promises to be very fruitful. Again, a common ground must be searched for and found if the national identities of the different developing countries are to be respected, while the interests of the advanced countries are taken into consideration. It is my hope that this meeting is the first of several to provide fertile ground for this collaboration. The fact that distinguished representatives from so many countries are involved is an excellent sign. Let us all work toward this end in the next few days, finding new solutions to the urgent problem of providing better education for all the inhabitants of our countries. We must ensure these new educational solutions are appropriate for the world our children will inherit. It certainly is worth the effort, since the beneficiaries of what we forge here will be the heirs of everything we own and everything we are: our land and all our wealth, the responsibility of administering justice, governing our nations, building our churches, writing our books, perpetuating our race, and carrying on as the trustees of our sacred honor.

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2

Technology Transfer in Educational Computing: Toward a Non-Magical Approach

ALVARO H. GALVIS

LOOKING AT THE PROBLEM

The transfer of educational computing technology is an unavoidable crossroads for the educational sector. There is no way to ignore the impact of computers in our society even if we live in developing countries. The educational sector cannot leave the transfer of educational computing technology to the discretion of the suppliers, nor can it indiscriminately accept technology transfer. Either alternative would be an open door both for increasing technological dependency (in computing as well as in education) and for widening the technological and educational gap among countries. Thoughtless technology transfer can be a path for amplifying crosscultural diffusion, a process that has intensified since the arrival of communication devices, and one that can weaken local cultures when it serves only to transplant foreign culture.

What can we do in developing countries to succeed in appropriately transferring educational computing technology? What conditions are pertinent for such a transfer so that it does not become just a new path for maximizing underdevelopment?

This paper does not intend to present final answers to these questions. It attempts to explore the topic from several perspectives concurrently, so that people in the educational sector of developing countries can channel their efforts towards aspects they feel are most likely to benefit them. The paper will focus on the trends in transferring educational computing technology; it will emphasize an analysis of related magical ideas and their impact on our countries. The paper will conclude by analyzing considerations that are critical to our truly profiting from the potential of computers in education and from related technology transfer.

Educational Computing and Technology Transfer

We must not allow a magical vision of educational computing—a belief that computing is a panacea that solves all of our educational problems—to pervade our thinking. Such a perspective, unfortunately, is not uncommon, and it is usually being resorted to when we simply transfer solutions (technological end-products) instead of the knowledge needed to find the solution to a problem (technology, know-how).

A magical vision of educational computing may lead us to a great disenchantment, as was the case in the gypsy's story in *One Hundred Years of Solitude.* Garcia Marquez (1967) tells of the gypsies that used to come to Macondo from time to time, bringing with them the latest discoveries from the wise people from Memphis, that is, the latest technology. One year they arrived with ice, "such a great invention of our time" (p. 23). Its arrival allowed Jose Arcadio Buendia to find the meaning of his dreams about a mirror-walled house. He thought that in the near future it would be possible to make blocks of ice on a great scale from ordinary water and use them to build the new houses of the village. Macondo would no longer be a tropical place, where "hinges and knockers were twisted by the heat," but a temperate one (p. 27).

When I think of the transfer of so many educational computing products—software, lesson plans, instructional packages, and even educational priorities—without a sound analysis of the embedded technology and of the problems it is intended to solve, I feel we have become the new, temperate Macondo.

A magical vision of educational computing technology would increase dependency on the producers of technology. As Clayton

(1974) mentions, such a vision of technology is common in people from nontechnological societies who are used to looking at technological products (plans, machinery, executives' behavior, clothes, and so on) and saying, "how can I use this wonderful product?" instead of looking at the processes that led to the solution and the basis upon which such a technology was developed. The magical approach, which does not help users to learn how to solve problems but only how to use certain products to solve certain problems, creates a dependency, not on the technology itself, but on its producer. Each time we have a new problem we need to find a problem solver, since we have not transferred the methods used to find solutions along with the technology.

EXPLORING THE IMPACT OF COMPUTING IN EDUCATION

Can we reach a realistic (non-magical) vision of educational computing technology without studying it—without adapting it and applying it to the satisfaction of our own educational needs? Definitely not. These are necessary conditions for education to incorporate such a technology, both in developed and developing countries.

The first questions we may want to address deal with the changes that educational computing may bring. Let's say before actually getting the equipment we would like to know, What can be done with it? Or from another perspective we might want to know, What significant improvements might educational computing produce in education? To answer such questions, we may start looking at major changes that computing has produced in the world we live in. Later on, we may want to go into the educational sector and analyze the changes that computing has produced, or will produce. Both aspects will help us make decisions about the relevance of the changes that educational computing will carry with it.

Continuing and Specialized Education

It is generally accepted that computers and informatics have produced significant changes in the economic, social and political aspects of our lives. For example, a recent study of the impact

of information concerning Colombian economic and social development points out that informatics, defined as the science and industry of information treatment, has contributed to the modification of working procedures and systems and, consequently, to the educational qualifications required of people who contribute to the production process. As computers play a role in more sectors, demands are placed on the educational sector to prepare people to survive in a world permeated by computing and informatics.

Adult education processes are especially challenged by the new technology. Its incorporation increasingly demands that more people understand the machine's capabilities and are able to use it accordingly. In this way, computer literacy and the ability to use computer programs become essential, but we must ask, "Is such literacy by itself an improvement of the educational sector? I think the answer is, No, not necessarily."

First of all, on-the-job and continuing education classes dealing with computers are the minimum necessary for education to be relevant. However, they do not imply an improvement in the quality of education. It is the scope of this kind of education that is critical, in my opinion. From the point of view of technology transfer, if we were to limit such educational processes to the knowledge necessary to use end-products, we would only be strengthening dependency. It would be a new way of maximizing underdevelopment. The relevant question has now become whether current strategies for transferring technology from "center" countries to those on the "periphery" allow the complete transference of knowledge which would be necessary as a basis for sound educational processes.

Studies by Hveem (1983) show that because of the relative advantages that a new international division of labor brings to center capital, industrialization is beginning in peripheral countries. Hveem establishes that such a new paradigm is not enough to overcome technical, structural, economic, and sociopolitical dependency. Technical dependency simply means that technology circulating to the periphery in "embodied form" (machinery, turnkey factories, and various capital goods) remains dependent on the center for its maintenance and reproduction. Structural dependency is based on the "packaging" of technology (which imposes patterns to control the circulation of the technology to the periphery). It is also caused by the dependency of the periphery on the innovative and reproductive capacity of center-based science

and technology systems. As a rule, the periphery is at the receiving end of the final stage of a technological process comprised of invention, innovation, application, and final production. Hveem states that the great majority of periphery countries really does not take part in this chain, but instead receives the final product. Furthermore, in those countries where a division of labor in production exists, little research and development is really transferred, since R & D transfer takes place mostly in low-technology sectors where monopolization is largely absent. In high-technology sectors, relocation, even to other industrialized countries, is negligible (Hveem, 1983:281–284).

It is quite evident that current patterns of technology transfer between countries by themselves will not allow developing countries to educate themselves significantly concerning imported technology. It will be necessary to modify imports through active domestic adaptation and other efforts in order to integrate the imported knowledge into the development process. As Hveem says:

> In the absence of such an integration, no real transfer of technology takes place. For it to occur, three conditions would have to be met. First, there would have to be an identifiable recipient in the periphery country with the capacity to make use of the technology according to self-defined goals. Second, all aspects of technology concerned which are necessary for it to be put into stable productive use by this recipient would have to be transferred. Third, there would have to be a clear net gain for the recipient in the exchange process, so that the resources the recipient accumulates would have to be greater than the resources transmitted to the other side (p. 285).

It is also important to reassess the value that we give to locally generated technology; such technology is usually referred to as "traditional," implying obsolescence and inferiority. Whether the traditional technology is in fact obsolete, or for which concrete purposes it may be obsolete, is often not demonstrated. And in many cases we know no more about the irrelevance or inappropriateness of foreign imported technology than we do about traditional technology.

These ideas would serve to reinforce technology transfer processes by training whatever specialists are required to perform functions such as those suggested by Hveem. However, in order to avoid a "reverse technology transfer" (because of internal brain drain), local policies that link technology transfer efforts with local production goals should be defined and implemented. In this

way, continuing and specialized education about computing form part of an integral strategy for a real transfer of technology and seem to have great potential to help our countries succeed in the development process.

Computing and Education

Another perspective worthy of analysis is the potential of computing in education itself. This component has several elements. We could talk about the pre-microcomputer applications in terms of administrative and research-oriented applications. There is no doubt about the importance of computing in these settings and the effects it has had in transferring knowledge with real local benefits. But, it is important in this symposium to focus on the uses of microcomputers in education; uses that flourish because of the effective arrival of computers into the core of the educational sector, that is, into the teaching-learning process. We should therefore analyze the so-called computer education—as well as computing tools for the teacher and the learner, and computer-based learning environments.

In any of the three major approaches stated above for putting computers to use in education, people from developing countries may encounter very interesting technological products and be tempted to simply transfer them along with the embodied technology. As we mentioned before, this would be the worst of the approaches—a magical one. People looking at trends as a basis for technology selection would be disenchanted. There is no agreement concerning the major function of computers in education. There is a coexistence of the three mentioned approaches, and each of them has significant possibilities and disadvantages for those interested in educational computing (Taylor, 1980).

The importance that developed countries have traditionally given to computer education is well known. A study by the Johns Hopkins University (CSOS, 1983–1984 in Delval, 1985) shows that at the elementary level 36 percent of computer time was devoted to computer literacy, and at the secondary level 64 percent was devoted to computer education. Another study, sponsored by UNESCO (Hebenstreit, 1984), shows a slight shift from this emphasis in the United States to computer-aided instruction (CAI) and tool-management. In Britain, the shift is in the opposite direction. Earlier emphasis was on CAI through the NDPCAL project,

while in the recent MEP project the emphasis is on computer literacy instead. For our purposes, looking at the reasons for a choice and at the research results concerning each of the approaches to computer education is more important than conforming to the trends.

Computer Education

Those people who advocate programming as a major computer use in education conceive of computer programming as a second literacy (Ershov, 1981:5). They see it as a means of enhancing explicit capacities already existing in human beings, such as those for solving problems. Because of this, they consider computer programming a new fundamental resource for developing such intellectual skills as structural thinking and problem solving by means of heuristics. This educational idea is echoed by other social and economic perspectives on computer programming. Hebenstreit (1984:10) mentions that a kind of social pressure to teach computers and programming even to young children has fostered this approach. This is because in time of economic crisis and increasing unemployment, parents believe that a knowledge of computers and programming will help guarantee their children's employment. Mass media has also played a significant role, promoting false ideas about the level of professional qualification required to find a job in informatics (e.g., "Be a man of tomorrow—buy a microcomputer," or "Become a programmer—learn BASIC in three days"). From the perspective of technology transfer, here we may also face a magical approach.

On the one hand, those listening to these educational ideas on computer programming but not understanding the knowledge that is required to implement them may think that just by learning a computer language people will improve their thinking skills. Experience shows that this does not happen. Many people have attended and passed computer programming courses without improving their thinking skills since the focus was on learning the language, not on learning its use as a means for acquiring problem-solving skills. Many of these people hardly know what to do with a computing language once they have learned it. Some people argue that such a counterproductive effect is a result of the computer languages that are being taught. A shift from BASIC (a high-level computing language available in many machines) to Pascal

and Logo (structured computing languages) and now to Prolog (a logic programming language) does not ensure that people will learn to think by learning the language. An open learning environment, purposeful, non-authoritarian, should be maintained while teaching computer programming so that it may become a means of helping people develop their thinking skills (Dwyer, 1974; Papert, 1978, 1981).

On the other hand, people who think of computer programming as insurance against unemployment will realize from statistics on developing countries, that there already exists a significant amount of unemployment for less qualified specialists in informatics and such people are obliged to go through lengthy and difficult professional retraining before being able to find new jobs (Hebenstreit, 1984).

Computing Tools for the Teacher and the Learner

In addition to being the training vehicle for computer programming, microcomputer programs provide a set of tools for people to use. Tools by themselves are important, as they help people do things easier and faster. They may preserve time and intellectual energy by taking over necessary but routine clerical tasks of a tedious, mechanical nature. This perspective, however, should not lead us to consider that any tool we can obtain for education is worth having.

There are general purpose tools, such as word processors, database management packages, electronic spreadsheets, and statistical packages. They are quite open-ended tools, and teachers may use them for improving and enhancing current work practices in the school setting. For example, a word processor could be used both to alleviate the burden of clerical tasks, and to help students improve their written communication by concentrating on the idea instead of the format. On the other hand, there are educationally oriented tools that educators could use, with the caveat that their selection should involve more than user-friendliness, technological compatibility, and cost. For example, a computer-managed instruction (CMI) system may not be worth having even though it alleviates the burden of individualizing the instruction and fits the characteristics of our computing facilities. Depending on the designer, it could be too rigid or too simple a tool and only capable of managing a cookbook-type curriculum. Or it could impose

an educational philosophy which may not be compatible with the educational ideas desirable in a school setting.

Educational technology products which are available as computer-tools are not content-free. They bring embodied educational ideas which need to be transparent if a discriminative transference is to be done. And for such a transfer to be complete, further adaptation and application to the satisfaction of our own educational needs is required. As a consequence, technology transfer concerning educational computing tools is also a field where something other than a magical approach ought to be used.

Computer-Based Learning Environments

The two educational uses of computers described above are shown as potentially powerful means for helping students increase their intellectual skills. As may be seen, the essence of technology transfer in both cases is not computing itself, but educational technology attached to the use of computers. A similar effect can be expected in computer-based learning environments. Computer-based learning environments include specific teaching-learning applications that have been designed and produced to help people learn something. There is no single way of doing this, and the evolution of educational technology has had a great influence on how this is done.

Educational technology is a practical field for the systematic application of scientific knowledge to the solution of educational problems. Case and Bareiter (Chadwick, 1983) note that educational technology has evolved significantly: in the early stages, it had practically a behavioristic-psychological orientation, emphasizing the characterization of educational situations as systems, with a subsequent search for efficiency and efficacy. Educational technology also stressed the use of specific objectives and sometime rigid instructional design paradigms. But the field has evolved, and the behaviorist bias has first turned toward cognoscitive behaviorism and more recently toward cognoscitivism. In this frame of reference, it can be understood that two poles for the systematic creation and use of instructional environments are in use; which of these should dominate is under discussion. Thomas Dwyer calls them the "algorithmic" and "heuristic" approaches (1974).

According to Dwyer, an algorithmic approach is oriented toward defined, predetermined sequences of activities for achieving

predetermined, measurable goals. It stresses a "pipeline" teaching model in which an efficient transmission of knowledge is intended by the designer. This may be called designer-controlled educational computing. Reasons for using an algorithmic approach are based on the relative superiority that educational technologists assign to the computer as compared with other man-created instructional media. As Gagne (1974) and Briggs and Wager (1981) mention, with computer support it is possible for a good instructional designer to simulate any of the external events that promote learning, such as providing differential feedback and reorientation, depending on the student's performance.

The idea of supporting critical events in instruction with the aid of computers has lead people to produce tutorials, drill-and-practice systems, and multimedia-systems controlled or managed by the computer. These programs have the merit of giving structure and precision to an otherwise fuzzy process and of encapsulating that precision in a reproducible form. However when the appropriate educational content is not used, the programs may simply become amplifiers of low quality material, a phenomenon that unfortunately happens with great frequency. In fact, related studies show that among the approximately 7,000 courseware products available in 1984, only five percent were assessed as top quality products and another 25 percent as being of acceptable quality (Delval, 1985).

The low quality of many algorithmic-approach products is not their only drawback. More important is the impact of these products on education. It is argued (Maddux, 1984; Delval, 1985:9) that there are traditional uses that may be of interest but that do not open new avenues to education. With these, teachers may have a new way of doing the same thing they have always done—transmitting accumulated knowledge—but that does not mean a real change in education.

A nontraditional approach is advocated by saying that computers may be a means of transferring control of the act of learning to the student. This may mean a shift from computer-assisted instruction (designer-controlled computing) to computer-assisted learning (student-controlled computing). Using this approach, computer-support to the students would allow them to create their own models of what they learn instead of imposing the teacher's interpretations (models) of the subject of instruction. "Student-controlled computing means that the student uses technology to

develop and test his own models; that the student learns to deal with failures: that it is in his power to debug the procedures that caused these failures. He also develops a powerful store of ideas ("ways of thinking") from his contact with real computing science" (Dwyer, 1974:97).

Paths for implementing this nontraditional approach are based on heuristic strategies and cognitive psychology. Heuristic strategies favor the exploration and discovery of microworlds through open-ended, student-controlled procedures. Cognitive psychology principles guide the teachers in inspiring, guiding, and propelling the learners to assimilate good ideas from the past and help teachers accommodate these ideas in their learning structure using their own models (Piaget, 1970). Heuristic computing devices include both simulators (educational games, high-level user-friendly computing languages such as Logo or Karel the Robot), and some general-purpose computing tools (word processors, spreadsheets, databases). Heuristic devices do not tell the learner what to do; they explain how to learn what he wants to do. They provide support for the learner to discover the knowledge he is seeking and to make his own interpretation (model) of these ideas.

Could we discard any of these approaches? Definitely not. "We are having access to an unprecedented technology upon which to build educational systems that distinguish between the transmission of past heritage, and the eliciting of new understanding" (Dwyer, 1974). Both student-controlled computing and author-controlled computing make important contributions to an educational system that needs to build upon past heritage but also needs to go further, helping people acquire a "liberating control" of their lives.

Toward a Non-Magical Technology Transfer of Educational Computing

All aspects of educational computing involve a challenge for people interested in the field. We may be tempted to follow the path of "magicians" merely by transferring the products of educational computing technology. If we are not to follow that path, what should we do to implement a non-magical approach to the transfer of educational computing technology? Attaining certain objectives would be critically important in avoiding this approach:

- To encourage the definition of local policies that really promote a technology transfer from center to periphery. This would include both a greater integration in research and production activities as well as creation of local projects that fulfill needs based on local priorities. Only from a complete dimension of technology transfer is it possible to overcome dependency problems.
- To make significant efforts to train local personnel in the foundations of both computing technology and educational technology. This would be a very important avenue for liberating developing countries from technical and structural technological dependency, and would also be the basis for a real technology transfer.
- To reinforce local research-oriented activities to generate new knowledge both in computing and education and to assess existing knowledge, experience, and products concerning local educational needs.
- To give support to local projects where educational computing ideas can be developed or adapted, implemented, and tested, and where technology transfer takes place in a controlled manner.
- To discard the idea that educational computing projects must produce immediate results. Political pressure for results may lead to indiscriminate technology transfer which, as well as causing negative results early on, may damage the innovation's potential.
- To encourage a revision of curriculum strategies and related teacher training, in order to implement a shift from what Margaret Mead (1950) called vertical to horizontal education. Ideas concerning a nonvertical view of education are not new; most educators agree with them. They are not put into practice however since change implies not only new knowledge and tools, but also a catalytic environment. Computers do not necessarily implement a different view of education. We may have them in place, but if the educational setting is not ready and willing to change, machinery and software would be worthless.

Should we wait to have computers in our schools before we begin to think about the benefits they may bring and to face the

major challenges they present? Educational computing is not currently under the control of educators. Vendors, producers, and the public in general are applying pressure for the introduction of computers into education and for an increase in computer education. Should we wait for others to make educational decisions? Should we just wait and see what happens? Again, this would be another path for maximizing our underdevelopment.

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3

Practical Training in Microcomputer Systems

GERTRUDIS KURZ DE DELARA

There is a very large demand for personnel trained in the field of microcomputer systems, especially if they have knowledge of both the hardware and the software of these systems. This demand comes not only from centers for teaching and research, but also from industry, business, administration, and hospitals, to mention some examples. Their training is certainly a very important task for our centers for education, and it is evident that it is not enough to simply train them as users of ready-made programs.

Some of our students of physics and engineering who are interested in computation want to become professionals in the computer field itself; others want to use computers only as a tool for solving problems in their own fields. This latter group is of interest to us in our cybernetics laboratory. Training, we have learned, must be a form of apprenticeship rather than classroom learning. Of course, some introductory classes are necessary to familiarize students with basic computational methods. The main part of their training however is in practical application: students must learn to handle at least one system by themselves, along with its possibilities for different areas. Principally, they must learn to formulate problems in such a way that they can be resolved with the help

of computers. This has to be learned by working in collaboration with experts in the field who can serve as guides. In my opinion, what is the most difficult part of this training is teaching the student how to make a very clear, explicit, and detailed description of either the problem to be solved, of the phenomena to be simulated, or of the model or instrument to be designed and constructed.

Once the requirement has been clearly stated, translating this statement into operations on the computer can be taught in programming classes, and, after acquiring experience through the use of machines for a great number of different applications, the student learns by self-instruction. This efficient method of training requires however that we place at the disposal of the student an adequate system for a period of time sufficient for him to acquire experience, be it in translating the formulation of a problem from natural language to a programming language, in carrying out the simulation of a phenomenon, or in translating a clear and detailed design of a model or an instrument into operations on the system with which he works. Because this process is also very useful for the student's command of his own subject matter and because it calls his attention to any vagueness in his concepts and helps him clarify his ideas, microcomputer systems can be considered a very powerful tool in instruction at the university level. However, this is only true when the student has received clear guidelines from his instructors or from more experienced students, and when his system's documentation enables him to learn most of the applications of the system by himself, without constantly resorting to a teacher. This last condition unfortunately is seldom satisfied, and frequently we are forced to rewrite the documentation so that it fulfills its intended purpose.

The conditions in our universities often make it difficult to carry out the type of training described for our students. To begin with, there is a shortage of qualified teachers; many teachers leave because they find much better working conditions outside the universities and a similar situation exists among the students who are already well trained, who could in turn train beginners. If to this we add the bureaucratic insistence on centralizing all purchasing of computer equipment, whether large machines or microcomputers, it is clear why there are not enough tools that can be put into the hands of the students being trained. The bureaucrats still have not understood that microcomputers are

made to be used individually and are perhaps a lever for that decentralization so often spoken of.

Naturally, the conditions of training are easier in fields in which the necessary programs are standardized so that ready-made programs can be taught and used. What concerns us here is finding the best way to coordinate the work of those who know enough about computation with the work of researchers from various other fields who are not prepared to study programming in order to utilize computers. We find that our own students (who have learned how to formulate their own problems in a programmable way) are able to obtain information from scientists in other fields that they need to help them in their work and to write programs that function as they have imagined.

4

Classroom Uses of the Computer: A Retrospective View with Implications for Developing Countries

JAMESINE E. FRIEND

Although mainframe computers have been used in education for 20 years in the United States and in Europe, this technology has not been widely used in developing countries, to a large extent because of cost: both the initial investment and the operational costs of mainframes have been too high. However, recent advances in hardware technology are reducing the costs considerably, and educational applications of large computers are becoming increasingly affordable in developing countries. In this paper, the current status of educational applications of computers is discussed with a view toward predicting the direction of such applications in developing countries.

TWO DECADES OF COMPUTERS IN RESTROPECT

Historically, computer use for education became possible with the advent, in the 1960s, of the time-sharing operating system. Within only a few years, interactive programming languages like BASIC were developed, as were primitive precursors of today's word processing programs. The time-sharing systems that made these programs possible allowed a number of people, each using his own terminal, simultaneous access to the computer; the method used was a "round robin" in which the computer would serve

each person in turn for an instant before going on to the next person. Because of the speed with which the computer worked, it appeared to each person that he had sole use of the computer. (This at least was the ideal; in practice, too many simultaneous users or operating programs that required a great deal of computer time could slow even the fastest computers to the point where the time necessary to complete the round robin became noticeable to all.)

With the advent of time-sharing, computer-based instruction became feasible, and the first instructional programs were implemented in the early 1960s, shortly after time-sharing systems became available commercially. At that time, students were expected to go to the computer; terminals were located at most a few hundred feet from the physical computer. By the mid-1960s, remote terminals became more common; students worked at terminals located at hundreds or even thousands of miles from the computer, with communication by means of telephone lines. The cost of telecommunication led to the use of the newly developed minicomputer for educational programs on a time-sharing system; its lower cost made it feasible for it to be shared by a smaller group located near the terminals.

The move from mainframe computers to minicomputers was part of a historical cycle: At first, computers handled only one task at a time. Then, as computers became more powerful, there was a trend toward connecting more and more terminals to each computer so as to share the cost of the computer over more users. As the terminals increased in number and moved away from the computer, the cost of telecommunications increased and there was a reactionary trend toward using less powerful and less expensive computers that could serve fewer people but did not entail extravagant telephone line costs. The current manifestation of this trend is the widespread use of microcomputers, generally serving one user at a time. The distinction between microcomputers and larger computers is becoming blurred from the individual user's point of view; the only distinction that promises to remain clear is between a personal computer and a shared system, be it a microcomputer, minicomputer, or mainframe.

The "power" of the computer being used has an effect on the nature of the educational programs that can be implemented. Power, which serves as a distinguishing characteristic between mainframes and microcomputers, has several attributes. One is

the speed of the machine; another is the amount of storage space available. Both the speed and the storage space have several constituents, and there are interactions between speed and space. The speed of the central processing unit (CPU) of the computer is not usually a limiting factor because most are so fast that, for educational purposes, slight differences are unimportant. The speed with which the computer can access data from remote storage devices, such as disks or diskettes, is often more significant in educational programs since most of the instructional messages are stored as data on a disk. In addition, machines with very small memories cannot hold all of a large program in memory at one time and must store part of it on a disk; the program is thus executed in pieces, with each piece brought into memory from the disk as it is needed. If a program is quite small and does not use much data, even the smallest microcomputer can run the program at incredible speeds; a very large program however might run so slowly that the user would lose patience. The speed of access, then, combined with the size of the memory determines the apparent speed of the program. In addition to its impact on apparent speed, storage space (primarily disk) may impose additional constraints: some of the large educational programs that have been implemented on mainframe computers will not fit into the storage available on the smaller microcomputers. This fact has greatly influenced the direction of educational software development in recent years.

Peripheral Hardware

Besides the computer and auxiliary storage devices, display devices and other "peripheral" hardware have influenced the style and, to some extent, the content of educational programs. Two types of peripherals are of great importance in the design of instructional programs: output devices that allow the computer to communicate with the human user, and input devices that allow the user to communicate with the computer.

Until the 1970s, typewriter terminals were the most common output devices, for the most part video displays have now replaced them. Keyboards continue to be the most common input devices. All can display printed words, so most instructional programs communicate primarily by means of printed messages and depend upon the student's ability to read and write. Video displays, however, can also be used for a dis lay of pictures, even

moving pictures. Although most video displays cannot show high-quality pictures, the use of even simple illustrations can enhance instruction greatly in many subjects. In a few subjects, color can also enhance the educational quality of the program. Displays of pictures, especially pictures that move, require a great amount of power and disk storage space. For this reason, the programs that use graphic displays are usually quite limited in content and total instructional time.

Not all subject matter can be conveyed by means of pictures, so oral communication is also useful for students who are not completely literate. A variety of output devices allow computers to talk. At present, all of these devices have some disadvantages—the storage space required, the low quality of the speech, or the cost of the device—but great progress is being made with synthesized and digitized speech, and there is much interest among educational programmers in such devices. Hundreds of educational programs are now available that use audio output. Not all are aimed at young nonreaders or other illiterates; many educational topics, such as music and foreign languages, are best taught with audio output even for literate students.

The computer's ability to input (and understand) human speech lags considerably behind auditory output, although even in this area there have been significant advances in the last few years. It will not be long before there will be effective, commercially available educational programs that will not only talk to their students but will also listen to spoken answers.

FACTORS INFLUENCING THE DESIGN OF EDUCATIONAL PROGRAMS

The development of educational programs for computers is influenced by these hardware developments, and, as a result, there has been a change in the flavor of educational programs over the last twenty years. There have been two main streams of development work. The earlier one started in the 1960s with the production of very large programs for mainframe computers. The concern was to provide instruction that could be used within the framework of the conventional school system. The programs were designed to be used as a part of the ongoing instruction, with students receiving some part of their daily instruction from the computer. Computer laboratories, containing dozens of student

stations, were built in schools, and students came to the laboratory regularly. There was a great effort to integrate the content of the computer-aided instruction with the teaching that took place in the classrooms. Teachers were not always intimately concerned with the operation of the computer laboratory, but they were kept well-informed of their students' progress and allowed to make decisions about the placement of their students in the computerized courses. Many of the computer-aided courses available at that time could supply months or even years of instruction. With a few notable exceptions, the instruction was highly verbal; messages were delivered to students by means of printed words, and the students responded by typing on a keyboard.

The second stream of development work had its roots in some of the programs developed for mainframe computers in the 1960s but did not come into full bloom until the late 1970s and early 1980s when microcomputers became more widely available. This stream of computer-based instruction consists of smaller programs, with more emphasis on motivation of the student than on cognitive concerns. The programs often use sound effects and graphics, frequently in color, sometimes in motion; these programs are generally more appealing at first glance than the older programs. Often, however, there is little content; many programs contain only enough material to occupy a student usefully for half an hour or an hour, perhaps in five or six 10-minute sessions. The pedagogical value of the new, smaller programs is, in some cases, extremely low. This is not to say that all of the earlier mainframe programs were pedagogically sound, or that all of the later microcomputer programs are not; I am only pointing out a tendency to sacrifice pedagogy for motivational qualities. In any case, it is very difficult to make a reasoned judgment about the relative effectiveness of the newer microcomputer programs since so few of them have been adequately evaluated.

Another tendency in the design of the smaller, newer programs is toward basing the decision about what content to include more on the capabilities of the machine than on the needs of the students. In some ways, this is good. Some of the older, more comprehensive programs did not adequately take into account the constraints of the medium; in their effort to provide complete courses of instruction, they sometimes included topics that would have been better taught by the classroom teacher. In other ways, it is not desirable to let the medium determine the instructional

content; we may end up teaching only those things that are easy to teach.

The explicit goal of computer-based instruction has been to provide individualized instruction. But there has been a continuing discussion for years on exactly how this should be done. One of the areas of most disagreement has been in the way decisions about the sequence of instruction should be made. Some designers feel that the control should be in the hands of the student (or teacher), while others feel that it is the duty of the program designer to provide mechanisms that will collect and analyze response data from the student in order to make optimal automatic decisions about the sequence of instruction. The arguments have to do with, among other things, the student's ability to make rational decisions in the face of content that he does not yet know; the desirability of allowing the student control over his own destiny; the power of the computer in taking into account many variables simultaneously; the inability of the computer to consider more subtle factors (most programs do not, for instance, have detailed information on the student's interests and certainly do not know his mood of the day); and the motivational value of involving the student in decisions. It is probable that the best solution lies somewhere between the views taken by extremists on either side of this argument; it could be argued that "strategic" decisions should be made by the student, who is often in the best position to know his global goals, while "tactical" decisions are made automatically by a well-designed instructional program that knows the most efficient way to reach those goals. In general, the tendency of the larger mainframe programs has been to take over the decision making, while the tendency in the microcomputer programs is to leave the decisions to the students. In many microcomputer programs, this means that the program designer has abandoned the responsibility for sequencing the material. Some of the simpler microcomputer programs, for instance, offer the student a choice between "easy," "medium," and "difficult," without any indication of the meaning of these terms in the context of the subject matter and with no advice to the student on how to make a rational decision.

Classification of Educational Programs

The computer-based educational programs that have been developed cannot be easily categorized. Traditionally, programs

that emulate a teacher have been divided into "tutorial" programs and "drill-and-practice" programs; although the concept has some meaning, the distinction is not always precise, for tutorial programs can, and usually do, contain a practice component, while drill programs may contain remedial sequences of instruction that are clearly tutorial in nature. There is also some evidence to show that skillfully designed drill programs can promote conceptual learning by providing the kind of environment that allows students to abstract general principles from the exercises given; this kind of "guided discovery" teaching can be quite effective for certain topics.

Another way of classifying programs is to determine if they are intended as supplementary to some other ongoing instruction. Drill programs that deliver "flash card" drills in spelling, arithmetic, chemical formulas, and so on, are generally of greatest use in conjunction with other instruction in language arts, mathematics, chemistry, and so on. Some tutorial programs were designed as completely self-contained courses, not requiring the support of a knowledgeable teacher; there are programs that teach foreign languages, physics, symbolic logic, computer programming, and many other subjects to students who do not have access to other means of instruction. Self-contained courses have generally been written for adults, while supplementary drill programs have generally been written for school children.

A third way of classifying programs is by the locus of initiative. In the traditional tutorial and drill programs, the initiative is taken by the computer. Although the program may ask the student to choose the topic or the level of difficulty, once that global decision has been made, the instruction is presented by the computer and the student is expected to answer. By way of contrast, in simulation programs the initiative is with the student; the student starts the dialogue and directs it as it continues. For example, in a simulation of electrical circuits, the student designs the circuit, specifying the resistance, voltage, reactance, and so on of the various devices to be incorporated in the circuit; while the role of the computer is to demonstrate the action of the completed circuit. There is a large variety of simulation programs which could potentially revolutionize the teaching of some subjects.

At this time, very few evaluations of the educational effectiveness of simulation programs have been undertaken. One open question about simulations is how well students will transfer what

they have learned to real situations, especially from simulations that are highly verbal. Many simulation programs do not illustrate or model a real situation; they simply describe the results in words. It is not known whether students perceive these results as having a strong relationship to reality, or whether they are viewed as being solely theoretical or, even worse, fantasized. Some of the simulation programs that have been developed are quite realistic imitations of the real world. There have been dental and surgical simulators that use constructed models of human bodies that exhibit human reactions to drugs, blood loss, etc. Flight and driving simulators operated under computer control can also be quite realistic.

Between the two extremes of programs that use realistic models and those that rely entirely on verbal descriptions, there are a number of simulation programs that show physical phenomena pictorially. There are, for instance, programs that show projectile trajectories under varying conditions of thrust, angle, and gravity. There also exist programs that demonstrate the actions of pendulums, the reflection and refraction of light, chemical reactions, the operation of internal combustion engines, and so on. Many simulation programs have been designed for noneducational purposes, some serious (stress on bridges under varying conditions of wind, population dynamics), some more playful (video arcade games). Under the right circumstances, even these programs that have not been designed for educational ends can be used for teaching purposes.

In some sense, programs like word processors and database managers can be considered to be simulators of typewriters and office filing systems, and these programs can certainly be used for educational purposes even though that was not the original intent. Perhaps a happier description of these programs would be as "tools," which we could then add to our classification—along with tutorial programs, drill programs, and simulations—of the kinds of programs that can be used in education.

A fifth kind of program that has been used in education is the beginner's programming language: Logo, BASIC, and Small Talk, for instance, were all designed as programming languages for beginners that would teach the fundamental concepts of programming in a simple—and fun—environment. This class of programs is quite different from the previously mentioned categories because the primary objective is not to teach traditional subjects in a more

effective way but rather to introduce an entirely new subject into the school curriculum. The advocates of teaching programming to school children are quite vocal, and sometimes promise more than they can deliver. Logo and Small Talk aficionados are prone to promising that students will develop "thinking skills" that will find applications far beyond the actual subject matter that is taught. So far, the more extravagant claims have not been substantiated, but there is nevertheless a good argument for adding some kind of computer literacy to the school curriculum.

The Design Principles Used in Educational Programs

Not all computer-based instruction has proven sufficiently effective to warrant the high cost of implementing it, but certain programs have been adequately evaluated and proven to be effective adjuncts to school instructional programs. There are also many programs that appear to be very effective, even though full evaluations have not been carried out. What, then, are the attributes of the successful programs, and what explicit guiding principles were used in their development?

One absolutely undisputed advantage of the computer over other media of instruction is the ability of the computer to deliver immediate and specific feedback to the student with each response that is made. *Immediate reinforcement of response* is a principle that is embodied in all programs, and is perhaps the only reason for the success of some. The power of this device is frequently not given due credit. Because it is widely known and widely applied, it is treated with the familiarity of an old hat. There are those who would argue that graphic illustrations can be delivered better by video tape, that printed material is best produced in book form, that foreign language instruction is best given by a native speaker of the language, and therefore, that computer-aided instruction that depends on low-resolution graphics, screens full of printed material, or synthesized speech of questionable quality is doomed to failure. These people are overlooking the enormous advantage of immediate feedback and its ability to compensate for many other seeming inadequacies.

Another principle that is used in the design of many, but not all, educational programs is the *individualized sequencing of instruction*. It sometimes seems that our ability to program elaborate branching strategies far exceeds our knowledge of how to

design educationally appropriate branching procedures. However, even very simple branching strategies can sometimes contribute greatly to the efficiency of the instruction. Pretesting students to determine whether they should skip over a section of tutorial instruction, for instance, can sometimes save significant amounts of the student's time.

The above-mentioned principles, immediate reinforcement and individualized sequencing of instruction, are the primary means by which computer-based instruction is individualized, and it is mainly these attributes of the instruction that give it its power and promise.

One encouraging trend is the basic research that is going on in artificial intelligence and cognitive science. Recent attention to the learning problems of young and to the design of "expert" systems may lead to the development of teaching programs that are much more astute than any we have seen in the past.

PROBLEMS IN USING COMPUTERS IN DEVELOPING COUNTRIES

When computers are used for education in developing countries, it is to be hoped that the most recent developments in the technology can be immediately applied, so that the history of the development of hardware and software, including the mistakes made, will not be needlessly replicated in other countries. In addition to the limitations and problems mentioned in the discussion of the history of educational computing in the United States, there are some additional constraints that are more pertinent to implementations in other countries that may stand in the way of rapid dissemination of the technology in the developing world. The major constraints have to do with the environment, power requirements, human resources, curriculum and pedagogy, and finances—with financial concerns being closely related to all the other constraints.

The environmental concerns arise from the fact that computers are sensitive to heat, dust, humidity, vibration, and mechanical shock. Many computers must be operated in controlled environments, with air conditioning and filtering. They cannot be moved often, and when they are, they must be moved with care. In many developing countries, heat and dust are great problems. Environmental constraints can be compensated for in two ways: the

environment itself can be controlled by artificial means such as air conditioning, or computers that are more resistant to environmental hazards can be purchased. These computers, however, are quite expensive in comparison with commercially available computers. Either of these solutions—control of the environment or the use of less sensitive equipment—impacts on financial considerations.

Sources of power are another great concern if computers are to be located in schools in developing countries. Many schools have no access to power utilities, and when they do, the power fluctuates more than most computers can tolerate. If there is no power utility, battery power, which is markedly more expensive, will have to be used. For most computers, battery power is not sufficient so computers with lower power requirements will be needed. There have been several technological advances in recent years that allow computers to operate with low power requirements—bubble memory, liquid crystal displays, complementary metal oxide semiconductor (CMOS) technology, very large scale integration (VLSI) technology, and high-density dynamic random access memory (DRAM) devices. These are the technological devices that allow the production of small but powerful portable computers. Although these devices currently are quite expensive, the price may go down considerably in the near future. In situations where a power utility is available, the power often drops and surges dangerously. To some extent, fluctuating power can be controlled by means of surge and spike protectors, supplemented with emergency battery-operated power supplies for temporary use.

The lack of human resources is another concern. There will be a need for trained operators (or for hardware and software that can be used effectively by untrained personnel) and for trained maintenance personnel. In many countries, neither kind of human resource is available, so training will be very important.

Engineering advances could take care of most of the above problems. A problem that cannot be taken care of by the engineers is that of the educational quality of the programs. Some people feel that educational programs from the United States can be exported, possibly with slight adaptations. I do not see such a simple solution. Most of the programs developed in the United States would not be suitable for use in the developing nations. The curricula of different countries, even in the same subjects, vary enough to make U.S. programs unacceptable to the ministries of education in many places. In some cases, this resistance

will not be completely rational; there is much chauvinism in supporting the notion of locally developed curricula. But in many cases, the reaction will be quite correct. The needs of the local populations are quite different from the needs of school children in the United States. The most obvious examples of this are in the areas of reading and language arts (in countries where English is not the mother tongue of the children), social studies, physical geography, music, and other topics that are highly dependent upon the culture, language, or physical and political characteristics of the country. Even elementary school mathematics, which is one of the most consistently taught subjects across national boundaries, cannot be exported *in toto*. Slightly different algorithms are taught in different countries, arithmetic applications vary, and the sequence of instruction may be somewhat different. Differences in educational goals and methodologies may be less important at higher levels of education because there has been so much cross-fertilization of ideas and textual materials. Calculus in Africa is not taught much differently than calculus in the United States, for example.

A related concern is the "style" of the programs. Many of the educational programs used in the United States have a game-like quality that is desired here for its motivational value. In other countries, education is perceived as serious business, and children are not encouraged by their elders to play in school. Programs that appear too game-like will not be culturally acceptable in those countries.

If the software cannot be imported from the developed nations, it will have to be written specifically for each developing nation. The difficulty of finding financing may well lead to a compromise.

High cost is the main impediment to the use of computers in education. Even in the United States, one of the wealthiest countries in the world, few school children now have or will have instant and unlimited access to computers, at present or in the foreseeable future. How then can the developing nations afford computer-based instruction?

The question should be addressed in terms of cost-effectiveness, not simply in terms of cost, and at present, I see few applications of computer-based instruction that would prove cost-effective. Even those applications that are cost-effective in the United States might not prove so in a developing country where

the salaries of teachers and the maintenance costs of school buildings are lower than in the United States.

THE FUTURE OF COMPUTER-BASED INSTRUCTION IN DEVELOPING COUNTRIES

The future of anything related to computers has proved extremely difficult to predict. Nevertheless, I want to point out some ways in which computers might be used in education in the developing countries in the next ten years. There are four possible application areas that might prove cost-effective.

The first area is in remedial programs for students who have fallen behind in their studies. This is a use for computer-aided instruction that has proven to be cost-effective in the United States. In most of the developing nations, such students are ignored, and they are often rapidly lost to the school system. In a few countries, however, there is concern for these students, and remedial instruction is supplied with rather high teacher-to-student ratios. If the teacher-to-student ratio is high enough, if the cost of teachers' salaries is substantial, and if efficient computer-based programs can be developed or adapted, this application area might prove cost-effective.

A second application area is in the use of simulation programs or combined tutorial-simulation programs in science teaching to replace rather costly science laboratory equipment. The cost-effectiveness of this application will depend on the current or planned levels of investment in laboratory equipment and on the ability of the computer programs to provide nearly equivalent experiences. There are now simulation programs in use in the United States that can provide students with experiences that are better in some ways than those they could obtain with more costly apparatus, and which are safer and more time-efficient. Physics, chemistry, and electronics are among the likely candidates, as are several areas of applied science and vocational training, such as automotive diagnosis or horticultural management.

A third area that may prove cost-effective is in higher education courses in which there is very high teacher-to-student ratio or in courses for which there are no qualified teachers. These would probably be either very advanced courses or courses that cover topics, such as computer science, that have not been taught in the past. In any one university, there may be only a few students

per year for courses like quantum mechanics, epidemiology, or topology. If these students have to travel to another university—perhaps in another country—to take such courses, the cost would be very high. Computer-aided instruction might be the best solution. Because the cost of developing such courses is high, the most reasonable approach would be for the cost of development to be shared by a number of countries. In this case, problems of language and differences in instructional tactics must be taken into account.

A fourth application area that is possible, although considerably more speculative, is the development of single-purpose microprocessor-based devices. Several such devices have been developed for education. There are, for instance, small hand-held devices that deliver drill exercises in specific subjects. Because the entire mechanism of a general-purpose computer is not used, the production costs of these devices are considerably lower than for microcomputers. Although there are few available mechanisms of this type and probably none that is suitable for direct application in other countries, the possibility for providing cost-effective instruction is high if the potential audience is large enough so that economies of scale in production can be attained.

In some of the above areas, there are programs in use in the United States that could be modified for use in other countries. Some of these modifications would be substantial and therefore costly, but of course less costly than developing completely new courses. In other cases, there are no available programs, or the available programs are so unsuitable that a modification would be less advisable than developing a new course.

A detailed cost analysis should be undertaken before any decisions to implement are made; it is possible that none of the potential application areas mentioned above would be cost-effective now. But it is also possible that costs will be greatly reduced in the near future by new technological breakthroughs. What might happen in that eventuality is that there would be a rush to implement computer-based instruction without adequate planning for the educational quality of the programs. There would then be an adverse reaction that would set development back further. Since engineering advances seem to come at a faster rate than advances in the art of teaching, it would seem that the time to plan for the future of educational uses of computers is now. Research into effective means of using microprocessors in education in the

developing countries could be undertaken now on not so great a scale that the programmers of educational materials would be caught unprepared when the day comes that the hardware costs are reduced to the point of acceptability.

Section 2
Teacher Training

5

Teachers in the Twenty-First Century

RICARDO NEMIROVSKY

The idea that human resources training is a bottleneck in the development of educational computation has become more widely accepted. Everyone agrees that it is easier to install equipment and programs than to train the teachers to use the equipment (Bustamante, 1985). "Current experiences show that the most successful implementations put teacher training first, consideration of suitable courseware second, and third, which machines will best accommodate the software. In other words, the order is people before programs, then programs before machines" (Williams and Williams, 1984).

Recognizing the importance of the topic, this paper tries to explain the criteria and approaches used by ORT Uruguay to train human resources for the creative education program that has been implemented by several schools in Latin America. A growing literature addresses the question of teacher training, dividing the subject into a number of categories.

COMPUTER CULTURE

Despite the recognized difficulty of defining computer culture, there is general agreement that society should diffuse computer

culture or computer literacy particularly among teachers. The following discussion outlines the dimensions of the problem.

> The essence of the problem is defining computer literacy. The group of nine national experts seemed to divide into two camps. One camp essentially thinks of computer literacy as a talking level of knowledge. This includes knowing some computer history; knowing definitions of computer-related words; knowing some applications of computers in business, government and industry; knowing about social and ethical issues, and so on. Many of these objectives are stated, "the student is aware of ..." Of course this talking-level-of-knowledge camp wants students to have some hands-on computer experience and hence a modest level of skill in actually using a computer.
>
> The second group admits that the ideas of the first group are important, but insists that the most important aspect of computer literacy is being able to make a computer do things. This group is then further divided as to what this might mean. Does it mean being able to program in Logo, BASIC or Pascal, or does it mean knowing how to use a word processor, an information retrieval system and an electronic spreadsheet? (Carey and Carey, 1984).

A number of papers describe study programs and course evaluations (Cannings and Brown, n.d.; Chen and Nachmias, 1984). A basic topic in computer literacy aimed at teachers is the link between informatics and educational theories and practices.

Implications for National Policies

Teacher training is a basic item in all national plans for educational computing. It involves complex problems of organization, support and evaluation.

Methods and Materials Methodological considerations range from self-teaching systems (Vogel and Aiken, n.d.) to detailed analyses of work assignments in a course (Globerson and Mioduser, 1985). Teaching materials are often displayed in these discussions (Cohen and Elkin, n.d.).

Psychological Factors Every training process involves emotions and phobias, fears and quests; this general statement is particularly relevant when approaching computing. The importance of the link that adults enter into with informatics is such that it should condition the contents and methods of the training process (Allen, 1984).

MICROCOMPUTERS IN LATIN AMERICA

Teachers, particularly in Latin America, have had to face daily contradictions between what should be and what is--unattainable curricula, the need for updating beyond possibilities, pressure from an unstable and uncontrollable social environment, and an endless list of others. The introduction of computers in schools, whether promising to overcome some of these conflicts or threatening to foster them, fits into this context, too. The criteria and attitudes of institutions and teachers working with computers reflect those of general educational activities. There is a clear relationship between the learning conditions created by a teacher in a science laboratory or a library and those generated in a computer center.

Cultural Influences

The social application and development of informatics affects the field of education both on the level of classroom instruction and on the more general level of influence caused by the cultural transformation inherent in the information revolution known and experienced by all of us. It is important to note in this context that such an influence is experienced whether the school has computers or not, and it encompasses all areas of school work. For example, a series of traditional elements of the curriculum becomes obsolete because certain instruments and resources are no longer used, and, at the same time, a number of new topics suddenly become important.

The increased availability of information raises questions about the role of the teacher as information transmitter and minimizes the importance of the learning activities centered on memorizing data. The possibility of automating mechanical intellectual processes reduces the importance of learning them. Instead, the new environment constantly generates the need to interpret and select information and calls for a critical understanding of it. The need to invent does not belong exclusively to inventors any longer; it is now a requirement of daily life.

These influences act as a cultural pressure. Normally, teachers and students are not aware of them, but sometimes they are manifest in conflicts in other areas, such as discipline or grades. On the other hand, the mere fact of recognizing the demands imposed by the cultural environment does not provide the means

to satisfy them. The common practice is that this knowledge is left at the level of slogans, such as "learning is thinking," that provide no practical aid to learning.

Classroom Influences

"Every work environment, every organization, ... has its own culture" (Pentiraro, 1984). This statement is perfectly applicable to a school: every school, through its educational practice, expresses a vision of reality, an attitude to learning, and a history. When computers are incorporated, they are not placed in emptiness, rather they are absorbed and projected in this cultural framework. Computers do not act by themselves. They do not have "effects" isolated from the culture that implements them.

However, the analysis of the integration of computers into school as a process without context, where computers "cause" such and such effects, is often found. This "technocentric" approach (Papert, 1985) is expressed in varied ways, such as thinking that computers can be demystified by merely providing technical knowledge, or speaking of the small or great importance of computers in education without speaking first of education.

These two types of influence, the general one from the culture and the particular one from the school, could in fact be in conflict with each other. The problem of the timeliness of learning is a constant topic for discussion, raising questions such as "What will it be used for?" or, "Are we getting ready for the future?" A school is not more modern nor does it necessarily prepare students better for the future by the isolated fact of computer use. Learning must answer the needs of the cultural environment. This environment calls today for training to face the unforeseen in order to assimilate the new and unknown. Incorporating computers into the school context and harmonizing these two influences is neither automatic nor simple. We are not dealing with "acquiring" technical knowledge but rather with acting upon cultural patterns.

Integration into the Informatics Age

Entering the informatics age, therefore, refers to more than computer literacy; we are dealing with the support given to teachers, with reconstructing attitudes, with sensitivity, and with the teacher-student relationship.

To make this point clear, I would like to present two quotations that refer to an earlier revolution:

> Obviously the Industrial Revolution had political and economic problems even before the material means to solve them were provided. But its greatest impact (and longest) was on people, and mainly those newly arrived into the cities. These people grew up with standards still latent in the traditional order but not yet suited to the new one. There were many people who, like the German craftsmen displaced in the 1840s, were considered as "invisible" and virtually excluded from society and State, incapable of participating in the new order to which they were required to adapt themselves (Lampard, 1981).

The lack of technical knowledge about the machinery and tools fostering the industrial revolution was a factor for social unfitness. There was however another more general and profound source of maladjustment:

> The technology of machines is, like any other tool, morally neuter. But when incorporated into the human society, it implants, whether we like it or not, some values associated with its main characteristics. These values are the causal sequence, order, functional efficiency, impersonality, uniformity, numbers, usefulness, energy, and movement (Sanford, 1981).

The fact that these values were alien and conflicted with those of the craftsmen resulted in a situation of remoteness from the world. This situation could not be remedied simply by providing technical training.

I have gone into detail in this analysis because I believe it illuminates what is happening to a large number of teachers today. Our generations have been raised according to a set of values (some of them associated with the industrial revolution) that are being altered by the process of the "informatization" of society.

It is not possible to present in this paper a detailed study of the new cultural values that are closely linked to the informatization process, but some that strongly affect education are worth mentioning:

- *Simultaneity*: Society gives varied answers, often in direct opposition to each other but equally well supported, to the same problems. It is difficult to make rational decisions. Opinion replaces the search for truth.
- *Instability*: We have a constant awareness of change, even in the most common and routine aspects of life. We do not know how we are going to be doing things in ten years;

we only know they are going to be different. Change is unpredictable and sudden.

- *Complexity*: We are aware of the existence of more questions than answers. There is always, beyond every explanation, a vast sea of uncertainty and a feeling of the growth of divergence.

Pedagogical Impact

This process of cultural transformation has deep pedagogical repercussions. Pedagogical approaches grow and decline in importance, not only due to their inherent features but also because of their link with the sociocultural environment that gives them strength and orientation. Approaches that may be considered avant-garde in one society and time are seen as conservative in others.

It seems clear, for instance, that the role of approaches based on Piaget's theory is not casual. They seem to be an enriching response to the threats and problems presented in the current cultural context. Moreover, the growing emphasis on innovation and problem solving ability is closely linked to this approach. All the skills that enable us to face today's unknown will still be vital in the unknown future.

Far from trying to propose an alternative "system" of teaching, we are speaking of the encouragement of an environment and a learning style that can be carried out in any type of school, be it "traditional," "Montessori," or "personalized." In every case, it is possible to enrich the cultural environment of the school. To educate for the twenty-first century has implications that have an overall effect on the learning process, with or without computers.

Pedagogical Approaches

Some specific teacher attitudes and approaches seem to facilitate the process of integration to the information age; among them are the following:

- Teachers who work with open situations; that is, they promote activities in the learning process that are not ruled by the aim of achieving a predetermined outcome. Instead, they encourage students to define obstacles they face and to reach original solutions and hypotheses not foreseen.

- Teachers who are question posers, rather than sources for answers, who foster quests that go beyond obvious and stereotypical solutions, and who are critical thinkers capable of encouraging students to think critically in turn.
- Situations that reflect a multiplicity of viewpoints, that are not confined to the known answer, that analyze problems from many different approaches before allowing judgments, and that extend the students' fields of interest.
- The development of sensitivity that is guided by the significance of issues and by the learner, rather than driven by the teacher or the curriculum. The teacher must feel and look for the meaning that a child, a teenager, (or, in general, any learner) attaches to a problem or an idea.

We believe that computer literacy should be placed in and oriented toward these types of educational attitudes; it could be a very valuable instrument in understanding our environment and fostering cultural patterns that would bring education into the informatics age.

These type of orientations, especially significant in Latin America, are guidelines for action. Theoretical schemes are indispensable in setting guidelines, but inserting a change in the complex grid of cultural reality is an art that implies concrete analysis. Proposals must deal with specific and heterogeneous educational environments. Cultural changes cannot be abrupt, nor are they homogeneous. There are general trends, but the paths for the integration of each social nucleus are diverse and varied. A program of educational improvement becomes viable to the extent that it can respond to obstacles. One example of a good program is the Program of Creative Education.

A Practical Example

The Program of Creative Education was created by ORT over 15 years ago, beginning in Argentina. It is now evolving and being developed for a school population of approximately 10,000 students in five Latin American countries. There are four areas of work at the primary school level: natural sciences laboratory, study center, creative workshop, and computation. At the middle education level there are workshops on technological education and the educational use of computers. Generally, each school employs advisors

and builds special facilities for each one of these areas. The specific applications advance the ideals expressed above. The concrete form adopted by the program in each school varies according to cultures and interests of each institution, and new programs are constantly being worked out. Important expansion plans, some of them outside Latin America, are in the process of creation. The most complete documentation so far is found in a book published by ORT Argentina in 1985 entitled *Creative Education.*

Teacher Training

Teacher training is undoubtedly a core activity in the Program of Creative Education. Courses, workshops, and working trips are constantly held for teachers. The main responsibility of coordinators and advisors is to meet the needs of teacher training, and it is not possible to give a detailed description of all of their activities. It would, however, be worthwhile to mention some of the criteria used to illustrate the work patterns applied.

A guiding principle in conducting courses and workshops for teachers is that they need to "seize" the resource or knowledge being discussed. Knowing about something is quite different from actually incorporating it as a personal tool to analyze and solve problems. This principle has a major influence in determining the particulars of a program: content, method, rhythm, and so on. A number of other guiding ideas have been recognized.

Teachers are not the only important element. Teachers work in a context that is not exclusively determined by them. For this reason it is better to speak about human resources training, taking into account officials and coordinators as well. Often some very valuable ideas held by teachers cannot be implemented because of a decision-making process in the hands of a third party. The training process involves the institution as a whole.

Teacher training attaches an important role to the organization of courses and special activities. The most important and decisive aspect however is the handling of daily and normal activities. The key factor is the work of the school coordinator who should provide training to meet clearly identified needs by giving support to the design and organization of activities as well as engaging in the evaluation and analysis of these activities. The relationship between the teacher and coordinator could be particularly rich in the development or adaptation of software.

There, the coordinator could provide the technical knowledge and the teacher the pedagogical approach. This type of interaction sometimes causes conflict, especially when there is no common language, so a training process is needed.

In a group of teachers we normally find a variety of attitudes, skills and rhythms. To design flexible activities that take these into account and allow each person to succeed is a complex task that calls for hard work. When they do not succeed as well as others in a course, teachers may feel incapable of facing the problem. They decide they are not good with computers and make themselves obstacles to learning. The importance of talking about this situation and discussing it openly and thoroughly cannot be overstated. There must be an environment where everyone can respect his or her own rhythm and approach to these activities.

Content of the Training

We believe it is important that teachers focus on programming as a feasible educational tool. Teachers need not program the software to be used because they can always depend on the technical support. However, they can use the activity of programming as part of the learning resources they offer their students. In addition, the ability to use certain basic tools (such as the word processor, database systems, and plotting systems) provides both teachers and students with a feeling of control over the technology. Terminology and information processing are normally introduced through short, intensive programs.

We believe that all decisions concerning social impact, historical aspects, and matters related to pedagogy should be based on critical reflection on the teachers' own educational practice and life experiences. If these are considered with an inquisitive and open mind—not confined by "final" answers—and such analysis is enriched by ideas from books by several authors, then the proper conditions to adopt innovations will be reached.

In the same way that scientific practices are not learned just by reading the scientific method, but by actual experimentation, every educator is formed by experience into the style of learning he or she wants to transmit. Methods applied in courses and workshops should combine basic themes of study and analysis, since in addition to gaining knowledge and skills, they are aimed at gaining personal experience. The most delicate balance must be

maintained between structured and unstructured activities. The former are focused on getting acquainted with unknown resources and must be linked to personal ideas and concerns. This linkage is greatly reinforced when new knowledge meets pre-existing needs and concerns, such as providing the solution to obstacles encountered in the development of a project.

The ORT program stresses the importance of integrating training around the enhancement of desired cultural patterns that are seen in all learning activities. This basic process, known as pedagogical generalization, strives to consider questions such as the relationship between mental images about facts we do not perceive in the use of a computer (such as the transfer of information between memories) and the mental images of an atom or a gene, or the links between the style a person uses in solving computer problems and the style shown in an art workshop. Teachers who enlarge their capacities to design scientific experiments with an open approach or to lead creative activities in a workshop are also acquiring the sensitivity to put together the educational potential of informatics.

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6

Computer Education for Teachers: A Maze of Realities

BRADER A. BRATHWAITE

The microcomputer has been accepted in schools because it promises a new dimension to education. Walker (1983) proposes that computers enhance education by providing the following: more active learning, more varied sensory and conceptual modes, less mental drudgery, learning nearer the speed of thought, learning better tailored to individuals, more independent learning, and better aid to abstraction. These claims are yet to be strongly supported by research. The challenge, however, is to incorporate the microcomputer successfully into the school curriculum and maximize its benefits to education. This demands that computing be accommodated in the curriculum of students as well as teachers.

Rogers, Moursund, and Engel (1984) pursue the magnitude of the teacher training effort necessary to attain the goals of computer education for teachers. They recommend four opportunities for consideration: pre-service training of education students, in-service training of practicing teachers, graduate programs on computers in education, and research on computer use in education. Yet the innovation of computers comes at a time when teacher education and the tasks of teacher educators are being called into question.

When David Berliner spoke on contemporary teacher education in 1985 he said:

> I believe that it is fair to characterize teacher educators, as a group, as being timid. In particular, they have been timid about instituting program change. Whenever I talked with someone in teacher education, they suggested ways it could be done better. But few changes took place. For decades now teacher educators have accepted, for numerous reasons, a level of mediocrity in teacher education that has all but sapped their strength.

Berliner's point of view aroused my personal interest in the topic of the computer in teacher education. I certainly did not think that teacher educators were timid. I felt that they were poised between the forces of continuity and change, and they had a tremendous task to perform. Their portfolio contains not only the controversies encountered in translating theory into practice but also the obstacles to be overcome in implementing innovations in teacher education.

Sheingold, Kane, and Endreweitz (1983) cited earlier research on the effects of implementing computers in private industry and government, and indicated that:

> The computer does not have a simple impact on an organization or the people in it. Its implementation and use are embedded in a compiled matrix of social and political relationships. At all levels of implementation and use, it is essential to consider the interaction of the computer with the social system that surrounds it ... this interaction should be viewed over time as computing activities influence the social system and the social system shapes the influence of the technology.

After reading this, I was able to visualize an education system as a series of intertwining contexts which impact on one another. My view is schematically represented in Figure 6.1, which shows a merger of the fundamental elements in an educational system as follows: the teacher educators and administrators, emphasizing their gate-keeping role, the innovation into the curriculum, and the classroom are all embedded in the society. Thus I have called my paper "Teacher Education: A Maze of Realities." By investigating interacting elements in the maze, we encounter factors that teacher educators must address. Interactions must be visualized within each element and at each interface and sector of the maze. Our purpose is an attempt to uncover the realities involved in planning for appropriate applications and outcomes in teacher education.

There are different opinions as to where planning for teachers' computer education should begin. Neill (1983) is of the opinion that planning for instructional use of microcomputers should start

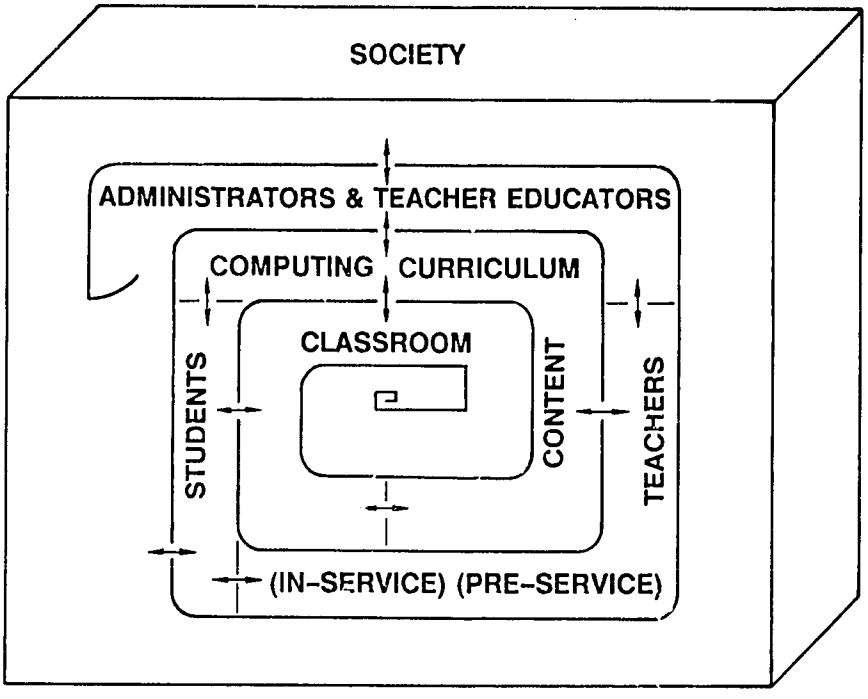

FIGURE 6.1 The Maze.

with an analysis of the current curriculum to identify the content, skills, and attitudes that are considered important. Sandoval (1984) asserts that planning should begin with the teacher's tasks. In the case of Trinidad and Tobago, the innovation began in 1983 with the conceptualization of a computer literacy pilot project in 30 secondary schools. Teachers first participated in a computer literacy project and were then allowed to introduce computer literacy with a degree of eclecticism. Implementation has not been smooth.

I am of the opinion that planning should always begin with a carefully thought out philosophy. I also acknowledge that teachers are capable of providing valuable insights into the education

process. If planning were to start with the teachers and their definition of curriculum goals, it would then be possible to determine whether the computer had anything to offer the curriculum. But wherever the planning process begins, it is essential for planners to be acquainted with the concepts and roles of each person involved in the change. I hope to reflect on the meaning of the change for teacher educators, teachers, and students as we analyze the maze.

INTERFACES

The Teacher Educator-Curriculum Interface

An evaluation of our computer literacy project in Trinidad and Tobago indicated that, in general, teacher educators and administrators would have to deal with the following areas: access to microcomputers; new roles of teachers in response to computers; availability, quality, and quantity of software; integration of microcomputers into the classroom and the curricula; training of teachers; and effects of the innovation. But how would the computer affect the teacher educators themselves, and what inputs are required with respect to their knowledge, skills and attitudes?

Of significance is the fact that teacher educators, seen as specialists in their own field, have had to acquire information from personnel in the society who have the technical expertise but not the knowledge of educational concepts. There are other areas of dissonance. Most teacher educators would be less interested in programming than those teachers who would like to specialize in programming, and so they need a somewhat less formidable curriculum devoid of the nonessential technical details. As such, the computing curriculum for teacher educators should include a course in computer literacy which includes elementary programming, integration of computers and subject areas, computer use in administration, the use of computer applications, and the evaluation of software and hardware. Most likely, appropriate learning situations could be structured from a choice of workshop settings, peer-tutoring, or self-directed search. At the graduate level, teacher educators should be able to program computers for use in education and to modify or design new applications.

The Teacher Educator-Teacher Interface

Pre-service and in-service teacher education will have its own special requirements and concerns. The first type of teacher education involves the preparation of teachers as agents of change to face an educational system which is steeped in tradition. In the second type, teacher education is geared toward helping working teachers accommodate this change. A new syllabus would be required for pre-service education with the possible recognition of computer literacy as a required subject area for certification. In both instances, the pervasive question will be; How will the teacher's role be conceptualized? Research has cast the teacher in several different roles. To date, most research paradigms have been unable to capture the true essence of teachers' roles amid the complexity of classroom interactions. A teacher, as a participant in planning, will contribute useful insight at this interface.

It will also be important for teachers to know that the innovation is intended to complement and not replace them. The reasons for resistance, inertia, and anxiety toward computer technology must not be overlooked. Since some software programs aim to reproduce human teaching activities, teachers may fear that their jobs will be usurped. The computer proposes a modified role for the teacher—one which emphasizes being a resource person and a manager of learning. Teachers are already pressured by time constraints, and they may have little time to devote to developing expertise in computer education. In addition to their normal duties, teachers will be given additional responsibilities for the security and scheduling of computer resources. Payne (1983) asserted the need for this important component of planning to reduce computer anxiety in teachers.

The Teacher-Curriculum Interface

The curriculum is usually structured via consideration of the choice of learning situations, objectives, learning tasks, materials and equipment, learning arrangements and settings, and instructional methods. Whereas the traditional pre-service training for teachers has emphasized content and method, computing is accompanied by three other possibilities for the curriculum: teaching about computers, teaching with computers, and teaching through

computers. These possibilities come from the three broad categories of computer uses in education (Ragsdale, 1982). Content related to teaching about computers involves courses in computer literacy, the impact of computers in education and society, and the congruence of computer use with the appropriate grade level and the subject matter. Teaching with computers refers to the effective use of the computer as a teaching tool. Teaching through computers includes using computer-aided instruction, and at a more intense level, the modifying, adapting, or writing of relevant instructional software material. Knowledge of the psychological theories and instructional methods according to which software is designed becomes relevant here.

The Computer-Curriculum Interface

This area covers content and method in the computing curriculum. The computer uses many learning modes: it breaks problems down into small steps, gives immediate feedback, provides correction impersonally, and repeats endlessly. Computer functions which are now available for school use include the following: computer literacy, drill and practice, programming to solve problems, recreational games, tutoring for special students, demonstration labs, administration, maintainig teacher records, designing tests, completion and correction of students' worksheets, and word processing.

Galanter (1984) in an article in *Psychology Today* vouches for the cognitive value of the computer. He believes that the modern day curriculum had unwittingly omitted the art of logical planning, and that this discipline can now be supplied by what he called "the third logic," an operational logic, and the rational execution of action. He demonstrated that programming languages offer a structure to discipline the mind toward exact naming and the use of precise and unambiguous instructions.

However, teachers still need to analyze computer offerings carefully to determine their educational value. The effectiveness of traditional teaching methods must be compared with the benefits to be derived from computer use. O'Shea and Self (1983) list what the computer has to offer:

- Linear branched and generative assisted learning programs
- Algorithmic thinking, as in flow charting

- Mathematical learning models for concepts which can be represented mathematically
- Time-shared interaction, computer-controlled information television
- Simulation, a program which models some process or system
- Games with audio and visual effects
- Emancipatory modes, using the computer as a labor-saving device
- Dialogue systems which restrict students' answers
- Artificial intelligence for remembering and accessing relevant knowledge.

The utility of each kind of program and its blending with the particular subject matter to be taught should be carefully assessed for the ability to enhance the education process.

Computer-Classroom Concerns

Would placing the computer outside the classrooms remove the challenge of integrating computers into the classrooms? This alternative is questioned because as soon as the computer is introduced into the curriculum, other concerns will emerge. Some further questions which merit attention are, Would the computer be used as a tool, a resource, a social organizer of learning, or a promoter of student achievement? Would it be used to assign students to work at appropriate grade levels? In attempting to resolve these questions, the task of planning is not merely to match the computer and the classroom but to mold them to complement each other, a process that may result in classroom reorganization. The computer appears as an individualized intellectual environment whereas classrooms are group interactive systems. Software has to be designed to attain the single focus found in the traditional classroom.

Computer-Student Interaction

The motivation—specifically the intrinsic motivation—and interest presently provided by the computer in the classroom may pale with time. For the moment the computer appeals to students and helps in the custodial function of schooling, but long, intense hours at a terminal may be considered a waste of time. It is feared

that the computer will alter the shape of the student's interaction, and may foster elitism, promote distancing, and generate students who are able to instruct their teachers. An insightful teacher education program should be able to structure diagnosis and remedies to allay these fears and recommend ways to further channel students' interests and abilities towards desirable outcomes.

Teacher-Student Relationships

Changes would occur in the traditional teacher-student relationship. The role of teacher as guide, monitor, resource person, strategist, organizer of learning, and diagnostician would be emphasized. In addition, the teacher could become an adapter of programs to suit the needs of the learners. Thus, the job of teacher education is to identify the changes in the teacher-pupil relationship and to help teachers to cope with the new roles which would be required. In-service teachers who are already experiencing some of the changes would be better able to assist in this training, thereby rendering peer-tutoring among teachers a potent recommendation.

SECTORS

Integration in Computer Education for Teachers

A few integrating themes emerging from my investigation of the maze and my interaction with the research works cited are to be presented here. They are listed as recommendations of computer applications which could serve to alleviate teachers' problems.

Is this the opportunity to rewrite the teacher's curriculum or portions of it with logical operations? Heavy course load has been a constant complaint in teacher education. The computer displays a massive information capability and so could be used to address the problem of teacher work load and the information explosion.

Diem (1982) suggests the introduction of communication and information studies into the pre-service teachers' curriculum. Such a course could be used to keep teachers up to date and would deal with computers along with other technology, while paying attention to areas like international relations, population trends, planning, cultural dimensions, research methodology, and ethics and privacy in information science.

Teacher educators must no longer be solely responsible for the training of teachers. The business of education and training of teachers must spread into allied fields and be concerned with inter-professional training. Computer programs which apply to training must also apply to teachers in training. This may include the use of generic programs—appropriate use of graphics, word processing, databases, and spreadsheets—integrated into the existing students' and teachers' curriculum. For example, creative application programs could address lab reports, lesson plan formats, teacher record and forecast, and routine tasks performed by teachers. Games which require the knowledge of subject matter may serve as entertaining evaluation.

Competency-based approaches use information gleaned from experts in the field in order to identify the minimum competency that professionals should possess. The individuals are then tested to ascertain their level of competency. The gap in knowledge provides the basis for selecting objectives of the course. The teacher trainer who is aware of a specific teaching skill that is required would be able to access that information on the computer from an individualized package.

The utility of the computer as a time saving device in the school day and in the teacher's schedule should be explored. The most pressing among teachers' needs is in this area (Fullan, 1982). Time spent per task is another area which can be monitored, for it varies widely from one teacher to another (Berliner, 1985). Computer-aided instruction for teachers would help them upgrade their subject matter competence giving them more time for research (on the use of computers in the classroom) and classroom teaching practice.

CONCLUSION

Existing models for teacher education in computing have been suggested in the OECD Publication (1971); Rogers et al. (1984); and du Boulay (1982). Diem (1982) reviewed several training models for innovative technologies. Wells and Bitter (1982) appear to offer the most comprehensive approach to the introduction of computers in education. Their research was conducted through extensive needs analysis, in-service training of teachers, teacher participation, and all of the above incorporating adequate coverage of the interactions which have been considered in the maze.

An effective decision-making system is usually devised from the careful assessment of the following: policy guidelines and a philosophical base, goals, needs, interests, alternatives, knowledge, skills and abilities. Few of the existing teacher education programs have been structured from a consideration of all these requirements. In addition, the computer and its capabilities are heavily invested with a strong component of cultural and ethical values, and these features must not be overlooked. A body of theory and research about software for education is imperative. This should include research on different types of software to meet different educational goals and purposes and the suitability of instructional designs for effective learning. This area requires the conferencing of researchers, software developers, and school officials. Time should be devoted to the study of classroom management in the presence of the computer. In general, planning, preparation, testing, and evaluation of procedures must be an ongoing task to determine the effectiveness of computing and the achievement of the goals of the computing curriculum.

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7

Training Teachers at the Colegio de Bachilleres in Computing

EDUARDO RIVERA PORTO

BACKGROUND

The Colegio de Bachilleres is an official senior high school level system. By 1987 it will be the largest system in Mexico at this level, and the trends indicate that it will continue to grow. Colegio de Bachilleres confers the diploma of *bachiller* (senior high school graduate), necessary for entrance to any university or college, and provides some technical training.

All of the teachers at this level of the system must have a bachelor's degree or at least have completed their studies for the degree even if they have not yet written a thesis. However, few have any specific pedagogical training or knowledge. Because of the salary levels, few teach full time; they may have other jobs or small children, or are continuing their studies. The majority are young and have very little practical work experience. Most teachers are very enthusiastic about continuing to learn, but because of their other obligations, training is difficult to arrange outside their work schedules. Introductory training classes are given in the inter-term period, and some of the academies of teachers (an academy is a group of teachers in one discipline) have periodic meetings, including workshops about specific topics, during the year. The teachers at this level usually belong to a union that normally

demands that they be paid while attending courses. This kind of compensation is difficult for many institutions.

In addition to these constraints, there is a question that must be answered honestly: Why introduce computers when there are other demands and needs in the classroom? It is not enough to cite the improvement of quality in education without allowing the teachers to decide whether the computer is the most effective assistance they can have. For this reason, the introduction of computers must be made gradually, rather than being imposed as another unilateral decision from above. Recognizing that the introduction of computing in schools depends mainly on teachers, it is necessary to train teachers in computing, despite the difficulties. The training must encourage their acceptance of and enthusiasm for computers in general and the use of computers in education.

EXPERIENCE AT THE COLEGIO DE BACHILLERES

Many courses are offered to teachers during the inter-term period, but most do not take advantage of them. Among these, the computer courses are unique because they concentrate on practical training. It would be desirable for all teachers to attend one of these courses, but we resist the idea of instituting them on a compulsory basis because of the possible reaction against computers.

Computer literacy for teachers must provide a new language, help the teachers rediscover the importance of information and its automation, and offer some practical uses for computers to provide assistance in their current classroom work. Perhaps the most important objective is to give them an overview and motivate them to continue learning in this rapidly changing field.

Problems in Teaching Computer Literacy

It is often thought that computing is associated with mathematics and that teachers outside that field have no dealings with it. It is true that teachers of mathematics and natural sciences more easily accept and adopt computers, but the objective is for teachers across fields to adopt them. For this reason, computing as a subject for students is taught on an interdisciplinary basis and

teachers in several fields share the decision-making responsibilities. We know that this will create some problems, but the risk is taken in the hope that the benefits will outweigh those problems.

The fact that most of the manuals, instructions for use, and programming languages are in English prompts resistance from some teachers who have no knowledge of English. In Mexico, the question of whether computer languages should be used in English or be translated, especially for beginners, is the subject of much debate. Both options have their advantages, but the fact remains that what is available is used. In any case, it is desirable to have both—packages in Spanish and English manuals translated into Spanish—to include all teachers.

The lack of computers is a general problem. When they are available, they tend to be in full-time use by students. The purchase of microcomputers specifically for teachers seems to be a good solution, as teachers have no time to wait for a free machine and will find it easier to learn without the pressure of students watching them. To enhance learning, it is a good idea to have some microcomputers for the teachers to take home. They could be inexpensive microcomputers which could be connected to a television (it is reasonable to assume that all teachers have a television) and to a cassette player. With this simple equipment the teacher could learn about computers at home without excess pressure.

Computer Literacy Courses

The courses about computers must be directly related to the experience of the teachers. It is preferable to use real examples and direct applications rather than esoteric or academic examples. This approach is very important and requires courses to be carefully prepared for teachers. An interdisciplinary group might be formed for the preparation of courses to make them relevant for the teachers and useful in learning about computers. There are no computer books written especially for teachers, as there are for professionals and children, so it is urgent that this void be filled.

Many teachers express their disillusion with audiovisual media, particularly in relation to learning. This disillusion also extends to computers and creates an atmosphere of suspicion. In this case there has been a misunderstanding about computers:

their possibilities, their uniqueness, and their complementary relationship with other media. Usually the computer is presented in formal demonstration sessions or tutorials, giving it an image of automation. It is then very important to emphasize that the teachers are the masters of the medium, that they must educate, and they must decide when to use the computer in their courses. Finally, it is important that they learn to use the computer as a tool. For instance, using the so-called fourth generation tools—relational databases, word processors, spreadsheets—gives teachers the freedom to organize their courses to offer a variety of computing experiences. Although computers are important in themselves, they are more important as a pretext to renew education by allowing for the possibility of experimentation. The experiments must be conducted seriously and the possibility of error accepted in order to improve education.

Writing Programs for Teaching Other Subjects

Most teachers will need continuing assistance after their computer literacy courses, especially if they use computers in teaching their regular course work. The traditional dependency on programmers must be broken. However, preparing courseware is a seriously difficult task that requires a mixture of resources such as pedagogical aids, colors, animation, speed, sound, graphics, user-friendly interface, and file management. The teacher or the academy must know what is needed and have the capacity to judge the quality of the finished product, but the actual software can be written by an external permanent consulting group. A team of teachers can be trained to assist with the design and evaluation of courseware. This expert team would serve as a bridge between the teachers and the external consultants. This team must also be the institutional memory in computing to avoid duplicating programs and to arrange the sharing of programs and packages. The group must be responsible for centralizing documentation so that it can be shared as well.

Thus, there is a need for planning the introduction of computers carefully and with the participation of teachers. Teachers must move into the computer era rather than allow computers to move into the pedagogical field.

APPROPRIATE LEVELS OF COMPUTER TRAINING FOR TEACHERS

In some other countries, the computer literacy courses for teachers are very ambitious. For example, the French plan "Informatics for All" foresees a minimum of 100 hours of computer training for all teachers and even more training for the leaders. In the United States, it is agreed that about 60 hours is the minimum for computer literacy. It seems that these goals cannot be achieved in the Colegio de Bachilleres in the short term. Therefore, there must first be a strategy of selecting and training leaders to increase the level of experience in the institution and then of compressing the content of literacy courses to reduce them to about 30 or 40 hours (a reasonable length for the inter-term period). These courses will not produce programmers but intelligent users, with no fear of using a microcomputer or of reading a manual and correcting mistakes made by the other teachers in using software programs. At the second level of strategy, a smaller number of teachers will be trained to understand the possibilities of a computer and how to request and evaluate expert assistance. At the third level, selected teachers will learn some programming languages and will use this knowledge to correct and adapt certain packages to make them more appropriate for use at the Colegio de Bachilleres. Finally, teachers at the fourth level will receive the training to be part of an expert team working in an interdisciplinary group to analyze a problem, design an application, write the program, and assess the result.

The enhancement of their capacity to teach, the participation in an experiment to renew education as the masters and not the slaves, and the adjustment of the teacher-training process to the new requirements of our era needs the enthusiastic support of teachers. The computer is their opportunity.

8

How Computers Change Teacher-Student Interaction

EVELINA VILLA

From the following course experiments, we shall see how the introduction of computers in traditional teaching and learning environments serves to modify the direction of teacher-student interaction in the classroom.

THE TRAINING COURSE

Instructional Methodologies

In Argentina, a 36-hour workshop, Introduction to Computers in Education, was set up for elementary school teachers and principals. The teachers' aims were to:

- Learn Logo
- Work in self-coordinated groups of three or four per computer
- Explore the possibilities of introducing computers in the classroom
- Increase their awareness of new teaching methodologies
- Acquire a mental model of the computer
- Learn about the integration of new technologies in society.

In addition, a model course was set up for the teachers' students, and was conducted by the coordinator so that the teachers could observe new teaching methods along with the children's responses. The course was planned for 42 hours. It met twice a week with each lesson lasting three hours, and with one fifteen-minute break. Once the course was completed, continuing in-service activities were offered. Each lesson followed this format:

- Turn computers on
- Participate in group and individual activities, with and without computers
- Turn computers off
- Engage in feedback, sharing, and general discussion for the final fifteen minutes.

The teacher training course covered the following areas:

- The computer: hardware and software
- The computer in our society: social and cultural impact
- The computer as an educational tool
- Human communication, languages
- Communication between human and computer
- Information
- Cognitive strategies
- Computer languages, Logo
- Psychopedagogical background
- Evaluation of computer use in the classroom
- Group dynamics techniques
- Computer course methodology.

Information on the aims of the course, course content, and a bibliography was distributed to the teachers to be read and discussed in the first lesson. Several Logo exercises were completed in each class. In the beginning, the coordinator handed out worksheets with exercises consisting of a series of designs. The teachers were asked to write a program to create each design on the computer. As the course progressed, the designs became more difficult. An example of these designs is shown in Figure 8.1.

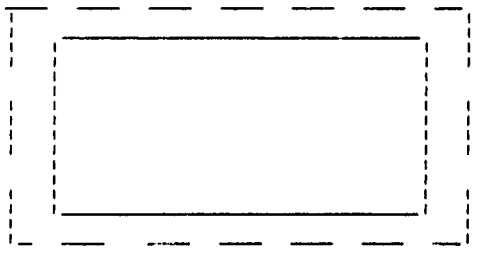
Introduction to new concepts, exercises, evaluation, feedback, review, and sharing of information were the main objectives of the course. A typical handout used to stimulate discussion of new concepts is shown in Figure 8.2. The bibliography included

Method of Writing a Program

1. Think what you want to do.
2. Design it on paper.
3. Analyze the design.
4. Write the instructions on paper.
5. Try them using the computer.
6. Evaluate if the result is correct, otherwise go back to the program and correct the mistakes.
7. Save the program in the memory of the computer. Name it.

Programming is done in the form of procedures and subprocedures that can be integrated.

THIS IS AN EXAMPLE:



```
TO DRAW A SQUARE
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
FORWARD 50
RIGHT 90
```

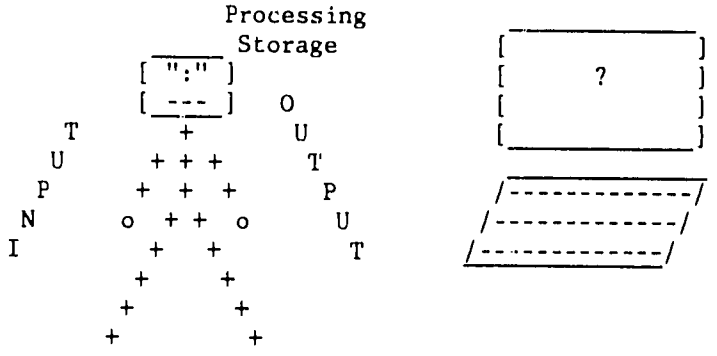
FIGURE 8.1 A sample handout for thinking through a design.

Parallels in Design and Function

A. Between a Factory and a Computer: The sectors in a factory and the parts of the computer are similar in their functions. They must both have input, decision-making, processing of information, storage, and output.

B. Between a Human Being and a Computer:

- o Acquisition of information = input.
- o Processing, organization, and analysis = the work of the CPU.
- o Storage in the memory = disks, tape, other memory devices.
- o Communication of information or language = output.



A. B.

FIGURE 8.2 A sample handout for introduction of new concepts.

Mindstorms, by Seymour Papert; several articles in Spanish journals (*La Revista del Instituto de Investigaciones Educativas*; *La Zapatilla de Cristal*, published by IBI; *Microcomputadores*, published by Editorial Plesa); and course notes on basic concepts in programming, Logo, and psychopedagogical background. These readings were then discussed in class.

The teachers worked in groups of three to four per computer. Following the coordinator's instructions, they divided into groups,

taking into account work style, difficulty or ease in understanding, personal characteristics, friendship, and teaching levels. When a set of exercises was completed, the entire class discussed difficulties in problem solving, and personal feelings. The last fifteen minutes were devoted to feedback and sharing of strategies to complete the assignments in the worksheets. New primitives were introduced through examples to the entire group; they were written on the board and then explained verbally. The individual groups' paces were taken into consideration.

After three or four lessons, the teachers felt more comfortable with the machine and the commands, as well as the methodology. As a result, they began producing their own designs.

The role of the coordinator of these sessions was to:

- Introduce new concepts and primitives
- Distribute exercises and readings
- Encourage independent work in small groups, sharing problem-solving strategies, and resorting to the coordinator only for special difficulties
- Lead the group discussions and feedback sessions
- Explain as many times as necessary
- Guide the teachers towards the achievement of the goals
- Observe the teachers' progress, working style, and communication
- Serve as a model for teaching style.

SAMPLE COURSE ACTIVITIES

Group discussion topics:

- Where are the computers in our environment? What is their role?
- How do we learn?
- What is information?
- How do we communicate among ourselves?

Information from computer magazines:

- What is a computer?
- What are the names of parts of the computer? How does a computer work?
- What is a program?

- What is a computer language?

Commands and concepts introduced:

HOME
FORWARD, BACK, RIGHT, LEFT
REPEAT
SETPC, SETBG
CLEARSCREEN, CLEARTEXT
CORRECTION FUNCTIONS
TO, SAVE, LOAD
TURTLE STATES: PU, PD, PE, PX, ST, HT
RANDOM
WAIT, SOUND, SILENCE
VARIABLES
IF THEN
RECURSION
SPRITES
LISTS.

After the teachers had completed the worksheet for the day they were free to make their own designs. Their methods of achieving results were discussed by the entire group. For the first contact with the computer, they had to find the command that made the turtle appear on the screen.

Exploring activity:

Measure the screen. The turtle has to go to the upper, lower, left, and right edges of the screen. Determine how many steps the turtle needs to reach them.

General activities:

- Combine all the primitives you have learned in a new program.
- Use the memory to save your programs.
- Turn the computer on and load Logo.
- Initialize a new disk. Save your programs on the disk, reload them.
- Imagine you are the turtle, test the movements and turnings with your body.

Small group activity divided by grade level:

Level 1: first, second and third grade
Level 2: fourth and fifth grade
Level 3: sixth and seventh grade.

- Design observation sheets for students' classes.
- Include intellectual, socio-affective and psychomotor areas.
- Comment on the observations made in the classes you teach.

Topics for group discussion (designed to recognize leadership styles and the group dynamic in the class):

- How do you feel while working with the computer?
- Can you work within your small group?
- Do you constantly need the coordinator's guidance?
- What is the best way for you to work in class?
- Is there a difference between your teaching methods and the methodology used in the computer lab? Yes? No? Why? What is it? How could you explain it?

GENERAL OBSERVATIONS

Some of the aspects that need to be taken into account during planning sessions are the following: the teachers' needs should be observed before the course is developed; group interaction, sharing, and freedom for project designs should be emphasized; the coordinator should serve mainly as a guide; the course should complement other teaching media; and provisions should be made for continuing in-service training.

The teachers' course started before the computer laboratory was opened to the students. For some of the teachers, the first lessons in the lab were very frustrating: they were afraid of the machine; some gave up very quickly upon the first failures in their programs; such statements as "I am not able to do this" were heard. Other teachers were very enthusiastic and started to explore many alternatives. They had no difficulties in understanding the instructions given on programming; they were very open to new ideas, exploring activities, and sharing; for many of them, the course gave them their first opportunity to experiment with the use of a new tool. The teacher training provided them with hands-on experience. When computers were introduced to the students, teachers attended the Logo lessons of their respective classes and were able to observe the coordinator's teaching style

and the students' responses. They assisted the coordinator when needed. Comments on their students' performance were encouraged. The methods used with the students were the same as those in the teachers' course. The groups helped each other, sharing information, problem-solving strategies, and project ideas.

The teachers realized that it is possible to let the students work by themselves, both because of their own experience and from observations of their students. They began to think of group activities for their classes, using worksheets, and gradually to change from a knowledge transfer teaching style to a more open one that encouraged exploration. The lab methods were transferred to the ordinary classes and adapted to the contents of the curriculum. The students began working in a more independent way, resulting in creativity, research projects, as well as sharing in groups and helping each other.

Some joint teacher-student activities were organized in the lab. Teachers and students visited a computer exhibition that enlarged their view and ideas about computers. They were provided with a written guide and had several questions to ask as well as observations to make. After the visit, the guide was discussed. For some of the students, it was the first opportunity to see different types of computers.

CONCLUSIONS

The computers were the "excuse" for initiating new teaching techniques, changing teaching and learning styles, and giving more freedom to the students to perform self-coordinated activities: to explore, to design projects, to work in small and large groups, to interact more in the class, and to communicate within peer groups. The teacher style changed to some extent from autocratic, teacher-centered to democratic and student-oriented. The key to the change appears to be the way the computer is used in the classroom.

9

Project ALFA-II: A Teacher-Training Strategy for Computer Education in Uruguay

JORGE A. GRUNBERG

INTRODUCTION

ORT Uruguay has been involved with high school level educational computing since 1981, within the framework of the ALFA Project (Grunberg and Bolata, 1985). Early in the project, we realized that teacher education would be one of the most complex issues to deal with. Different strategies were tried, aiming at training and involving teachers in the computers-in-curriculum process. The long-range goal is to train a new generation of teachers who could become the leaders of educational technology renewal. Educational technology is an educational issue and, as such, leadership cannot be provided by technocrats or politicians while teachers stand by and observe.

During the first two years of ALFA Project work (1982–1983), intensive programming seminars for teachers and theoretical self-study courses were tried and evaluated with varied results (including some immediate failures) (Grunberg and Bolata, unpublished). Some of the problems found in this "everything-to-everybody" approach were as follows:

- Training focused on technical skills (mainly programming) rather than on educational applications.

- Courseware packages used as examples were either too simplistic or inappropriate to Uruguayan teaching methods and curriculum.
- Permanent education was not ensured; no systematic follow-up and support were offered between seminars and courses.
- Course content was the same for every teacher and every subject.
- The number of teaching hours was not reduced to enable the teachers to carry out project tasks thoroughly.

Experience acquired since the first project enabled us to develop an entirely new approach based on a better knowledge of the teaching community's reactions to computers, the students' attitudes after the first year "new toy" period, and the special conditions of the so-called developing countries.

FACTS AND CONCLUSIONS DERIVED FROM PROJECT ALFA

Project ALFA's main objective is to integrate information technology with available teaching and learning resources to assist the educational process in the secondary education environment. Our computer education planning was guided from the beginning by the principles that courseware must not replace teachers, books, or real lab work and that courseware must require and fit the computer.

Some facts were recognized in the field during the first teacher training period (1982–1983) including:

- Positive attitude on the part of the teachers is an essential condition to attaining project goals and objectives.
- All teachers need minimum operational skills to manage, use, adapt, evaluate, or even consider computer use in their specific teaching process.
- Not all teachers have the time or vocation to acquire the whole body of computing knowledge needed to develop courseware and strategies to integrate courseware into the curriculum.
- Creating languages is not a general solution; it may represent a tactical choice for limited purposes but not a long-range strategic option.

- Teachers must see themselves as "owners" of the technology and principally responsible for its selection and use. If they see themselves as mere "buyers" or "advisors," they will not integrate it smoothly into the curriculum as a naturally used resource.

Based on these facts, we decided to consider the teaching community as composed of two groups: the users, on one hand, and the authors, on the other.

Teacher-Users and Teacher-Authors

Users will be expected to be able to use off-the-shelf courseware "intelligently" and manage the day-to-day operations of the computer lab as it relates to their specific subject. They will decide whether to use courseware packages and when to use them. When a positive decision is made, they will have to make evaluations and select a courseware package or set of packages according to their specific teaching objectives. These teacher-users will be trained to do minor modifications to unbundled courseware packages, to develop very simple applications on their own, to adapt the suggested courseware to their own environment, and to give intelligent feedback to the authors.

Summing up, the teacher-users will use and adapt. They constitute an educated market that will be able to capitalize efficiently on all the technical support they can obtain and raise the standards of available courseware. These users will receive periodic short seminars (2 weeks or 30 hours) and technical support to pursue computer training on their own until the following (holiday-time) upgrading seminar.

Authors attend a long in-service course (20 weeks or 120 hours) in order to be able to work in teams with computer programmers to design coursework and outline strategies to integrate it into the curriculum. Potential authors will be offered admission to those multidisciplinary groups depending on their interest in the computer-in-education issue, their pedagogical records, field experience, and in-depth knowledge of their specific subject. The course for teacher-authors has the following major objectives:

- To create in the teachers a favorable disposition and positive opinion about the educational use of information technology;

- To make the teachers computer literate, demonstrating the broad range of possibilities that this new tool can offer in different educational environments from both social and technical points of view;
- To give the teachers the basic know-how in computational techniques to solve simple problems by themselves; and
- To create a common language for the teachers to interact with computer programmers in courseware-development teams. They will be trained to analyze the teaching process systematically, to define the requirements, to propose useful enhancements, and to design and validate the functional specifications for computer implementation.

Appendix 9.1 describes the objectives, curriculum content, and teaching guidelines for the teacher-author course.

REFERENCES

Grunberg, J. and A. Bolata. ALFA Project: A Pilot project for the integration of information technology in the national secondary school educational system in Uruguay. *Proceedings of WCCE 85*, North Holland, 1–17, July 1985.

Grunberg, J. and A. Bolata. Computer education for teachers: an in-service course. Unpublished.

APPENDIX 9.1
CURRICULUM CONTENT AND TEACHING GUIDELINES FOR THE TEACHER-AUTHOR TRAINING COURSE

TOPIC OF UNIT	HOURS
1. Introduction: Social impacts of information technology	4
2. Computer uses in education	8
3. Introduction to courseware	6
4. Systems approach and problem solving with algorithmic techniques	6
5. Introduction to computer systems	6
6. Using computers	10
7. A programming language	10
8. Courseware development	20
9. Project implementation	40
10. Field test with students	10
	120

SUMMARY OF COURSE UNITS

UNIT 1

Introduction: Social Impacts of Information Technology

Objectives: To create an adequate environment and a fertile ground for the development of the course. To discuss different moral, social, political, and economic issues related to these new technologies.

Didactics Implementation: Group discussions at general knowledge level using press reports, scientific papers, and other documents. The topic will be covered using key questions to stimulate personal opinions, e.g., What is the relationship between technology and unemployment? (4 hours).

Contents:

- Social impact of technology.
- Common applications of information technology with real world examples (robotics, automation, computer-aided design, telecommunications).
- Technological influence on different professions and skills.

Suggested Activities: Students will choose one of the issues and prepare a brief position paper (using the laboratory library) for an open discussion.

Evaluation:
- Relevance of the chosen subject.
- Development of the position paper.
- Associated set of questions and answers.

Bibliography:
- The information age, Davis & McCormack. 1979. Addison-Wesley.
- Le defi mondial, J.J. Servan-Schreiber. 1980. Grijalbo.
- Time, Special issue. 1983. "Man of the year".
- National Geographic, October 1982.
- Scientific American, No. 74.

UNIT 2

Computer Uses in Education

Objectives: To analyze different methodologies for the use of computers in education and their advantages on a comparative basis. To study the theoretical foundation of each approach.

Didactics Implementation: Lectures and group discussions supported by practical examples (8 hours).

Contents: Introduction. Why should we integrate computers to educational tasks? Methodologies: a historical perspective.
- Testing.
- Administrative uses.
- Linear programs.
- Branching programs.
- CAI, CAL, CMJ.
- Simulations Modeling.
- Logo.
- Problem solving.

Various projects such as MECC, Plato, Conduit, MEP, "Informatique pour tous" and ALFA, as well as all the related courseware available. Analysis of the theory of education courseware underlying each kind of approach and methodology.

Suggested Activities: Comparative analysis and conclusions of the different methodologies covered (oral and/or written answers). Suggestions of new approaches.

Evaluation: Position paper on the comparative advantages of those methods previously analyzed and personal suggestions.

Bibliography:

- Learning and teaching with computers, Tim O'Shea, John Self. 1983. The Harvester Press.
- Learning with computers, Alfred Rork. 1980. Digital Press.
- Using a microcomputer in the classroom, G. Bitter, R. Camusse. 1984. Reston Publishing Co.
- Run: Computer education, Dave Ahl. 1981. Creative Computing Press.
- Computers in education: Proceedings of the IFIPS TC3 world conference on computers in education, WCCE 81, Lausanne, Switzerland, July 27-31, 1981.

UNIT 3

Introduction to Courseware

Objectives: To train the teacher in a methodology for choosing topics to be taught with courseware assistance. To evaluate available courseware, to determine its relevancy, and to devise strategies for its integration into the curriculum.

Didactics Implementation: Lectures and practical sessions. Actual examples of selected courseware. It is very important that teachers themselves use computers. At the end of the sessions, all of them must participate in a critical analysis of each piece of courseware shown (6 hours).

Contents:

- What is courseware?
- Main characteristics, objectives and contents.
- How to select a topic to be taught with courseware assistance (checklist).
  - Objectives.
  - Contents.
  - Interactivity.
  - Documentation.
  - Screen output.
- Simple projects to be solved individually.

Suggested Activities: Selection of a topic in each discipline for determining whether it might be taught with courseware assistance. Once written, the courseware will be presented to the rest of the group so that it can be analyzed.

Evaluation: Project relevancy and personal opinions based on the level of implementation and curriculum appropriateness.

Bibliography: Same as Unit 2.

UNIT 4

Systems Approach and Problem Solving with Algorithmic Techniques

Objectives: To introduce to teachers the use of a methodology to allow them to define their specific problems with a systems approach.

Didactics Implementation: Resolution of practical problems of increasing complexity using algorithmic techniques and a generic algorithmic language (6 hours).

Contents:

- Introduction, general considerations
- Basic structures (if..then..else, do...until, do...while, case...)
- Exercises
- Tool kits.

Suggested Practice: Exercises of increasing complexity to be solved using the algorithmic language.

Evaluation: Resolution of some of the proposed exercises selected as the most representative of each structure taught.

Bibliography:

- Introduction to computer science, an algorithmic approach, Jean Paul Tremblay.

UNIT 5

Introduction to Computer Systems

Objectives: To introduce basic computer concepts in order to avoid the "black box syndrome."

Didactics Implementation: Theoretical-practical approach supported both by audiovisual media and available computers (6 hours).

Contents:
- Importance of information. Information vs. data.
- Information cycle.
- A brief history of data processing.
- How a computer works. Main features, functions, components, and their relationships.
- Concepts of language (micros, minis, mainframes, supercomputers).
- How computers are used (real time, batch, distributed processing).

Suggested Activities: Comparative analysis of different types of computers and their common uses. Technical and economic concepts of their applications. Slides, videos and written material about different types and brands of computers. Guided tours to different kinds of computing centers (industrial, educational, commercial, financial, etc.).

Evaluation: Certification will be given based on exercises on basic computer system concepts.

Bibliography:
- The information age, Davis & McCormack.
- Introducion a los computadores en los negocios, Elias Awad. 1980. Prentice-Hall Inc., 1979.
- Operating systems, Davis. Addison-Wesley.

UNIT 6

Using Computers

Objectives: To train the teacher in the basic concepts and operational skills needed to use the computers available in the school computer lab.

Didactics
Implementation: Hands-on approach (10 hours).

Contents:
- Introduction to the specific computers available in the school lab.
- General hardware and software features.
- Basic operations concepts.
- Basic operating system commands and software tools available.
- Using word processors, spreadsheets, databases, graphics, communications packages.

Suggested Activities: Exercises creating files, creating reports, backing-up files; use of the text editor, compiler, and interpreters. Use of software packages in educational situations.

Evaluation: Grades will be awarded upon performance in these practical sessions.

Bibliography:
- Programmer guides and user guides of the specific hardware and software available in the school lab.

UNIT 7

A Programming Language

Preliminary Information: This course should be taught as independent of hardware as possible. For the purpose of this teaching guide, we have chosen BASIC, which is one of the most widely used languages available on microcomputers. As this teaching guide has been designed in a modular way, however, this unit could be replaced entirely by an equivalent one using Pascal, Logo, Prolog, or any other language.

Objectives: To give the minimal programming knowledge for the teachers to be able to write simple programs and solve problems by themselves. To give some programming experience so the teacher can develop a common ground with computer programmers for team work.

Didactics
Implementation: Hands-on approach. Implementation of the algorithms developed in Unit 4; problem solving with algorithmic techniques (10 hours).

Contents:

- Introduction to BASIC, general features.
- Constants and variables, operations hierarchy.
- Assisting values: (IFT).
- Printing results: (PRINT).
- Logical conditions and programming control: (IF, GO TO, FOR NEXT).
- Commentaries and program end: (REM, RUN, STOP).
- Entering data: (INPUT, READ, DATA RESTORE).
- Subroutines: (GOSUB, RETURN)
- Functions.
- Basic debugging techniques.
- Arrays processing, associated sentences.
- Functions, intrinsic and user defined.
- Files, file organization, file processing databases.

Suggested Activities:

- Solving practical problems of increasing complexity.

Evaluation: Grades will be awarded based on performance of some of the exercises given as practice.

Bibliography:

- BASIC programming manuals for the available computer.
- BASIC for students with applications, M. Trombetta. Addison-Wesley.
- BASIC, Kemmeny & Kurtz.

UNIT 8

Courseware Development

Objectives: Courseware design, implementation, evaluation and refinement using the methods and techniques learned before. Project experience and team work with computer programmers.

Didactics

Implementation: Teachers will be asked to propose several curriculum topics as candidates to be taught with courseware assistance. The relevance of each specific topic and various implementation strategies will be discussed by the group. Final products will be used in trial groups and student feedback will be analyzed (20 hours).

Contents:

- Review of Units 2 and 3
- The computer as a tool
- Criteria to evaluate courseware
  - Topic development
  - Documenting
  - Pedagogical interest
  - Motivation for the students
  - Computer implementation
- Courseware design
- System concepts
- Documentation concepts.

Suggested Activities: Project work.

Evaluation: Final products will be rated taking into account

- relevancy
- modularity
- level of implementation
- documentation.

Bibliography:

- Operation and programming manuals of the available computer.
- BASIC for students with applications, M. Trombetta. Addison-Wesley.
- BASIC, Kemmeny & Kurtz.
- Design of man-computers dialogues, James Martin.
- Sistemas de documentación en informatica, J. London.

10

The Use of Microcomputers in the Training of Science Teachers

SIMAO PEDRO P. MARINHO

THE STATE OF INFORMATICS IN BRAZIL

Brazil has been the first developing country to adopt a national policy relating to telematics and its effective economic significance (Machado, unpublished b). At present it has the most developed policy for informatics and telecommunication in the Third World (Spero, 1982), thus assuming the leadership of the developing world in sophisticated telecommunication facilities. During the late 1970s and the 1980s, Brazil launched informatics as a science. The somewhat abrupt introduction and the impact of this new technology has brought about a permanent concern in various sectors of our society for the establishment of clearly defined action policies.

Despite the country's serious economic crisis, the industry of informatics has been one of the few segments of Brazil's economy to show signs of real growth in 1984. The growth has been fostered by a national policy for informatics, as defined by the Special Secretary of Informatics. (This post was created in 1979 as a complementary organ of the National Security Council.) That policy, which aims to significantly reduce the country's technological dependence, has created the necessary conditions for the development of research. A portion of the market reserved for

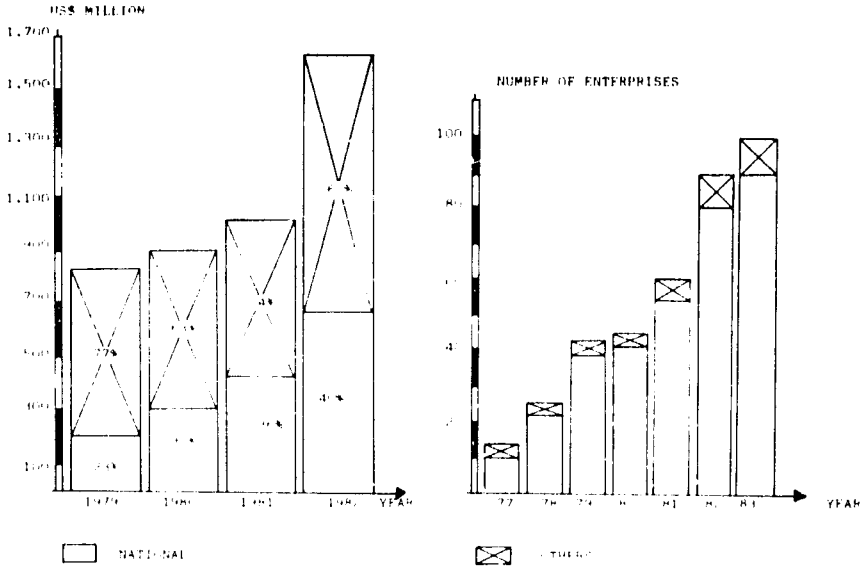


FIGURE 10.1 Growth of the Brazilian computer market.

national industries has made it possible for many national enterprises to invest in research and development and has fostered a rapid evolution of hardware.

A growing share of the market is being satisfied by national industry, as shown in Figures 10.1 and 10.2. Brazilian equipment is derived from similar foreign hardware, with or without our own technical contribution. One can detect, however, a relative predominance of the existing technology, as has been demonstrated by the growing proportion of nationally produced equipment and the relative reduction of imports, as indicated by the total sales of enterprises. Of the total now being used in the country, about 80 percent are micro- and minicomputers produced by Brazilian companies.

Unfortunately, there is a marked difference between the evolution of hardware and software. The software market is still basically founded on imports, although some steps have already

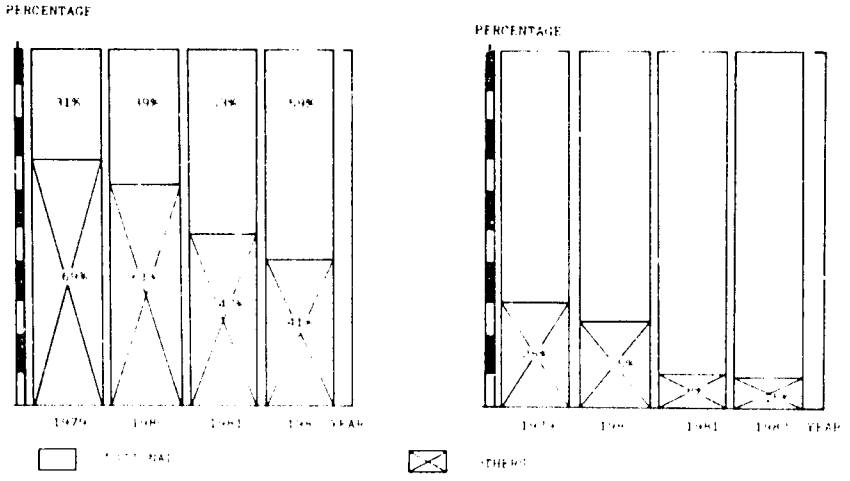


FIGURE 10.2 Domestic and import shares of the Brazilian computer market.

been taken to remedy the problem. Considering the lack of locally produced software, the situation in relation to educational software becomes even more critical.

The Brazilian Policy on Informatics in Education

The technological development of informatics in Brazil in the past has led the Ministry of Education to design outlines to organize the use of the new technology as an alternative auxiliary teaching aid, according to the national policy of informatics. Most significant among those outlines are:

- The training of human resources necessary for the promotion, development and proliferation of the principles of informatics
- Research and preparation of the community for the changes that will foster the introduction of the new technology without harming the cultural values and social habits of the country.

In 1981 and 1982, the Ministry of Education, the Special Secretary of Informatics, and the National Council for Scientific and Technological Development sponsored two national seminars on informatics in education with the objective of debating and looking

into the position of Brazil's academic and scientific communities on the use of computers as an auxiliary tool in the teaching and learning process. In 1983, a Special Committee for Informatics in Education was created to take charge of project EDUCOM: Informatics in Education. The creation of the committee was based on the special secretary's acknowledgment of the relevance of informatics technology in education; the Brazilian academic and scientific community's recommendations concerning informatics in education arising from the two national seminars; and the necessity of developing technology in our country for the use of microcomputers as teaching aids, controlled by the values of our own culture.

In 1983, the Center of Informatics (CENIFOR) of the Brazilian Foundation Center for Educational TV (FUNTEVE) took over the coordination and technical supervision of the execution of Project EDUCOM. This project has the general objective of encouraging the development of multidisciplinary research in the use of informatics in the teaching and learning process through these specific steps:

- Establishing a nucleus for research into and development of informatics in education
- Establishing pilot centers in institutions with recognized qualifications in science and technology in the areas of informatics and education
- Training the personnel needed to develop and implement the EDUCOM program in view of the requirements of the sector of educational informatics
- Following up and evaluating the experience gained in the pilot centers created by the program
- Disseminating results produced in those pilot centers.

Project EDUCOM is being developed, at present, in five Brazilian universities, four of which are supported by the federal government, and one by the state government.

Microcomputers and Brazilian Schools

The use of microcomputers has already begun in Brazilian schools; therefore, it is not necessary to discuss the relevance of the use of microcomputers as a teaching aid in Brazilian schools (Marinho, n.d.). According to Machado (unpublished a), an initial

question is, "What is it that makes a country such as Brazil, undergoing a process of development and deeply concerned with more urgent educational problems, get interested in education through informatics?" As Jaber (1981) points out, "there is a conscious and responsible will to insert Brazil in the context of the developed countries now using the computer as a teaching-learning process aid." However, discussions prior to introduction were intense.

Within the classification of innovations proposed by Robertson (1967), the computer falls into the category of those qualified to bring about the deepest changes in the social system. Such a classification is likely to provoke heated discussions and wide criticism. On the one hand, some consider the adoption of computers as a strategy for the reduction of the distance between our country and the developed ones. Others emphasize its role as a learning aid, mainly in remedial programs. There are those who believe in the machine as a means of liberating the teacher for the execution of nobler tasks in the art of teaching. On the other hand, some think that the importance of the computer in education has been overestimated not only by those in its favor, but also by those against it. There are others who, although recognizing its positive aspects in the educational process, do not consider the introduction of the computer as a priority in Brazil at present. We would like to analyze such criticisms a little further on.

Education in Brazil has become an object of concern particularly in the last twenty years. A progressive deterioration in quality has been detected, with harmful consequences. The great majority of Brazilian schools, mainly those supported by the government, are not provided with adequate equipment. They lack the most elementary didactic resources, including laboratories and libraries. In addition, the teachers are poorly paid, contributing to a low standard of teaching. This sad reality is the main argument of those who press for a solution for problems of higher priority before considering the use of computers in school. Such a position, insofar as it is a stance taken by educators, is likely to be criticized. As Chaves (n.d.) points out, it is understandable although lamentable that bureaucrats and politicians should restrict resources for education. However, it is difficult to understand why educators should limit their demands in favor of education.

The school has the duty of preparing students through learning correlated to life, in what was promised to be an exciting

intellectual adventure (Hesburgh, 1979) that will characterize the end of this century. Our schools, in enabling future citizens to face technological changes (Gomes, 1976), will have to specifically prepare those who will work with computers. According to Servan-Schreiber (1976), people who lead an active life need constantly updated educational programs to keep pace with change. Microinformatics is another aspect of this permanent updating of the school system (Marinho, n.d.), and its introduction into schools must be part of the educators' demands.

In Brazil, microcomputers are being used only in some private high schools attended by students from the highest social levels. The more poorly-funded state schools lack the necessary conditions for introducing any kind of education based on the computer. Therefore, the introduction of the microcomputer runs the risk of increasing the existing social inequality. If it is not introduced in state schools, the higher social strata will benefit more than the less advantaged population. The Brazilian schools' current needs justify introducing computers in public education, unless we accept the risk of creating problems for future generations (Marinho, 1985).

TEACHER TRAINING FOR SCHOOLS IN A NEW AGE

The use of the microcomputer in Brazilian schools is very recent, and there is a shortage of qualified teachers, which is a social as well as a technological problem (Seminario, 1982). In a world where change has become routine, the university must not be limited by today's reality; it must project into the future (Souza, 1979). However, with regard to informatics, the Brazilian university has not anticipated the new reality. The computer has not been introduced in teacher training courses, despite its introduction in high schools.

The introduction of microcomputers must follow serious discussion of when, where, and how it should be done. For the machine to be adequately introduced, it is clear that the teacher must be qualified, so as to avoid limiting its use only to basic language training. Thus, the introduction of new material into teacher training programs at schools with computers becomes absolutely essential. We believe (Marinho, 1985) that such preparation should include emergency training of those already teaching

along with a basic and continuing use of the microcomputer in future teacher training. Computer training for teachers is fundamental because teachers will be responsible for the development of educational software and the software will delimit the action of the microcomputer.

Those who now prepare software tend, on the one hand, to be computer experts, or on the other, to know specific high school course content, and consequently their interests sometimes conflict. The solution will be in training those who can control both content and computing techniques. Adequately trained teachers will be able to innovate and discover potentials of the machine as yet unexplored. Therefore, it is vital to act, in the preparation of these new human resources, by:

- Promoting a wide discussion of all aspects of the implementation of microcomputers in schools, including their social, psychological, educational, and other implications;
- Accentuating and exemplifying the auxiliary role of the microcomputer in the teaching and learning process, showing that the machine is not an end in itself;
- Encouraging critical analysis of the use of microcomputers in education, of varied programs, of software adjustment and compatibility, and of cost-effectiveness;
- Training teachers in programming languages, a skill fundamental to the development of educational software;
- Introducing a degree of knowledge about hardware, thereby imparting a limited critical basis for the choice of the best equipment for specific educational purposes;
- Using the microcomputer more frequently and consistently in training teachers; and
- Using educational software (including imported software) critically, and analyzing its applicability and efficiency.

The necessity for wide-ranging training of teachers and school administrators has been emphasized (Machado, unpublished a; Marinho, 1985; Sabbatini, 1983) as a fundamental strategy in any project introducing informatics in education. To overcome teachers' unfounded but existing fear of being replaced by machines, the innovation project must be planned in such a way as to offer them opportunity for improvement and progress in their careers (Carvalho, 1985). Machado (unpublished a) reminds us that teachers will be replaced by machines if, not admitting the importance of

modern technology, they insist on playing a traditional role in the face of irreversible social changes.

Recent research conducted in Belo Horizonte among high school teachers offers a panorama of perceptions of the introduction of microcomputers in schools (Aroera and Barbosa, 1985). (See Table 10.1.) Some points are particularly noteworthy. Of those interviewed, 73.3 percent agree on the priority of pedagogical questions such as evasion, repetition of grades, and low teaching standards with respect to the introduction of microcomputers (which are not considered as solutions to those problems). At the same time, 62.8 percent believe that the microcomputer will be an extra motivation for the student in the learning process. The question of using microcomputers in state schools in Brazil gives rise to the so-called syndrome of the school lunch. The term describes those who believe that, given very limited resources for education, priority must go to problems such as school lunches for needy students, school infrastructure, school laboratories, or better salaries for teachers. Among teachers, 62.4 percent find the introduction of computers totally irrelevant in state schools, since they are deprived of the most basic teaching necessities. Only 24.2 percent believe that computer use is fundamental in the training of our youth for the society of the future.

Teachers will play a decisive role in solving the question of poor educational programs, since the solution depends on the arrival of new teachers educated in a computing environment. They must be aware of their role during the planning of the introduction of computers in schools, in order to justify the high investment involved. The investment will not be merely in equipment, but also in professionals, to assure its positive impact as well as its return on the investment. However, as universities start using computers in teacher training, the result of the investment in computers will be more certain.

SCIENCE TEACHING IN BRAZIL

The main problems in science teaching in Brazil are not recent and exist despite some efforts (organized or not) to introduce modern science teaching through laboratory classes that allow a direct contact between the learner and his area of study. Among others, the following problems could be pointed out:

TABLE 10.1 Selected Opinions of Brazilian High School Teachers Concerning the Introduction of Microcomputers in Education

Statement	Percentage Responding				
	A	B	C	D	E
The quality of teaching can be greatly improved by the introduction of microcomputers in the classroom.	3.2	12.1	30.0	38.0	16.6
The introduction of microcomputers in public schools is absurd since many do not have even the most basic needs.	7.7	19.8	10.1	32.4	30.0
In spite of the lack of resources the microcomputer must be used in public schools.	18.2	36.0	21.5	20.2	4.0
Before considering the introduction of microcomputers in schools, we should address some serious issues such as evasion, repetition, and the low quality of teaching.	2.0	19.4	5.3	32.8	40.5
If continually used, the microcomputer will make our children inhuman like robots.	11.7	28.3	27.9	25.1	6.9
The introduction of microcomputers in the classroom will motivate the student in the process of learning.	2.8	8.1	26.3	47.0	15.8
The use of microcomputers in education will accelerate the development of children's intelligence and reasoning.	4.9	16.6	34.0	32.0	12.6
The use of microcomputers in education is fundamental to the preparation of our youth for a computerized society.	2.8	10.9	16.2	46.2	23.9

Key: A: Totally disagree, B: Disagree; C: Don't know; D: Agree, E: Totally agree

- The bookish character of science teaching
- The teacher's lack of preparation for the full use of aids that might make the teaching activity in that area more practical
- The inadequacy or total lack of laboratories
- The uncritical repetition of practical activities (when they occur at all) following classical experiments, in a routine where everything is prepared to work, and eventual failures are never explored; there is rarely a moment of reflection by the students
- The teacher's lack of creativity as a result of inadequate training
- The progressive reduction of the number of science classes in favor of other disciplines.

Current science teaching in Brazil demonstrates once more the distance between educational theory and practice. Emphasis is, in theory, given to the experience of the scientific method, practical classes, and discoveries, but the teaching is, in fact, based on books that do not stimulate the student or encourage his creativity. The school purports to be a socially engaged institution,

but the relevance of science for the solution of social problems is never demonstrated through science teaching. The students lack the necessary preparation for understanding the impact of technological products on the quality of life itself, and scientific knowledge seems to have no direct application in everyday life. It must be remembered, as Atkinson (1984) points out, that the value of teaching science consists not merely in its immediate practical results, but in the fact that it is a means of obtaining a higher quality of life. Science teaching must meet the demands of a changing society.

In 1983, the federal government created PADCT, a program to support scientific and technological development as an instrument to carry out a national policy of science and technology. Education for Science is one of the subprograms of PADCT developed by CAPES/MEC. This subprogram aims at stimulating the implementation of new strategies and consolidating current effective initiatives so as to improve science and mathematics teaching through the development of a project with the following objectives:

- Identifying, training, and supporting leadership at all school levels to ensure that the strategies and activities directed toward improving science teaching be effective in the short and medium term while ensuring the continuity, diffusion, and multiplication of successful efforts;
- Improving science and mathematics teaching, particularly in elementary schools;
- Improving the training of science and mathematics teachers; and
- Promoting the search for local solutions to improve science and mathematics teaching; stimulating the adaptation of these disciplines to local conditions and to the level of learners; and effective local coordination of personal and institutional initiatives that contribute to the improvement of teaching science and mathematics.

This project must reach its objectives through activities in four areas: (1) research in science teaching leading to the development of curricula and the implementation of pilot programs; (2) training of science and mathematics teachers, both before certification and in-service; (3) extracurricular and out-of-school activities for students; and (4) dissemination of information about science to the community.

Microcomputers' Role in Improving Science Teaching

As we think about the school in post-industrial civilization and look for means to improve science teaching, we cannot overlook an important aid: microcomputers. The application of a microcomputer in simulating and constructing models and in creating student-machine interaction to deal with real problems is one of the first uses of this educational aid. Its power to make available to the student the experience of different phenomena renders it absolutely essential in teaching the relationship of observation, theory, and experiment.

Another important role of the computer is in the development of creativity (Klein, 1983) and in teaching problem solving. It has been difficult for schools to teach methods of solving problems (Chaves, 1983). The programming of a microcomputer makes it possible for students to develop their problem-solving capacities, a fundamental activity in the formation of a scientific mind. After all, scientific activity consists precisely of continuous creativity and the solution of problems. Formulating questions, presenting and testing solutions, and breaking complex problems into simpler ones are common scientific activities, and they are also fundamental stages of structuring computer programs.

In all these ways, we believe microcomputers will contribute to the experience of scientific methodology. By requiring that students exercise objectivity, the capacity to make decisions, and creativity in solving problems, the microcomputer helps them in the design of their personal and professional lives, even though they may eventually choose a career in fields other than the scientific and technological ones (Berardinelli and Ribeiro, 1982).

For those reasons and others that will emerge as it is effectively integrated in the teaching and learning process, the microcomputer must be widely used in the necessary reform of science teaching in Brazil. As Castro (1982) has said, either we improve science teaching in Brazil now, or we shall definitely miss "the development train."

Training Science Teachers at the Pontificia Universidade Catolica de Minas Gerais

Undergraduate education in Brazil consists of three levels: the first, compulsory from 7 to 14 years of age, is made up of

eight grades in elementary and junior high school. The second has three grades (senior high school). The third corresponds to the undergraduate level of the university. Science teaching has different connotations for each level. In the first four years of the first level (elementary school), science teaching is integrated into other areas (Portuguese language, mathematics, geography, history). From the fifth to the eighth grade (junior high school), science is taught separately from other disciplines, although biology, physics and chemistry are combined in one course. Each one of these sciences is taught separately in the second level (senior high school).

According to the current legislation, the university is in charge of training science teachers for junior and senior high school. In the current structure of undergraduate courses for science teachers, training is in two stages:

- Junior high school teachers are trained in five terms, with a minimum of 1,800 hours.
- Specific training to teach one of the scientific disciplines in senior high school, biology, physics, chemistry, or mathematics, requires three more terms, with a minimum of 1,000 additional hours.

The Pontificia Universidade Catolica de Minas Gerais (PUC-MG) now trains teachers for junior high school, but senior high school teacher training is offered only in biology. The curriculum includes 2,285 hours for junior high school teachers and a further 1,475 hours for senior high school teachers. It has played a pioneer role in offering, alongside the traditional disciplines and education courses, other training including: (1) anatomical and histological techniques and taxidermy enabling the teacher to prepare material for practical classes and (2) courses in documentation that enable the teacher to produce with limited resources Super-8 and video cassette teaching films and to organize sets of slides with synchronized sound.

We believe that the microcomputer will help teacher training programs to achieve satisfactory professional levels of competence.

One Project Introducing Microcomputers Into Science Teacher Training

The Department of Biological Sciences of PUC-MG has developed a project for training science teachers that aims at the implementation of a nucleus of courses for science teaching through informatics with the general objectives that follow (the outline of this project is shown in Figure 10.3).

- Progressive implementation of the regular use of microcomputers in our biological sciences licensing, both through specific disciplines (logic of programming structure and programming languages for microcomputers), and as a tool in other disciplines of the undergraduate program;
- Developing, adapting, and evaluating educational software applied to science teaching; and
- Developing in-service science teacher training programs.

In Brazil, many different microcomputers are being bought and used in schools. A further aim of thisproject is to satisfy the considerable demand for compatibility of software, so that the programs written for one machine may be used with another. The features of various microcomputers are sufficiently different to inhibit this compatability, and some aspects, such as graphic resolution and color, are serious barriers to complete adaptation and compatibility. In our project, we will use several types of microcomputers, all made in Brazil, allowing the adaptation of some software to different machines. We expect that in three years we will have the nucleus of a science training program using educational software developed and adapted by our multidisciplinary staff. We recognize that microcomputers will rapidly change education in Brazil, as in other nations. Teachers and computer professionals must work closely to ensure that these coming changes are for the better.

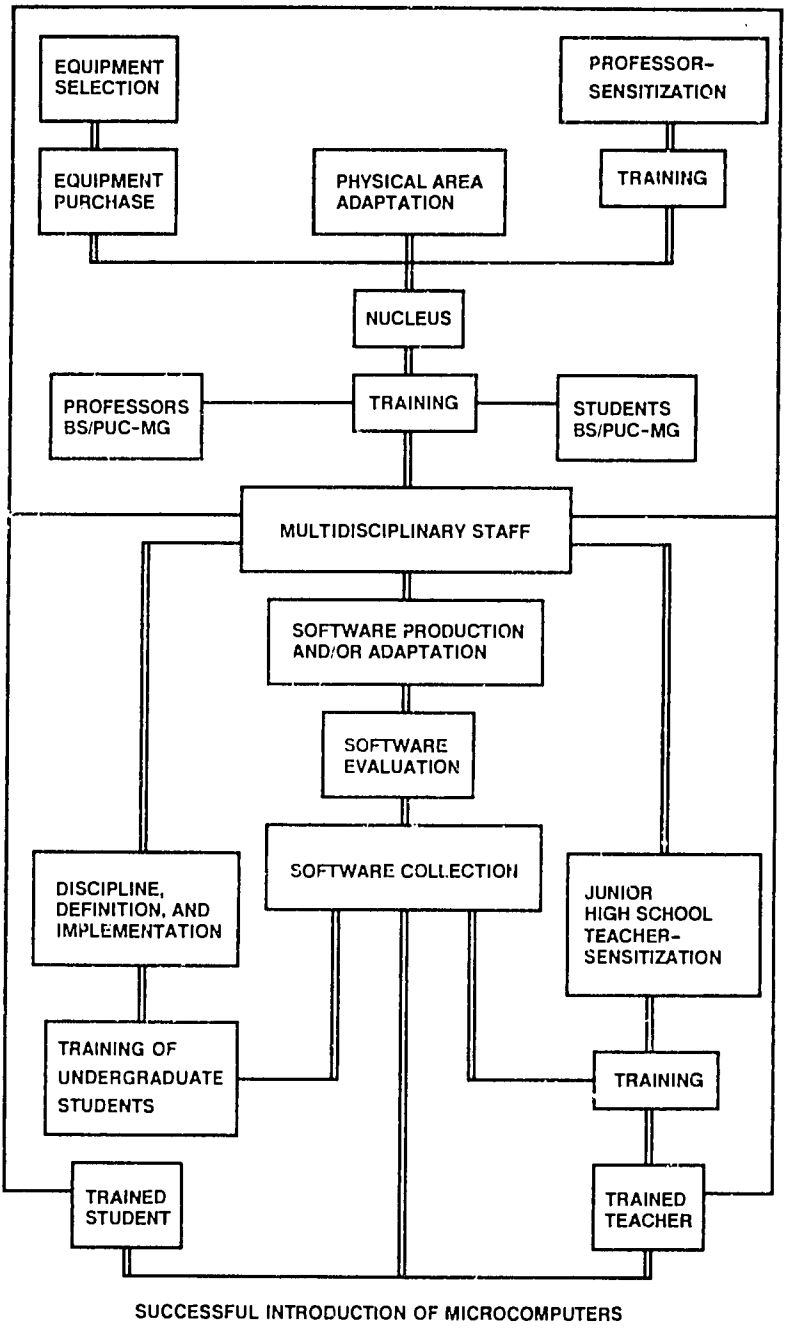


FIGURE 10.3 Conditions for the use of microcomputers in junior and senior high schools.

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Section 3
Software

11

A Support System for Instruction

JAVIER ANGELES ANGELES AND SALVADOR ORTIZ GARCIA

INTRODUCTION

The use of computation systems in education has been limited in our environment for several reasons, including:

- The high cost, until a short time ago, of the hardware
- The communications gap between the teachers (potential users of the systems) and the systems personnel (programmers, analysts, etc.)
- The lack of software programming for education in general (more than 97 percent of programming support provided in Mexico is geared to the areas of administration and management).

Even in the developed countries, where many programs geared to education are produced, the results obtained in their application are often poor. For this reason, teachers, who are in the classroom with the students and the machines, need to be responsible for the preparation of their own instructional systems.

This paper describes the Package Support System for Instruction (PSI) in its Apple II version. PSI is a tool that enables the teacher interested in using computers to prepare instructional

software, without being restricted by a lack of knowledge of programming techniques or computer systems management.

PSI is a package that permits the automatic generation of instructional programs on an Apple II microcomputer. It was developed initially by Project ALFA at the School of Sciences and Humanities, Universidad Nacional Autonoma de Mexico between 1981 and 1983 and was used intensively in the preparation of instructional programs at the intermediate and middle advanced levels. The version described here is the one expanded and updated in October 1984 by Educational Systems Research and Development. Periodic enhancements are made to the system based on the results of research by its various users, and other versions are expected in the future.

CONCEPTUAL DESCRIPTION OF PSI

The material to be taught is divided into small interactive teaching units called *cuadros*. These are designed to lead the student to the acquisition of a new concept, be it the structuring of an algorithm, the comprehension of a definition, or the formulation of a new rule.

PSI has sufficient versatility to be used in the preparation of linear or branched programs, simulation, or the heuristic management of data. It is a powerful system for the verification of responses and handles anything from the "yes/no" Boolean response, to the evaluation of a complex sequence of concatenated responses or image patterns.

The system includes the following instructional resources:

- Immediate verification of the responses provided by the student with generation of feedback messages
- Verification, if necessary, not only of the content of the response but also of the correct distribution thereof
- Variable speed in the presentation of the material
- Variable pauses
- Animation and movement.

Although the package is designed to be used under the computer-based instruction (CBI) mode and all the programs generated with it to date have followed this mode, it also can be used successfully in the generation of programs that follow the computer-aided instruction (CAI) or "drill-and-practice" mode.

OPERATIONAL DESCRIPTION OF PSI

The system constitutes what in computational terms is known as a "metalanguage for specific use," that is, a set of routines that, using procedures of artificial intelligence and commands given by any person, automatically generates a program for some particular application.

The package is made up of three parts:

- The image editor that permits the design of tables on the screen
- The processor that compiles the image, the sequence, and the effects in the desired order; and that generates the routines for evaluation of the responses of the student
- The applicator that is actually the interpreter of the goal language of the program generated at run time.

The programs generated with PSI are interpreted by a virtual machine, making them transportable to other computation systems, even though they were originally designed on and for an Apple II.

12

Educational Software Development Strategies for Developing Countries

ROBERT F. TINKER

Educational tool software offers the possibility of good pedagogy at low cost. Well-designed software tools can be used by students at many educational levels and often involve little text. As a consequence, a small collection of such tools could be the only software requirement needed to supplement school instruction. The adoption of a national strategy based on educational tool software would simplify teacher training, reduce dependence on imported hardware, and reduce the cost of domestic software development.

Several examples of educational tool software are illustrated in this paper, including two types of less well-known tools with broad applicability in math and science.

PROBLEMS WITH EDUCATIONAL SOFTWARE

Many styles of software can be used with microcomputers in an educational setting. Tutorials, computer-aided instruction, and drill and practice are styles that have been widely used and shown to have educational value in certain settings. Programming languages, especially Logo and BASIC, are popular because of the problem-solving skills that students acquire through their use. Simulations are widely used to allow students to experience

situations that are impossible, expensive, or dangerous to explore in reality.

Schools that are attempting to use microcomputers in a broader way than in the teaching of programming and that are trying to incorporate a full range of educational software styles throughout their instructional program are faced with a deluge of software. A 1983 survey of software (Tinker, 1984c) found over 3,000 titles of commercial math and science software, representing approximately one-third of the available commercial educational software. Extrapolating from this base, it is likely that there are currently over 20,000 commercial educational programs in all fields in addition to a large number of public domain programs.

Many of the educational programs are of no serious educational value, and others address a very narrow audience. Any program that uses extensive text, typical of tutorials and computer-aided instruction, is appropriate only to a certain reading skill-level. Text-intensive and drill-and-practice software packages usually make numerous assumptions about students' prior knowledge, culture, and vocabulary, as well as the topics in the curriculum and their sequence. Simulations are often very specific and can be applied at only one point in one course. If a school wishes to use narrowly focused software (such as most tutorials, computer-aided instruction, drill-and-practice, and simulations software), a large number of individual programs must be reviewed, acquired, and managed to make a significant impact on instruction. This is a costly undertaking, beyond the resources of most schools, particularly those in the developing countries.

CHARACTERISTICS OF SOFTWARE TOOLS

One class of software avoids these problems: general-purpose software tools such as word processors, graphing utilities, spreadsheets, databases, computational aids, microcomputer-based instrumentation, and modeling packages. The characteristics of educational tool software are as follows:

- It is user-controlled. A software tool, like a wrench, is something one uses for many purposes to extend human capabilities. There is no curriculum built into tool software, and there is no right or wrong use of the tool. The tool may include a tutorial on its use, but not on its role in the curriculum.

- It is multipurpose. A well-designed tool has many uses, including ones that the designer could not foresee. A screwdriver can be used with screws, or it can be used to open a can of oil or dig a hole in the ground. A good tool can be used by students at many different educational levels.
- It does not depend on language ability. Most software tools include little or no text. They usually use menus to select options. Icons that represent concepts pictorially using no words at all are increasingly being used in software tools.

The three characteristics of software tools listed above are important educationally. Pure tools put thestudent in control, avoid the problems of software judgment of student knowledge, and minimize cultural bias. The issue of control is important, because tools empower students, making them active participants in their education, while some other styles of software allow the computer to control the student. The relative absence of text makes software tools accessible to all students, even those with language deficiencies and mild learning disabilities.

Software Tools in Developing Countries

The characteristics of software tools make them particularly important in the context of developing countries. Because they can be used in many contexts, a relatively small number of tools will satisfy the needs of many students in many courses. Because only a few tools are needed, teacher training requirements are simplified, and implementation on more than one computer is conceivable. Their limited use of text makes tool software easy to translate or to use without translation.

Good software tools are complex to develop, to use in the classroom, and to teach to teachers. They tend to be large programs, best developed by teams of professional educational programmers. Their use in the classroom tends to be supplementary, requiring the presence of a teacher and appropriate text material. Their best use is creative, requiring imaginative teaching and an open, risk-taking educational environment. They are not "teacher-proof" and thus, require teachers to be trained in their use. Offsetting these problems are the educational advantages of tool software and the practical matter that only a small collection of tools is required.

A national or regional program to produce, implement, and support educational tool software in developing countries would have many advantages. The small number of programs required would make this approach economical compared to the effort required to develop equivalents of even a fraction of the end-use programs available in the United States.

The small number of programs required also help to limit the problems caused by using different types of hardware. Should a developing country decide to develop its own educational computer, it would be a relatively simple matter to translate the support tools to the new hardware. As new commercial hardware becomes available and less expensive, many of the tools, especially those useful outside the schools (such as word processors and spreadsheets), will be developed by microcomputer manufacturers or third parties. If they are using only a few programs, schools will not be locked into one computer but will be able take advantage of inevitable improvements in computer technology.

While educational tool software places more responsibilities on teachers than do either drill-and-practice, tutorials, or computer-aided instruction, a national policy to support this style of software would result in teacher training economies because of the small number of programs and because obsolescence is unlikely. The alternative, introducing teachers to even a significant fraction of the commercially available software, is a hopeless task. Thus, each teacher must learn on the job about the software used where he or she teaches or else must acquire the software he or she learned. Transferring between grades or schools requires learning about a new set of software, and often the software available changes as hardware changes and software vendors change.

If a small set of educational tool software was supported nationally, these problems would be minimized. Pre-service courses would train teachers to use the software in schools, the software would be similar at different grades and schools throughout the country, and, while the software may change over time, the same functions would be available and supported nationally even as the hardware changes.

EXAMPLES OF EDUCATIONAL TOOL SOFTWARE

The remainder of this paper will explore some examples of educational tool software to illustrate the importance of its characteristics in education, especially in developing countries. Some of these tools are well known and have been used in the schools for some time.

Programming Languages

Programming languages represent the ultimate software tool, able to cause the computer to perform any task within its hardware capability. Languages designed for students, especially Logo, Smalltalk, and Bozer, make the computer's capacities particularly accessible to students. While there has been considerable interest in teaching programming languages to students, programming has become an end in itself and is seldom used as a tool to support instructional goals in other courses except in post-secondary technical courses.

Using programming as a tool in support of instruction is difficult unless the teacher and students in a class are fluent enough in a programming language to apply it successfully to other problems. Without fluency, the programming language gets in the way of learning instead of facilitating it. It seems unfair to a chemistry instructor, for example, to make extensive use of programming if this would penalize a promising chemistry student simply because he or she has a weak background in or aptitude for programming.

A large-scale effort to teach all students and faculty reasonable levels of programming is required before the use of programming in instruction is feasible. Then an additional effort is required to integrate suitable activities based on programming into the curriculum. Such efforts are probably most appropriate in programs for the gifted or schools specializing in technical subjects.

Spreadsheets

Spreadsheet software, such as VisiCalc and Multiplan, has proven to be the most popular type of computational software for business applications. Spreadsheets are a form of tool software often overlooked in education. In addition to being used for planning and budgeting, spreadsheets can be used for many types of

calculations in math, science, and other quantitative fields. In fact, almost any programming problem can be cast into a spreadsheet form, and often spreadsheets seem to make it easier for many students to visualize a problem. Programs require a type of linear thinking that only a fraction of students find natural; spreadsheets seem to be easier for many students to set up. Spreadsheets are defined by relationships between cells and permit a less linear approach based on relationships that may be more natural for the majority of students (Haynes, 1983). As a result, spreadsheets can be successfully used in many educational settings.

Spreadsheets have been applied (Tinker, 1984 a,b) to rule guessing, the binomial series, functions, slopes, recursive functions, difference equations, simultaneous equations, and two-dimensional fields. Many of the more recent integrated business packages combine spreadsheets with graphing packages. This adds a powerful capacity for visualization onto spreadsheets and makes them even more valuable for education.

Graphing Utilities

The ability of modern microcomputers to generate graphs, bar charts, and histograms has been used in many educational tool software programs. "Exploring Tables and Graphs," developed by The Technical Education Research Centers, Inc. (TERC) and published by Xerox Educational Publications, is one such program. This package is of particular interest to developing country educators because many parts of this software use iconic menus, as illustrated in Figure 12.1. Because of the icons, non-English reading students might be able to learn to use the software without modification.

One of the best features of the software is its speed. All the code is resident in the computer, avoiding the slow chaining from disk that larger and more sophisticated programs must use. This makes it easy for a student to modify a table and see the result of the modification in a graph immediately. This quick feedback is quite important because it allows students to learn the relation between numbers and graphs through exploration.

Many graphing packages have been used successfully to enhance mathematics instruction, including Arbplot (Conduit), Cactusplot (Cactus Software), Green Globs (Conduit), and Guess My Rule (HRM Software). These packages can be used to supplement

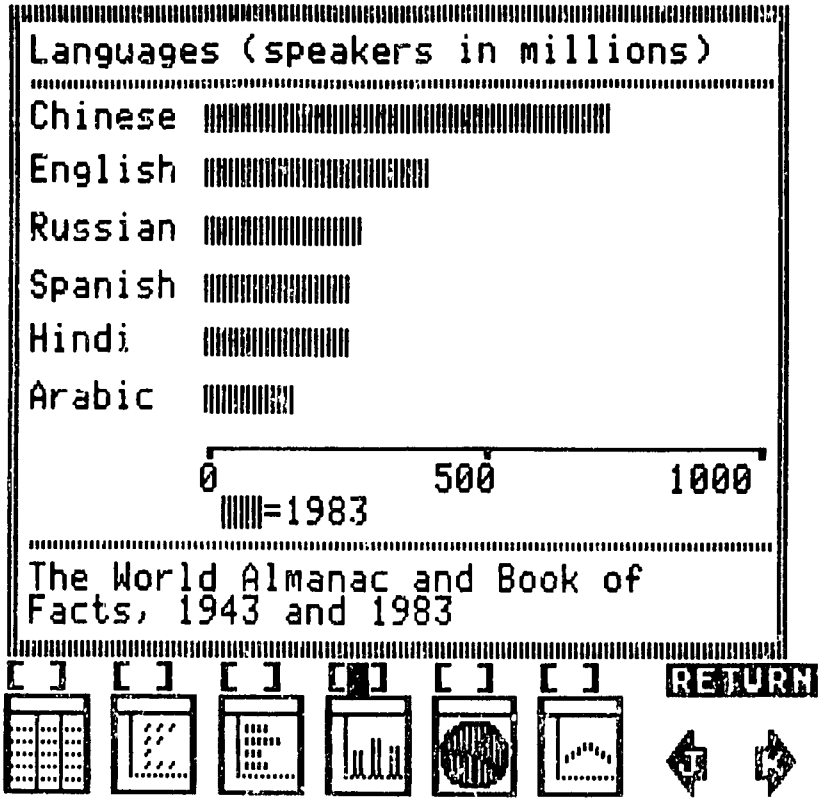

FIGURE 12.1 A screen from "Exploring Tables and Graphs" showing a bar chart output and iconic menu giving the user options for alternative display formats. (The Technical Education Research Centers, Inc., Xerox Educational Publications.)

the curriculum from the time students are introduced to the idea of graphing, through pre-calculus, calculus, and advanced analysis. Some of the same packages can be used in science and social science courses to visualize data and relationships.

Some other tool software has been more recently introduced and is aimed more specifically at education.

Microcomputer-Based Laboratories (MBL)

The educational use of personal computers in the laboratory to gather, analyze, display, and store data, is a class of educational tool software that has only recently begun to gain recognition. We

have named this type of application microcomputer-based labs, or MBL. Four relatively new instructional units developed at TERC illustrate the educational potential of the MBL tool approach: The Bank Street Laboratory (CBS/Holt, Rinehart & Winston), Exploring Heat (DCH Software), Experiments in Chemistry (HRM Software), and the MBL Project Sonic Grapher (unpublished).

The Bank Street Laboratory

A TERC-developed package, the Bank Street Laboratory enables students to perform a wide variety of experiments involving light, temperature, and sound. One of many possible measurements—Sound Print—illustrates the sophistication of the package.

Sound Print captures one second of sound and displays the compressed waveform and a representation of the strength of frequencies present in the waveform. (Figure 12.2 illustrates output obtained from a whistled tune.) Sound Print is quite sophisticated. The hardware interface samples the microphone every 112 microseconds, storing 8K points. These points are transformed in groups of 256 using a fast Fourier transformer assisted by a hardware multiplier. Students have no more of an idea that all this is happening than they know of the inner workings of their television or telephone. All that matters is the relation of input to output. Students learn that whistles give single lines that go up and down with pitch. They can attempt speech recognition visually, and learn to appreciate the sophistication of their own auditory system.

The Bank Street Laboratory can be used over a wide range of educational levels. Supporting print material is now available for grades four to six and seven to ten.

Exploring Heat

Exploring heat is an MBL unit developed with special attention to the needs of mildly learning disabled (LD) students in the higher grades of elementary school. The adaptation of temperature measurement and graphing software to the needs of LD students involved careful attention to screen layout, user interface, and other features of the student-computer interaction. The resulting software has as great a capacity for data acquisition and scientific investigations as earlier software not designed for LD

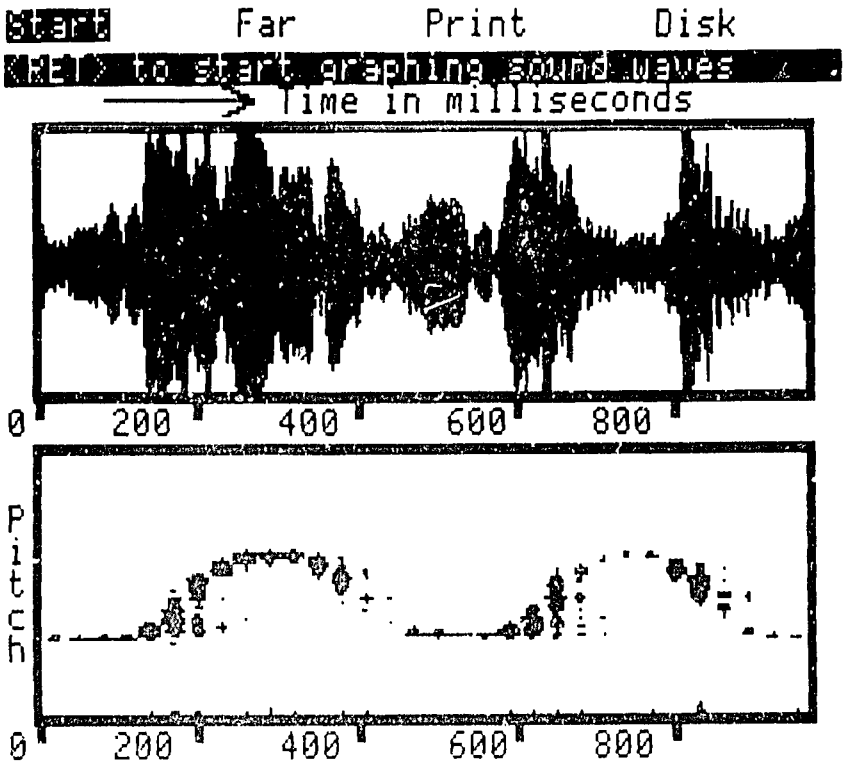

FIGURE 12.2 A screen illustrating sound waveform analysis. The upper trace is a compressed one-second waveform captured during a short whistled tune. The lower trace is a sound print showing frequency over the same time. The vertical frequency scale is linear from 0 to 4 kHz. (The Bank Street Laboratory; CBS/Holt, Rinehart & Winston.)

students. The same features that make it usable by LD students make it easily used by all students and, therefore, an ideal tool for classrooms in which some of the students have learning disabilities.

The material was carefully tested in public school classes with a mixture of LD and other students, all of whom fell within the normal distribution range for intelligence. There was no significant difference between the performance of LD and other students on the material. It seems that the MBL package was able to bypass the communication difficulties experienced by LD students. For the LD students, understanding the material was important psychologically, giving them a rare, positive learning experience from which they could gain confidence.

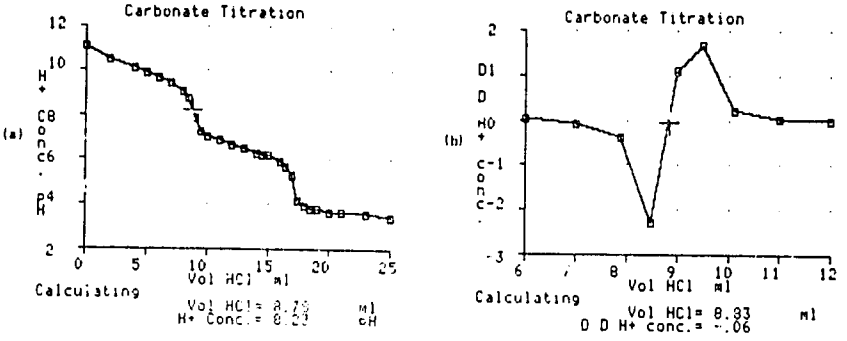

FIGURE 12.3 Graphs showing a) an MBL titration, b) the second derivative of the curve near the equivalence point. (Experiments in Chemistry; HRM Software.)

Experiments in Chemistry

Experiments in chemistry are designed for advanced high school and general college chemistry courses. An integrated program provides the ability to record, graph, and analyze pH, EMF, and temperature data. Compared to other MBL packages, its data display and analysis functions are unusually strong. Figure 12.3 illustrates this capacity with pH data from a titration. By expanding the graph around one equivalence point, and then differentiating twice, Figure 12.3b is obtained, from which the equivalence point can be easily read. The package also provides two independent screens and allows data to be fitted over selected parts of the range to best fit straight lines.

The Sonic Grapher

The Sonic Grapher is one in a series of 18 MBL units currently under development at TERC with funding from the National Science Foundation. An ultrasonic transducer, adapted from a camera's automatic focusing electronics, is interfaced to the computer to provide real-time graphs of position, velocity, and acceleration against time, as is shown in Figure 12.4. Very brief exposure to experiments that utilize this capability seems to permit students to understand kinematics concepts that have traditionally been difficult to teach. Substantially similar MBL packages have been used successfully with both sixth graders and introductory college students (Thornton, 1985).

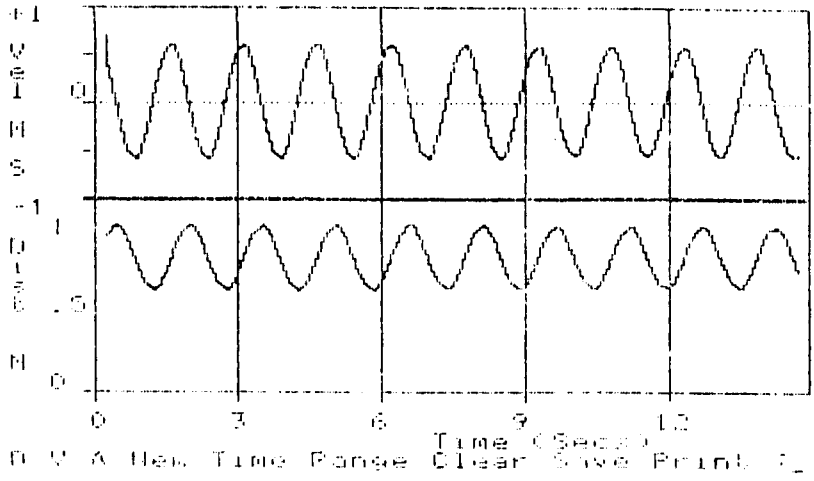

FIGURE 12.4 Graphs of the position and velocity of a pendulum obtained from a prototype version of the Sonic Grapher. (TERC; NSF.)

In summary, MBL tools offer a powerful new approach to science education that can improve student's learning, expand the science topics covered, and be used across many grade levels.

Modeling Software

Software can be used for exploring models of the real world in many ways. The best use of models involves educational tool software that allows students to create models rather than simply explore a simulation, that is, a canned model that someone else has created. The ability to create a model is central to the goals of science education. Creating a model is a form of theory building, and testing the accuracy of a model is a part of the essence of science.

Dynamic model-building software can allow students who do not understand calculus to gain insight into dynamic systems; it gives these students the ability to solve interesting, complex problems, even if the problems do not admit to a closed analytical solution. The software has the potential to eventually force the reorganization of the mathematics and science curriculum. Science teachers will want to use modeling software to allow students to explore and solve otherwise intractable problems because these problems are interesting and realistic. This will permit the earlier introduction of theoretical treatments of science content that must

now be delayed until students have learned calculus. One of the chief motivations for including calculus in math is to give students the tools to solve some of these complex problems. With modeling software tools providing a better alternative method of solution, there will be a powerful pressure to cover numerical methods earlier in the mathematics curriculum and delay the formal study of calculus.

Nancy Roberts has pioneered the use of dynamic models at the pre-college level. She has developed curriculum material (Roberts, 1983) and participated in the development of micro-Dynamo (Addison-Wesley), a microcomputer version of Dynamo (Richardson, 1981). Dynamo is a mainframe systems modeling language widely used in academic applications. Professor Roberts has successfully taught students in grades nine through twelve to create sophisticated models and to solve them using microDynamo. Although dynamic systems are based on calculus, these students required no more than the usual mathematics taught in a first course in algebra.

The interactive graphics, sophisticated user interface, speed, and computational power of more recent software and computers offer exciting possibilities for better software for solving dynamic systems that could make dynamic modeling much more widely applicable in education.

Dynamic models can be specified graphically, using icons that have been developed to represent elements of systems. The iconic representation is used as a way of thinking about systems that is accessible to students with a modest command of mathematics. The critical calculus ideas of rate and change are incorporated into icons representing reservoirs and values.

This kind of iconic representation is usually translated into another representation for computer solution. The exciting possibility presented by modern personal computers is that this iconic representation can be the only input required; the software can compute the system performance directly from the iconic diagram. Stella (High Performance Systems) is an example of a system solver that works directly from icons. Figure 12.5 illustrates an iconic model specification together with its solution dumped from a Stella screen.

The model can be created and changed graphically using the mouse. For instance, a few changes in the model to link high population with a decreased birth rate are easily incorporated

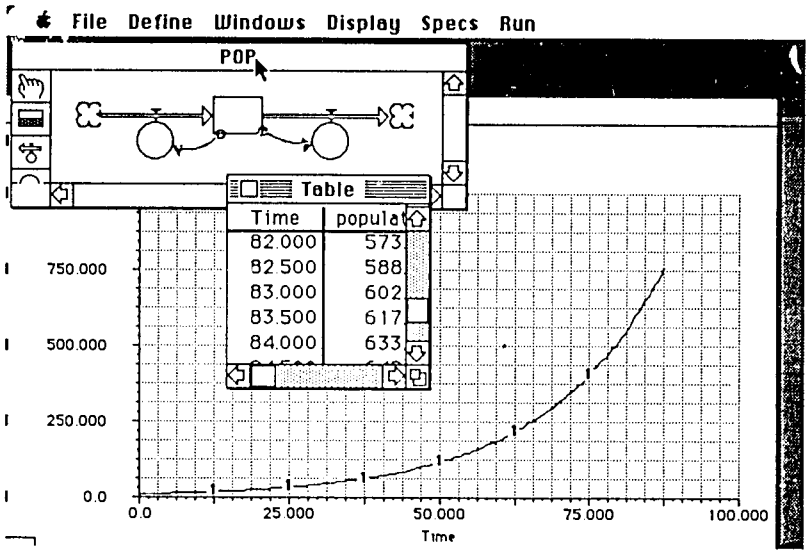

FIGURE 12.5 An iconic specification and graph of a system (population) that has simple unrestrained growth. A constant birth rate of 0.1 per unit time and death rate of 0.5 per unit time was assumed. (Stella; High Performance Systems.)

and result in the model shown iconically with its solution in Figure 12.6. Not all the details of the model are evident in the picture. Details of the assumed relation between population and birth rate are "inside" the birth rate circle. The user can access them by clicking the mouse on the corresponding icon.

While Stella is now a unique program available only on the MacIntosh, it is the harbinger of a new class of modeling software that is easy to use, iconic, fast, and highly interactive. By combining iconic representations of complex systems with the interactive graphics now possible on personal computers, any student who can draw can begin solving systems. With this new technology, not only will calculus no longer be a prerequisite, but algebra will not be absolutely necessary.

Mary Budd Rowe (Rowe, personal communication) has shown that students in early elementary grades can create plausible models of interacting systems in an iconic representation. This new technology could convert these students' models into quantitative predictions. Perhaps the ability to interpret graphs will emerge as the only traditional mathematical prerequisite to a sophisticated understanding of complex systems. Recent results (Barclay, 1985)

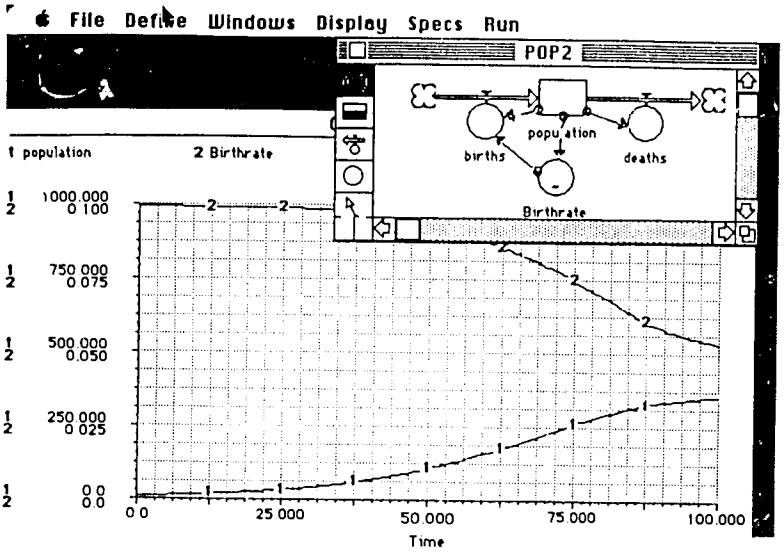

FIGURE 12.6 Screen dumps showing a more complex model that relates birth rate to population and a graph of its solution. (Stella; High Performance Systems.)

indicate that MBL software may facilitate graph interpretation and comprehension by students as early as the mid-elementary level. If this is the case, surprisingly young students will be able to undertake independent experimental and theoretical investigations given the combination of emerging MBL and modeling educational tool software.

Figure 12.7 gives an indication of ways that MBL and modeling tools could be used together. The top graph shows the displacement of a pendulum as a function of time, using data recorded by the software. The apparatus consists simply of a game paddle with a rod taped to it. The game controller acts as both the axis of rotation for the rod and the transducer used to record the rod's motion. The lower graph is a dynamic model of the pendulum. The terms in the model that control the frequency and friction have been adjusted to match the data. The squares on the lower graph are data points transferred from the upper graph and indicate how well the model fits the data. It was necessary to adjust the model to incorporate a type of friction not usually considered in introductory courses.

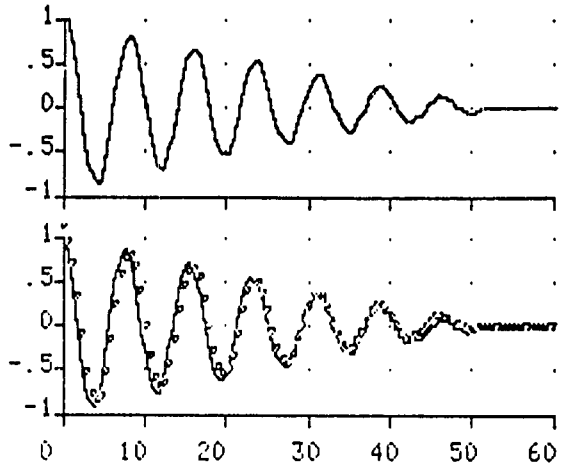

FIGURE 12.7 A graph of MBL pendulum data (upper) and the solution of a dynamic model of the system. The data have been normalized for easier comparison to the model.

SUMMARY

Software tools should have a central role in educational applications of microcomputers, especially in developing countries. A limited collection of tools could be the core of a country's response to the opportunities presented by the new technologies. Some of these tools would be well-known educational or business tools like Logo and spreadsheets. Others would be more specialized tools, such as packages for graphing, microcomputer-based labs, or modeling. The use of tools, though rewarding, is not an easy path; a coordinated approach to software development, curriculum materials development, hardware acquisition, and teacher training is required.

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Software Publishers

Addison-Wesley Publishing Co.
Jacob Way
Reading, Massachusetts 01867

CBS/Holt, Rinehart & Winston
383 Madison Avenue
New York, New York 10017

DCH Software—D.C. Heath & Co.
125 Spring Street
Lexington, Massachusetts 02173

High Performance Systems
13 Dartmouth College Highway
RR 1, Box 37
Lyme, New Hampshire 03768

HRM Software
175 Tomkins Avenue
Pleasantville, New York 10570

Xerox Educational Publications
245 Long Hill Road
Middletown, Connecticut 06457

13

A Practical Guide for Developing Educational Software

JAIME PRILUSKY

There is little doubt that the microcomputer can be an invaluable help in education and training. The fundamental aspects to consider while developing software for education or training are therefore noteworthy, so we will discuss different aspects of the interaction of microcomputers with teachers and with students. We will also discuss the selection of an adequate communication pathway between the user and the computer, considering at the same time the degrees of participation that can be established through the program to ensure a maximum response from the user. After following a flow diagram for one educational program, we will analyze in-depth a working software program, pointing out the positive and negative aspects we will encounter.

USES OF THE MICROCOMPUTER IN EDUCATION

The microcomputer in education is used for teaching computer literacy, as a tool for presenting images (like a slide projector), and in the principal role of computer-aided instruction (CAI). The use of computers for teaching computer literacy, programming languages, and structured logic does not need to be discussed; the best way to learn how to program a computer is to program a computer. The application of the microcomputer as a slide

projector is spreading, since powerful software is now available for developing attractive slide-like pictures that can be seen on a giant screen. All sorts of graphs, line charts, bar charts, pie charts, and scatter charts help lecturers express themselves clearly and allow the audience to comprehend the information more fully. However, these illustrations can be prepared by other means. The computer only becomes uniquely necessary when we consider CAI applications. Generally speaking, we can find three different kinds of CAI programs: drill-and-practice, problem-solving, and event simulation.

Drill-and-practice programs allow the student to develop an instantaneous response to a given task. Basic mathematical operations are performed faster than ever before because the student competes against the clock. The repetitive practice develops an effective skill that can help the student carry out similiar tasks in the future.

Problem solving has a different attraction. Using software based on the "problem-solving" principle, the student needs to solve different problems each time, applying general given rules. In practice, the student develops the capacity to extend concepts and learned strategies to similar but not identical situations, providing him with a good preparation for solving everyday problems.

But not all real-life problems can be solved using mathematics. There are situations that can only be solved by taking the optimal logical action or performing an accurate series of movements. The only way to increase the student's ability to solve these particular types of problems is to give them the logical cues or necessary manual skills. For example, to learn to operate an automobile skillfully we must drive a car again and again. To improve a student's ability to fly an airplane, we must allow the student to fly as many times as needed. The same applies in learning how to operate any industrial machine. Economic restrictions on the one hand, and safety considerations on the other, usually make learning while operating the machine absolutely impractical. Computer simulation allows the acquisition of at least a minimum skill-level by operating a simulated machine.

To teach scientific principles, we can also apply computer simulation. Generally speaking, we can divide scientific events into two broad groups: those that are too expensive or dangerous to be included in a regular classroom, and those that are too

fast or too slow to be observed directly. The first group may include almost any standard science laboratory demonstration. For instance, many chemical reactions or physiological experiments involving test animals can be simulated on a microcomputer. The simulated experiment is less expensive and less dangerous, can be repeated as necessary, and is more humanitarian because experimental subjects need not be killed. Among the experiments too fast to be observed we can consider the production of light, the changing of the orbit of an electron, and other similar phenomena. As examples of experiments too slow to be seen we may include the simulation of our solar system, the movement and interaction of the galaxies, the reproductive cycle of mammals, and so on.

STUDENT INTERACTION WITH THE MICROCOMPUTER

An educational program requires two important elements: a computer on which to execute and a user to receive the message. When designing an educational program, we must carefully consider which role we want the user to play. As shown in Figure 13.1, we can classify the participation of the user into four general categories: null, weak, medium, and strong.

When the student watches the message passively as though watching a television show, we say that the participation is *null*. The computer generates situations and shows facts at an internal rate, independent of the needs of the user. This kind of software will satisfy the expectation of some users while being too slow or too fast for others. When the user is allowed to control the speed at which new concepts are shown on the screen, the program allows *weak* participation. In this way, each concept remains on the screen long enough to satisfy the particular needs of a particular user. In a *medium* participation mode, the flow of the programs depends on the user's answers. This kind of software not only allows the user to think about any concept as long as needed, but also provides information related to the requirements of the particular moment. It is evident that different users may have previous knowledge of the subject thus requiring a special treatment and a different way of explaining the same principles. A good educational program working in a participatory mode should give each user what is needed to relate his or her particular background and facility to the new concepts to be learned.

CLASSIFICATION OF EDUCATIONAL PROGRAMS	
PARTICIPATION OF THE USER	
NULL	user just as a 'show watcher'
WEAK	user controls the rate at which new concepts are shown
MEDIUM	the flow of the program depends on user's answers
STRONG	user controls simulation of complex phenomena

FIGURE 13.1 Educational programs classified by user participation.

When interacting with software able to handle a *strong* user participation, in addition to the advantages described for the previous mode, the user is able to control the simulation of complex phenomena. This participation allows the user to generalize about a particular phenomenon by studying its development under different conditions. This way of recreating general rules by observation is the best way to learn. At the same time, the solving of real-life problems can be accomplished by asking the user to control the interacting parameters to simulate the phenomena under study. This option combines manual and intellectual skills to create a realistic simulation.

The physical means by which the user interacts with the computer can be of a diverse nature. We can develop software able to detect keyboard pressure or to receive inputs from a paddle, joystick, light pen, touch-sensitive screen, and even spoken commands. Not every computer facility has all these resources nor does every software program need them.

A software program with null participation by the user will not require any link to the exterior at all. As described, the user watches a show without interacting. A weak participation will require at least a simple interaction to signal the computer when

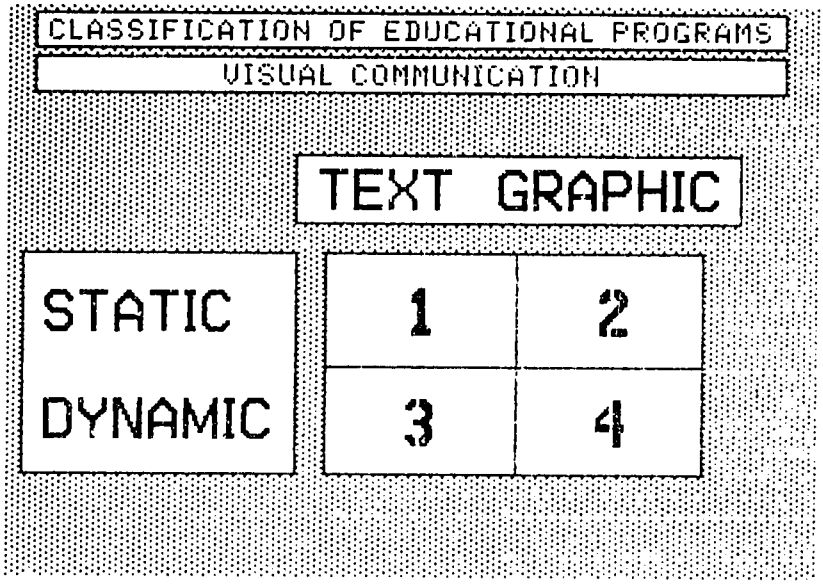


FIGURE 13.2 How software presents concepts to the student.

to continue to the next concept. In a medium participation program, the user must control the flow by choosing between different options or by answering questions at different times. This can be accomplished by entering data through the keyboard, pointing to answers on a multiple-choice test with a light pen, or by pressing a touch-sensitive screen. The most rewarding link exists for those programs designed for strong participation. Besides the keyboard, light pen, or touch-sensitive screen, this software may require analogical signaling through paddles or joysticks. Out of all the possible links described, voice input would allow the most natural communication path from our human point of view.

HOW MICROCOMPUTER PROGRAMS COMMUNICATE WITH THE USER

We can classify a training or educational program into one of four categories according to the way in which it presents concepts to the student (Figure 13.2). In this classification, we are considering just two dimensions: text/graphic display and static/dynamic presentation.

```
GREGOR MENDEL CAN BE CALLED THE FATHER
OF GENETICS. WHICH OF THE FOLLOWING IS
NOT TRUE ABOUT MENDEL.
1. HE STATED THAT TRAITS ARE INHERITED
2. HE SAID TRAITS EXIST IN 2 OR MORE
   FORMS
3. HE EXPERIMENTED WITH PEA PLANTS
4. HE WAS AN AUSTRIAN MONK
----------------------------------------
?1

WHOOPS! A WRONG ANSWER!

MENDEL'S REASONING WAS BASED ON
OBSERVATIONS AND EXPERIMENTS. MENDEL
WORKED ON FINDING OUT HOW TRAITS ARE
TRANSMITTED FROM PARENT TO OFFSPRING.
HE CHOSE PLANTS THAT WERE EASY TO
CULTIVATE AND PRODUCED MANY GENERATIONS
IN A SHORT TIME SPAN.
```

FIGURE 13.3 A static text-based program. ("A Review of Modern Biology," Text-based program by J & S Software.)

Figure 13.3 shows an example taken from a text-based static educational program. During its execution, pages of text are shown, and the student is confronted with a multiple-choice test. It is only the ability to automatically record the performance of different students for later evaluation that makes this program different from a textbook.

In Figure 13.4, we find a graphics-based static program. The software in this example uses graphics for showing the meaning of the legends on a map attractively. Even when static graphics are shown one after the other, the better representation of the subject under study makes this program a better choice than a text-based program.

The next option is to have a dynamic text-based program like the one that teaches the replication of DNA (Figure 13.5). The screen represented shows the actual replication of DNA. A long DNA molecule is drawn and a ' ' sign representing the DNA polymerase enzyme separates both sides of the chain. The student observes how the elements of each half of the molecule find the appropriate complement from the medium. When the process ends we have two DNA molecules, each of them identical to the original one. The program is rather simple and short, but the effect on

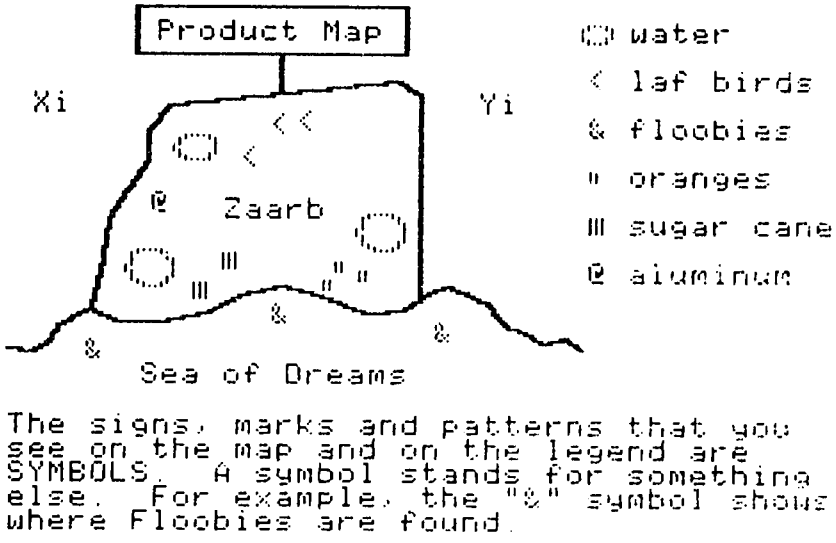


FIGURE 13.4 A static graphics-based program. ("Legends," a sample lesson from Apple Pilot.)

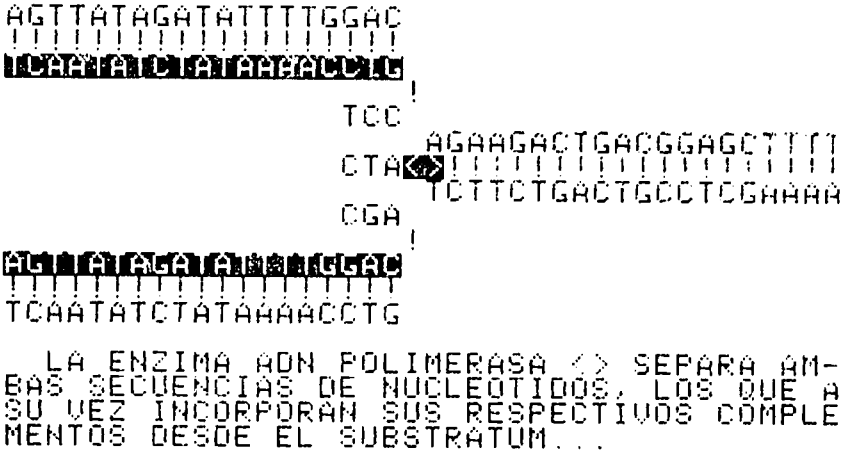


FIGURE 13.5 A dynamic text-based program. ("Replicacion del DNA," a dynamic text-based educational program by J.L. Sersic.)

the students of observing a simulated DNA division makes this program a good example of this type of software.

Figure 13.6 shows dynamic graphics-based software. As in motion pictures, different portions of the graphs move depending

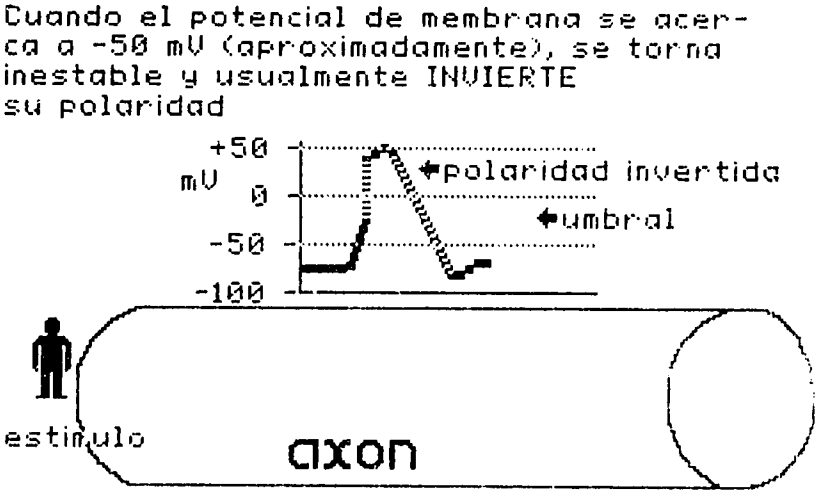


FIGURE 13.6 A dynamic graphics-based program. ("El impulsa nerviosa," a dynamic graphics-based educational program by J. Prilusky.)

on the student's actions. The membrane potential, for example, changes as a stimulus is applied and an action potential generated. As in the previous program, movement keeps the students' attention focused on their work.

A third dimension, sound, can be included. Music and appropriate sound effects add to educational software, and spoken words on those systems with speech synthesizers give training software the optimal cue to keep the student alert and learning.

A FLOW DIAGRAM FOR CREATING EDUCATIONAL SOFTWARE

Figure 13.7 shows a sample flow diagram for creating educational software. The first thing an educational program must do is orient the student to the general objectives to be covered. Fear of the unknown may interfere with concentration, so we must make two important things clear: what we will show to the student and what we expect the student to do. After an appropriate introduction to the subject to be covered, a repetitive loop begins: explain a concept, integrate it with previous knowledge, evaluate the student's grasp of the concept. If the student did not understand the new concept then we must go back to the point where it was explained. Otherwise, we go on to explain the next concept if any

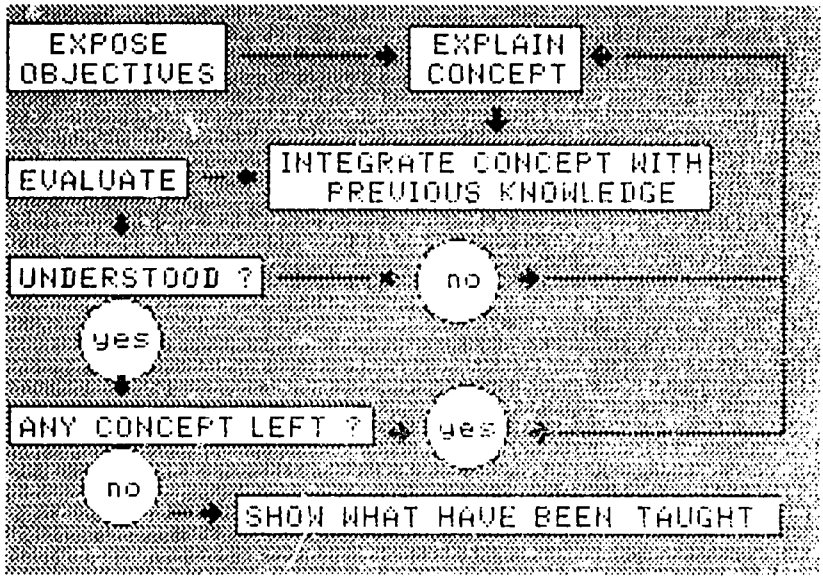


FIGURE 13.7 A flow diagram for preparing educational software.

remains. When the list of concepts to be presented has been exhausted we return to an overview, that is, a comprehensive review of the material to allow the student to integrate it with previous knowledge.

A carefully measured amount of new information should be given at each step. We must never present more new information than the related familiar information included. Each new idea should strike the students but not knock them out! A balanced and gradual introduction of new concepts is the key to success.

A Practical Example

The following figures were taken from an educational program that teaches the law of heredity. It is a dynamic graphics-based software that utilizes a simulation of biological events. The program first provides the students with the minimum elements needed to establish a valid communication channel. They are instructed that "the longest key on the keyboard is the 'space' key" and that every time they want to speed up the presentation, that key should be pressed. At the same time, students are alerted to the location of the numerical keys because at selected times they

need to answer questions by pressing the appropriately numbered key. The general objectives of the program are then summarized and the actual program starts.

Figures 13.8 and 13.9 show how students are introduced to the concept of the gene by establishing a relationship between the external aspect of the cow, the internal representation of the gene, and the symbolic nomenclature used to describe the genotype. Next, Figure 13.10 integrates concepts while showing the possibility of there being an individual with one gene of each kind. The graphics are continually expanded.

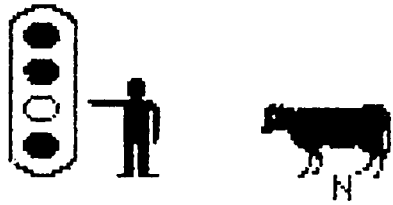
Reproduction and genetic combination are simulated in a dynamic graphic scene that leads to the picture shown in Figure 13.11.

A second generation is then created and a final picture (Figure 13.12) allows the student to follow step by step the new recombination. On the right side are test questions to help focus the student's attention.

Next the student is introduced to the concept of the existence of more than one pair of genes determining more than one external characteristic. From here, the result of the combination of two cows is shown in the first and second generations. Special care is taken to show the student where the magical numbers of 9:3:3:1 come from (Figure 13.13).

Up to this point, the program has shown a fixed sequence of concepts and figures, altered only by a return to a previous concept if it was not understood. However after this point the students assume control of the computer. They are asked to select a pair of cows from the four basic types and combine them and their offspring for as many generations as they wish. Figure 13.14 shows a typical second generation. The student has selected the option of producing a third generation by combining the individuals within the squares. Since there is no limit on the number of generations that can be produced, many of the students tend to carry on until a "pure" breed is developed.

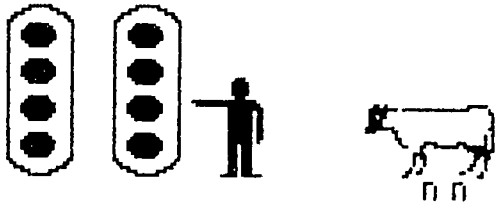
It is obvious that it is not possible to anticipate which cows will be selected as parents and how many generations a student will produce. Therefore, the outcome of each generation is simulated in the program as an actual genetic recombination. The genetic contribution of each parent is taken into account, and the 16 possible combinations are calculated. Then each animal is drawn according to its genetic structure.



Este GEN determina si el individuo presentara pelo negro (N) o rojo (n) (el que sale mas claro en la pantalla) ...presta mucha atencion...

FIGURE 13.8 Introduction to the concept of the gene.

en los individuos que se reproducen sexualmente, para cada caracter le corresponde un PAR de genes ubicados en dos cromosomas distintos



y el aspecto exterior del individuo respondera asi al efecto conjunto de los dos genes que actuan sobre el mismo caracter

FIGURE 13.9 Showing how genes combine.

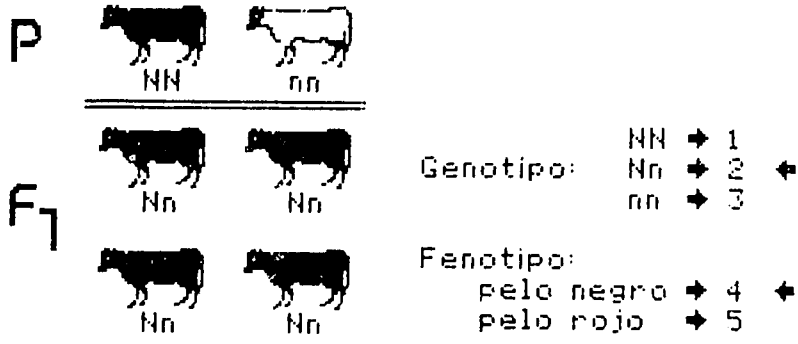
Cuando los dos genes (uno en cada cromosoma) de un mismo caracter son IGUALES se dice que el individuo es HOMOCIGOTA para ese caracter

Cuando los dos genes (uno en cada cromosoma) de un mismo caracter son DISTINTOS se dice que el individuo es HETEROCIGOTA para ese caracter

FIGURE 13.10 Result of mixing two types of genes.

This software can be improved at many points, but it stands as a good example of an attractive software that contributes to a clearer understanding by explaining an arid biological theme.

Esto se puede expresar diciendo que
el genotipo de la F1 es 100% Nn
y que
el fenotipo de la F1 es 100% pelo negro



Genotipo ➔ 100% Nn
Fenotipo ➔ 100% pelo negro

FIGURE 13.11 Genetic combination in the first generation.

Ademas de utilizar porcentajes, podemos
indentificar la descendencia como:
Fenotipo ➔ 3 pelo negro : 1 pelo rojo
Genotipo ➔ 1 NN : 2 Nn : 1 nn

Fenotipo ➔ 75% pelo negro : 25% pelo rojo
Genotipo ➔ 25% NN : 50% Nn : 25% nn

FIGURE 13.12 The second generation.

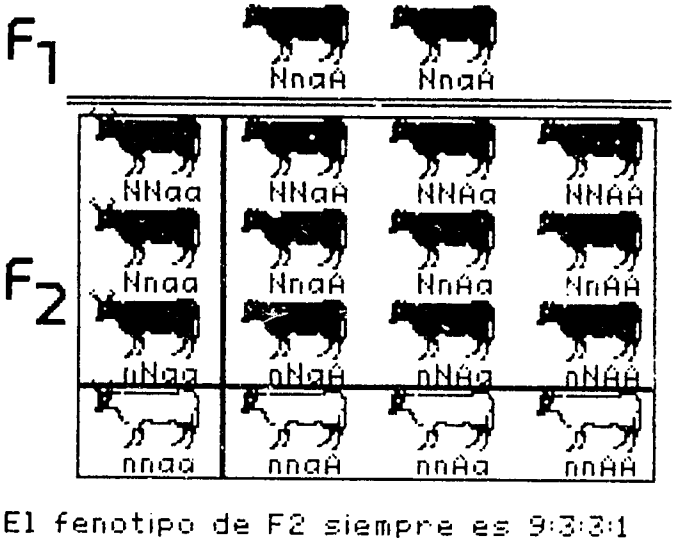


FIGURE 13.13 Screen showing 9:3:3:1 relationship of genotypes.

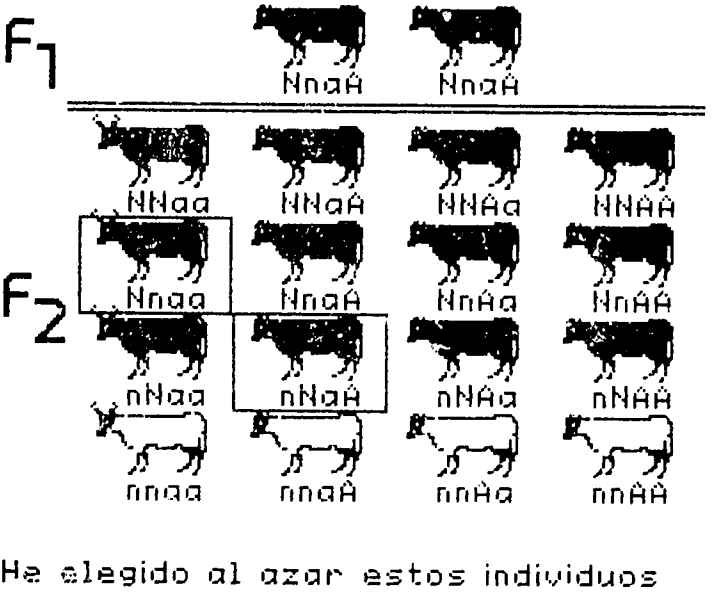


FIGURE 13.14 Screen showing a typical second generation.

Section 4
Primary and Secondary Education

14

Expanding the Use of Microcomputers in Elementary School Teaching

JORGE APEL

BACKGROUND

This paper is written from a specific point of view; it describes the difficulties and possibilities facing the headmaster of an elementary school in introducing microcomputers.

In Argentina, elementary schooling is compulsory, serving as a leveling factor and an element of social progress. Children start at six years of age and attend for seven years. Schools may be national, provincial, municipal, or private. In general, they are divided into state and private schools. In all cases, the state supervises their work, legalizes their functioning, approves the certificates granted, and prescribes a syllabus for the seven years. This syllabus may vary in response to political changes, but it is usually basic, middle of the road, and conservative.

During the military era (1976–1983), there was a deliberate policy of freezing education, and a diminished budget and restricted admission in all branches and at all levels. In Dr. Alfonsin's government, there is a different policy. At the university level, remarkable efforts and advances have been made in many aspects. At other levels, there is no clear, continuous policy. A pedagogical congress is planned for 1986.

A Brief History of Computers in Argentine Schools

The first microcomputer equipment was introduced in private elementary schools in Buenos Aires in 1980. The work of two people was fundamental: Horacio Reggini, an engineer who translated Logo into Spanish, and Antonio Battro, a physician, psychologist, and Piagetian educator. Both promoted, explained, and justified the introduction of microcomputers with Logo language. They were the founders of the Friends of Logo Association. Due to their efforts, since 1980 there have been Logo congresses in Buenos Aires, Mar del Plate, and Rosario, and in October a fourth will be held in Montevideo, Uruguay.

Elementary school teaching of computers is directed mainly toward the use of Logo. The members of the Friends of Logo Association estimate unofficially, that there are approximately one hundred thousand children working with Logo.

In many state schools, the parents associations pay for the central processing unit and combine it with an old black and white television set and a cassette recorder. The fact that these simple computers are being brought into distant parts of the country is generating a new cultural phenomenon. The Friends of Logo Association is also beginning to focus on the subject not only as a school phenomenon but more fundamentally, as a cultural one. They are encouraging the provision of computers and instructors in cultural and artistic centers throughout the country, as well as in public libraries in the city of Buenos Aires, without charge to the user.

A Specific Example

The Jean Piaget School is 20 years old. It has 250 pupils from the upper middle class, with a maximum number of 24 pupils in each classroom. It is a coeducational school with no religious affiliation and is privately supported.

The school day starts at 8:10 a.m. and finishes at 4:00 p.m. Each class has a teacher who remains with the class for the entire day but, in addition, the pupils have subjects such as gym, music, art, carpentry, handicrafts, and English, which are taught by special teachers.

In 1983, Logo was made a compulsory subject for fourth and fifth grade students. In 1984 a second computer was added. The

cost of a complete set of computer equipment in Argentina is about $1,000 (with very little variation among brands).* When I refer to a complete set, I mean keyboard, screen, Logo cartridge, memory expander, and diskette drive. (I exclude a printer of any kind.) By comparison, a new diskette costs $5, a good book for elementary school (pupil's textbook) is about $10 to $12, and an inexperienced teacher's salary part time (4 hours' work) is about $100.

The experience at the Jean Piaget School during these last two years and the projects planned for the future are the main topics of this paper. My findings do not, of course, apply to every school in such a complex and diverse country as Argentina. While reporting the experiences of this school, I have tried to point out some of the general educational applications.

This paper is based on the firm conviction that work in elementary school with microcomputers and the Logo language is very important for a variety of reasons. One of these is the fact that computers are the wave of the future, but the same could be said about teaching with the aid of computers using previously constructed software chosen by adults. We have not, however, chosen this path. It is not merely a technical question; it is a long-term educational policy. We think it is the task of the school to allow the pupils to build up their knowledge by providing for the following:

- The student's training in the structural possibilities of thought
- The teacher's participation
- The consideration of the student's environment and peers, and the geographic and economic situation.

The Logo language and the Logo environment specifically, allow pupils and teachers to carry out personal research. It introduces the scientific method of trial and error as a source of knowledge. It helps the pupil develop self-motivation. The strong hypothesis that underlies the educational program at the Jean Piaget School is that the Logo laboratories are important models for modernizing the traditional structure of Argentine education.

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* Figures are given in U.S. dollars.

Difficulties in Introducing Microcomputers

There is of course resistance to the introduction of computers. Two difficulties that are constantly mentioned are the dehumanization of teachers' work and the policy implications of introducing computers in a country with a high percentage of illiterate people, with the need to retain children at school, with hungry pupils, and with unemployment or underemployment.

Despite this resistance, the Jean Piaget School decided to provide computer instruction. In introducing microcomputers we faced two major problems. The first was a shortage of hardware and the impossibility of obtaining more. Second, and perhaps more important, there was little or no enthusiasm on the part of the teaching staff to study Logo. During 1981 and 1982, the teachers were offered training in Logo. Only one teacher among twelve was interested enough to study it systematically. Two others attended a few classes and then left.

In addition, we wanted to avoid having a "computing period" in which the teacher would turn his pupils over to a special teacher and be totally free of responsibility for the course. With such an arrangement, the transfer of computer learning to the regular curriculum becomes very difficult. The pupils consider what happens with the machine as completely separated from the ordinary classroom. This is similar to the situation that often occurs with music and art classes. In those periods the pupils sing enthusiastically, play melodies on the recorder, or color pictures. They do not, however, integrate these skills into their regular studies, nor does the teacher ask them to do so. It was clear that if Logo were taught in separate classes by special teachers, it too would fail to be integrated into education as a whole.

Basic Decisions

We began with some clear ideas based on experience. Three pupils shared a screen. This was not a random number. In general, groups must determine the projects they are going to execute. When the team is in agreement, the size of the group does not matter, but when there is a dispute, the size of the group may be crucial. In groups of two, it often happens that one submits to the other; groups of four generally divide into two irreconcilable sub-groups. When pupils are in groups of three, they areable

to discuss. In Logo, discussion is essential to make changes and produce agreement.

The experience of other schools showed that 30 hours was a favorable length of time for a Logo course. We wanted to give each pupil at least that much time, so as to offer some continuity.

The Jean Piaget School emphasizes the children's autonomy in other courses. For example, beginning in kindergarten the teacher generally organizes the class in such a way that many diverse activities can take place simultaneously. Tables and chairs are moved and different task areas are established. During the week, the student is free to move from one working section to another. This arrangement allows several projects in the same classroom, creates a school environment favorable to the discussion and exploration of ideas or knowledge, and encourages the autonomy of the pupils. The individual tasks very often require specific amounts of time that the pupil learns to allocate.

The computer workshop is organized as a working section, taking advantage of the previous experience of both pupils and teachers. For example, the fifth grade has the following simultaneous activities every Tuesday and Thursday afternoon: Logo (six children), math (six children), language (four children), and science (four children). At the end of each hour, the children change working sections. In this way, the teacher has six fewer children in class as they rotate into the computer section, and when the children return, they mix with other sub-groups. They are able to share their problems and experiences with Logo, and the teacher learns what has happened in the Logo class immediately. The teacher can also visit the computer workshop, since the pupils in the classroom are carrying out activities that do not depend on the teacher's continuous presence.

Each working group of three pupils at one screen is fixed for three months. Since their production speed is very low, they would not be able to carry out any project if groups were changed more often. In this way, with two sets of equipment, we manage to allow 80 pupils working four times a week to complete 30 hours of Logo instruction per year.

THE EFFECTS OF WORKING WITH LOGO

A significant difference has been recognized between the traditional classroom and the Logo classroom that provides an education oriented toward cognitive search. In the traditional school, testing shows what the pupil remembers—or can reproduce—of what has previously been said by the teacher. In the Logo group, not knowing is the source of knowledge. Pupil test their propositions and learn to diagnose their mistakes. There are no grades given, and copying the successes of other groups is essential. It is therefore important for pupils to see the other groups' work, to listen to other children's analysis, and to accept other pupils' criticism.

The performance of each group is also evaluated for group dynamics, for differences between what the project is designed for and what it achieves, and for obstacles that prevent the achievement of the project's goals. Finally, each group gives a demonstration of its work for the rest of the pupils in the grade. After the evaluation, the group may ask either for its members to be changed or to continue with the same three.

THE PROBLEM OF MOTIVATION

In the Logo workshop motivation is a major problem. Once pupils have passed the stage of exploring with the turtle, they begin to ask, "What shall we do now?" The teacher must not wait passively until the pupils think of a project. Education is a permanent interaction. In this way, the Logo class is similar to an art class—the pupils may be inhibited by a clean sheet of paper. Three possible sources of project ideas can be identified: (1) the work of other groups; (2) an unfinished project or a specific suggestion made by the Logo teacher; or (3) a project based on problems encountered in other classes.

We have learned from the success of the program at the Mary Graham Institute where teachers provide verbal or visual challenges by creating notice-boards or making incomplete programs for the pupils to finish. In another school, the Bayard Institute, modules are suggested, and pupils create programs within the suggested areas.

The classroom teacher may provide the computer class with a problem to work out. For example, the pupils in the language

section may create a story to be illustrated in Logo. As an experiment, the third grade pupils (who will start to work with the computer in the fourth grade), were asked to create the story to give them an early interest in the computer.

Carrying Out Logo Projects

We have found that once the idea for a project occurs to the group, they start working without really measuring the difficulty and without reaching an agreement on their goal for the project. We think this is a crucial moment that may be neglected since traditional education never values the pupils' projects but concentrates on the teachers' plans. Logo creates a revolution in this attitude.

We proceed in the following way: Once the group knows what it wants to do, the teacher writes the group's project proposal. The teacher reads it and asks the pupils if that is exactly what they want to do. He discusses the difficulties they think they will encounter, and asks them for an approximate schedule to achieve their goal. If there is no clear agreement, each member of the group is asked individually to state how he or she thinks the project will end, so that they can adjust their mutual expectations.

This technique is used regularly in the classroom. Putting thoughts into words is fundamental in planning and in visualizing difficulties. Even before microcomputers were introduced, pupils at our school were trained in programming activities that they were going to undertake. There are projects that the pupil can plan and can subdivide into stages. Some are very simple, such as arranging birthday parties; others, such as planning their homework for a school term, are more complex.

The pupil's experience with planning increases their potential in using Logo. Speaking about planning or anticipation is the same as speaking about thinking or participating intelligently. Planning, whether with or without computers, is an important tool for the autonomous development of the individual.

Using Logo Skills for Instruction

Logo controls the mobility of the turtle in a two-dimensional space. The turtle turns left or right according to the program. When children work, they frequently want to place the turtle in

different parts of the screen. To achieve that purpose they must handle the x and y axes and make them correspond using the grid that comes with the language. The relationship we establish at school between Logo language (special handling of the turtle and handling of variables) and the syllabus is based on topological relationships.

The teacher can use what the pupils have learned from Logo in a number of related classroom activities:

- Games of rotation and turns (the pupils are the turtles and other classmates the operators)
- Building an imaginary three-dimensional city
- Games of streets and crossing to handle addresses and sense of streets
- Rotation of the base of the scale-model to change the cardinal points
- Relationship between the external axis external to the subject (right and left depending on the individual)
- Distance and distance traveled
- Games using an imaginary grid (one example is Battleship)
- Relationships in their own city (in this case Buenos Aires) using street guides
- Finally, their work may be related to maps of Argentina using parallels, meridians, and location of geographic points.

It is remarkable how experience in using Logo makes syllabus changes possible not only in the areas of class dynamics and pupils' participation, but also in the subject matter that can be studied. Logo also makes the teachers question their own knowledge of space epistemology and the learning theory that they put into practice. If they come to the conclusion that learning must be constructive and genetic, they will change their methods of teaching.

THE RELATIONSHIP OF EPISTEMOLOGY AND LOGO

The aim of the Jean Piaget School is to give elementary school pupils the necessary tools to build up their knowledge. To do this, the pupils must develop good study habits while learning to read and write, master the techniques necessary to use the computer, study from different sources of information, and most importantly,

acquire techniques to evaluate what they do not know. Pupils must be able to recognize their mistakes and decide on a course of action to correct them.

Underlying all these ideas is the supposition that in encounters with the environment, children are builders of their knowledge; knowledge is not absorbed in an automatic way, nor is it stamped on them by teachers. The active students assimilate new information according to their previous experience. In this conquest of knowledge, they must accommodate the reality; it is neither an easy nor a linear process. Even a superior teacher's abilities would not help child assimilate information (although in this model no superior teacher can exist). Each child will assimilate information according to previous individual experience.

In this Piagetian model, knowledge is the creation of a valid reality. The recognition of the environment in which the child moves is fundamental. As in the scientific community, the accepted or rejected paradigms do not always have an objective validity but may reflect personal and group prejudices. In building individual knowledge, the epistemological obstacle is essential, but it is often not recognized until a paradigm is presented to a group of peers for validation.

The Logo environments provide a good model of scientific inquiry, since there is group and individual work to develop a project and, after the project has been reviewed, error is accepted. When an error is recognized, we help pupils divide the problem into small parts so that they can distinguish which is the true obstacle, "what does not work." Sometimes it is possible to offer an alternative, but many times pupils must admit that they are on the wrong track and that it is impossible to do anything with the reality they have proposed up until that moment. We have shown by experiment that if the teacher gives the solution, the student does not benefit.

It is the purpose of this work to emphasize the fact that education must be considered as a system. If we want the computer to have a real effect, we should analyze and adjust other aspects of the system simultaneously.

FUTURE PLANS

The planned expansion of the program at the Jean Piaget School will extend the influence of the Logo environments to a

larger number of pupils. We plan to purchase another set of hardware so that pupils will have 45 hours per year of Logo, and the third and sixth grade classes will be included in the program.

Now that the teachers have seen the effect produced on the pupils by their work with Logo, we intend to offer Logo classes for teachers during the holidays. These courses will provide examples of ways that microcomputers can be used in classroom work, that is to say, Logo techniques will be taught so that teachers may profit by the use of Logo in the next term. The Logo teachers will also work with the classroom teachers on a regular basis during the term.

To encourage pupils to make more use of the microcomputers outside of their Logo courses, we plan to start a diskette lending and exchange program in the school library. The pupils are also being assisted in starting a "Project Club." It would meet after classes and provide a place where pupils are stimulated to conceive, express, and develop a project (which may or may not be class-related), with the support of the computer. In addition to providing teacher support for these projects, trained specialists will study how children develop their projects to assist the Logo teachers in developing their teaching methods.

15

The How and Why of the Computer in the Educational Process

GUILLERMINA YANKELEVICH

BACKGROUND

When the problems related to the incorporation of computers into education are discussed, the most attention is usually focused on those problems dealing with *how* this tool may be converted into an element for daily use and *how* it can help children and young people with their studies. (A full discussion is given in Yankelevich, 1985c.)

Fewer questions are asked about and less discussion is directed toward determining what changes occur in students who have entered or are entering into the world of computers. Moreover, an evaluation of the goals achieved by the use of this educational tool is not a point often considered. As a result, theoretical reflections on *why* the use of computers generates the benefits usually attributed to it seems to be treated as an incidental topic in most meetings.

The intellectual benefit derived from the computer is seldom called into question because the advocates of computerization continually report observations about the interest, dedication, dexterity, and amount of learning that pupils show when exposed to computer education. Discussions on the topic usually concern strategies to optimize the cost-benefit ratio or the problems of access to this technology for each individual in the population.

These concerns, of course, become more critical when discussing developing countries.

Computer technology has had a notably rapid development and, therefore, an accelerated process of commercialization. Our understanding of the changes caused by this tool, in society and especially in the individual, has not advanced at an equal pace. The fact that tools that result in the multiplication of human potential generate intellectual changes in the individual and society practically guarantees that such evaluation could not be complete at this time.

The Role of the Computer

This paper presents some thoughts on the development of abstract intellectual processes that occur during the growth and maturation of children and on the role that working with a computer may have in these events. The discussion is based on a group of experiments on human communication using images. They have led to several hypotheses on the possible relations between the process of maturation of the perception of images and the development of abstract concepts. Using the computer in the education of a young person (12 years old or more) not only familiarizes the student with the technology but also provides the opportunity for the student to analyze and to exercise his or her own thinking mechanism.

The role the computer may play in the educational process in the primary school should be analyzed separately. In the case of a child under ten years of age, the situation is entirely different; the computer is incorporated into education at the precise moment when the intellectual mechanisms are under construction. Under such conditions, it becomes important to understand the effect that this tool may have on the development of thinking mechanisms and the possible creation of new modalities.

Diverse theories have been formulated concerning the development of the intellect, some from the physiological point of view, others from a psychopedagogical angle, and still others that take the sociocultural determinants of the process into account (see Coren et al., 1984; Fodor, 1983; Inhelder, 1983). Among the most widely recognized postulations at present are the constructivist hypotheses based on the ideas of Piaget (Oleron et al., 1985).

The experiments on communication and on the role of communication in the development of abstract thinking are based on these models. The following is a summary of the ideas that have arisen from these studies that bear on this discussion.

Background of the Studies

The studies were organized around a group of images of increasing "complexity." The complexity was estimated by comparing the number of "input bits" of information to the amount of information, or "output bits," retained by individuals of the diverse populations studied. The images used in these studies were considered to contain different abstraction levels: iconic, schematic, and ambiguous images; metaphorical drawing (an editorial cartoon); and illustrated story (comic books, either commercially produced or of our own design). The populations studied were diversified in terms of age, sex, occupation, education level, socio-economic level, and area of residence (rural or urban).

From these studies, a theoretical framework was derived within which observations on the behavior of the individuals in the study could be consistently organized. On the basis of the behavior of different populations, an ordered sequence of "ciphers" in the images was also derived that may represent increasing levels of difficulty in the abstraction of the information content (Yankelevich, 1983).

DEVELOPMENT OF THE HYPOTHESIS

In brief, my hypothesis is the following: The development of abstractive intellectual activity occurs during a child's growth and maturation as a result of diverse activities. One of the essential activities is "visual perception" and the learning necessary to abstract information contained in images. The exercise of this function occurs in infancy in three distinguishable, sequential stages that contribute to the gradual maturing of the abstractive activity. In the first of these stages, the abstractive intellectual activity occurs in relation to the concrete world; in the second, this abstraction occurs not only in relation to the concrete, but also with mere evocations; and, in the third, this activity can take place independently from the environment.

In the first stage, which develops between birth and approximately three years of age, the infant abstracts starting with the visual perception of objects and scenes in the surrounding environment. In the second stage, the child develops the thought process necessary to evoke images of past events or of scenes that are not physically present. Learning to recognize representations in two dimensions, for example, may be initiated by an evocation of objects or scenes previously perceived in their natural, three-dimensional environment.

The start of the third stage (at about 12 years of age) apparently demands prolonged preparation. In this stage, the young person acquires sufficient maturity to carry out an intellectual process completely separated from the concrete universe. The formal disciplines of the levels of abstraction reached in pure mathematics are accessible to the individual when he or she has satisfactorily developed and matured his or her intellectual activity by diverse methods, one of which is the exercise of perceiving images containing different levels of abstraction.

In accord with this proposed general scheme, there are two critical moments in the overall process corresponding to the transitions between stages. When the development of abstraction ability occurs in a gradual manner by means of the appropriate learning and practice, the transition between stages happens without effort. If for some reason the child has not appropriately exercised these faculties, the transition to the next stage requires great effort and occasionally is unsuccessful.

It may be speculated that passage from the first to the second stage depends greatly on the learning and exercise of verbal language. The association of a word with an object known through observation introduces an abstractive activity evoking known images. Language, in itself, is an evoked conceptual world.

When the representation of verbal language is achieved through such varied abstract images as drawings, pictograms, ideograms, and ultimately the elements of an alphabet, we may speculate that a link is established between verbalization and the perception of images, both expressed in increasingly abstract forms.

It is proposed that difficulty in passing from the second to the third stage may be diminished by exercising the abstractive faculty through training with image information-abstraction prior

to the transition. Such training, done in a gradual manner, would help the children acquire the maturity that they have not reached.

Design of the Studies

In the first series of studies, we used commercially produced comic books. My previous research suggested they would be an adequate tool for the exercise of the abstractive faculty for images because of the particular way in which the concepts of space and time are handled (Yankelevich, 1983). The results of these studies indicated to us the possibility that for children, the association of the illustrated comic book with some ideas on computing and concepts of programming might form an amalgam appropriate to help in gradually training them in abstract thinking prior to the transition to independent abstraction.

The computer not only offers the possibility of "visualizing" some aspects of formal thinking that usually have been handled within a totally abstract universe but also permits the creation of special presentations in sequential images of the abstractive levels the child needs to grasp. In addition, the computer offers the additional advantage that such sequences and exercises may be repeated as many times as necessary.

Results of the Studies

In the second series of studies, a short story comic book was written consisting of five pages dealing with the legend of Theseus and the labyrinth. There was also a program (in BASIC or in Karel) on the route. The last page contained an integrated scheme into which the four levels of abstraction—drawing, language, geometrical scheme, and computer program—used in the story book are incorporated. The children, feeling they were in a relaxed atmosphere, participated actively, and showed pleasure in what they were doing. A clear sense of satisfaction in playing with the computer was evidenced by each child. However, some interesting results occurred:

- None of the children ten years old or younger performed satisfactorily. None was capable of understanding a new command, such as "for," although previous commands had

apparently been learned during an introductory programming course. Some even showed difficulties in comprehending images at a lower level of abstraction (such as a geometric scheme) or a transfer to the computer screen of a scene pictured in the story book.

- The majority of those older than ten years did perform satisfactorily in the problem presented to them, that is, they were able to assimilate and even to use the command "for" (Yankelevich, 1983, 1985a).

CONCLUSIONS DRAWN FROM THE STUDIES

- It seems that an evaluation of the changes that occur at the level of the individual or of society as a result of the introduction of the computer into the educational process could bear heavily on the question of how this tool should be implemented.
- If more such studies are carried out, a better understanding of how the abstractive intellectual faculty of man develops could be determined. This, in turn, would permit the stating of hypotheses concerning why one must wait for a certain result in education (whether or not computers are introduced into the process).
- These points take on a special transcendence when one is dealing with children up to approximately twelve years old (primary education) in whom intellectual activity is in the process of construction and consolidation. In contrast, for older youths, the incorporation of the computer in the educational process may well achieve an improvement in their intellectual development through excercise with this tool.
- The results of these studies appear to show that the optimal moment to incorporate computers into the education of children comes during the fifth or sixth grade of primary school (ten to eleven years old). At this time, intellectual abstract activity is, on the average, sufficiently developed so that the transition to the third stage, that of intellectual abstraction "foreign" to the concrete universe, may successfully occur.

- Using the computer, children can exercise their intellect in relation to images, advancing in the abstractive process according to their individual potential and at their own speed. The computer provides a great variety of images at diverse levels of abstraction, such as iconic representations, schematics, caricatures, geometric figures, and text, which may be organized in an attractive, gradual sequence. It also provides an opportunity to introduce the child to intellectual activities that demand progressively higher levels of abstraction and that can be individually suited to the capabilities of the child.

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16

SYSTEMANDI: From Kindergarten to Information Systems*

RAUL DORFMAN

INTRODUCTION

The word "SYSTEMANDI" is formed from the words "*system*" "*an*alog," and "*di*gital." SYSTEMANDI is an instructional design model for learning, teaching, and research in systems, cybernetics, informatics, structured programming (without computers), and computer technology. A group dynamics technique was developed for implementing SYSTEMANDI through an interedisciplinary seminar entitled "From Kindergarten to Information Systems."

Constructing and playing ANDI games allows the user to build models and develop a semantic network based on sensory motor analogies. With reference to field experience (Monti and Dorfman, 1984; Dorfman, 1984a; 1984b), systems vocabulary bibliography (Van Gigch and Francois, personal communication; Robbins and Oliva, 1982), and etymological research on the origins of sensory motor words, an interdisciplinary semantic (verbal) network is presented for further research and discussion (O'Kill, 1984; Corripio, 1979; Dauzat, 1971) in Appendix 16.1. The results of preliminary field experiments are given in Appendix 16.2.

*Note: ANDI, SYSTEMANDI, PROGRAMANDI, and "From Kindergarten to Information Systems" are copyrighted by Raul Dorfman.

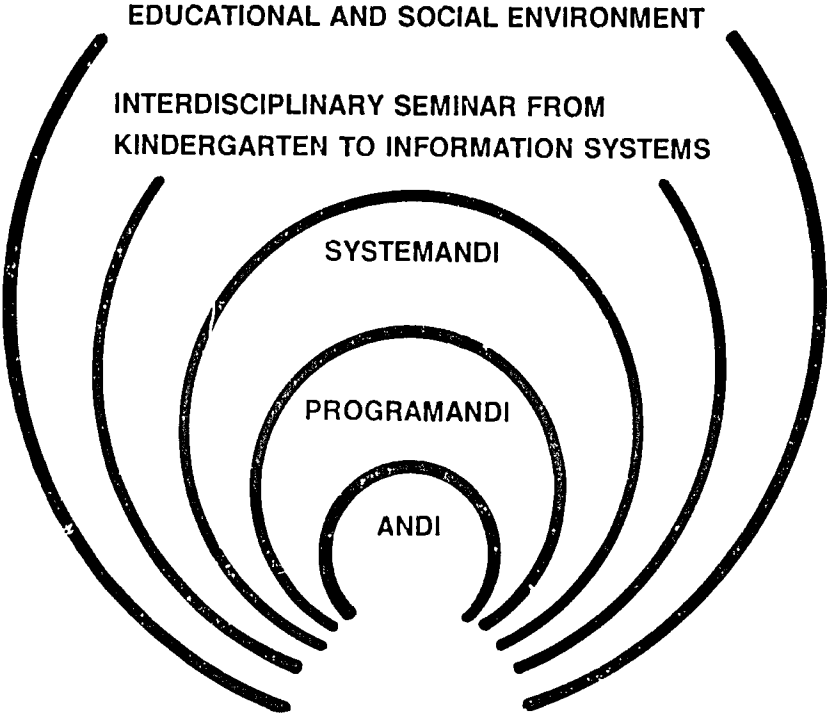

FIGURE 16.1 Activities, concepts, and techniques hierarchy.

Structured algorithm solving and structured programming are introduced by means of a set of games related to the elemental programming structure and operators. The modular set of games is called PROGRAMANDI. The hierarchy of activities, concepts, and techniques is given in Figure 16.1.

Objectives

Incorporated in the methodology are objectives for students, teachers, researchers, parents, and educational policymakers.

The objectives for students are the following:

- To stimulate the capability of understanding, building, and using models to cope with simple and complex systems;

- To increase the perception of regularities within a system and analogies among different systems through interdisciplinary activities involving music, sports, biology, physics, geography, mathematics, and informatics;
- To impart an understanding of the differences between technology and methodology, problem description, problem solving, and solution execution; to study the design of information systems;
- To analyze the computer as a system;
- To introduce a modest knowledge of structured programming emphasizing analogies among different graphic and mixed languages with a systemic approach; and
- To introduce information systems handling.

Objectives for teachers include those set for students as well as:

- To develop and stimulate awareness in learning and teaching systems, cybernetics, and informatics as part of individual and professional growth, using a simple, easy to understand, and inexpensive methodology; and
- To encourage participation in a rational and informed analysis of methodological and technological innovation in the classroom through interdisciplinary projects.

Objectives for researchers are as follows:

- To facilitate the integration of interdisciplinary research groups;
- To initiate the study of cognitive processes using the proposed material and/or related techniques; and
- To develop evaluation tools for the proposed methodology.

Objectives for parents and educational policymakers are these:

- To promote awareness of the role of technology and methodology in the complex environment of the classroom, the school, the educational system (conventional and nonconventional), and the community using simple concepts that allow communication between all interested parties; and
- To promote participation in the systems and informatics literacy programs.

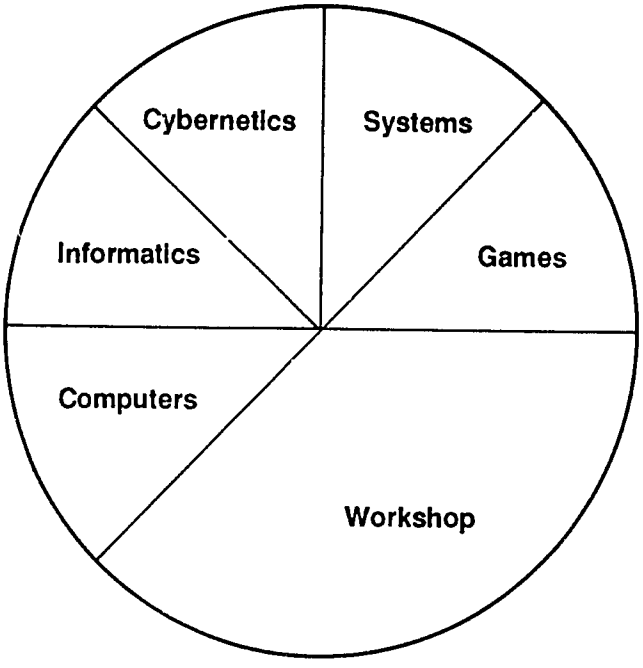

FIGURE 16.2 The interdisciplinary seminar.

Group Dynamics

In addition to these general objectives, the interdisciplinary seminar aims to define, plan, implement, and evaluate concrete and feasible projects. Figure 16.2 shows roughly the distribution of time at the seminar. The seminar agenda is as follows:

- ANDI materials and techniques are presented using slides, transparencies, and books;
- Participants ask the basic questions: What do I observe? How is it made? What does it do and how does it do it? Why? For what purpose?
- Participants divide into small interdisciplinary groups of six to eight members; define their own goals; and model the scenario and/or system under discussion using ANDI material;
- Each group presents its project in a plenary session for discussion by the entire seminar; and

- Participants review, modify, evaluate, and select projects for pilot implementation, and define follow-up procedures.

The length of the seminar depends on the resources and the target audience. For example, a nationwide seminar in Argentina (120 participants, four months preparation) took 40 hours. Several primary school projects were defined, and some have been implemented by the Ministry of Education. For elementary school teachers and decision makers in Uruguay and Colombia, 16-hour seminars worked very well to create and stimulate permanent interdisciplinary groups. Seminars of similar length were offered to begin literacy in systems, cybernetics, and informatics in Peru and in various educational centers in Argentina. At the other extreme, a seminar was arranged for a small medical group in France to study isolated and perfused biological systems and to design a pharmacological database; the work of this group lasted for two months, eight hours a day.

SYSTEMANDI

Starting with ANDI games, systems concepts are developed through more formal games and activities. These systematic activities promote the growth of systems analysis and synthesis literacy, enabling seminar participants to learn programming. Starting from the other direction, in many institutions individuals already have experience with programming and computer use in languages such as Logo, BASIC, and Pascal. On the basis of this experience they can be directed through PROGRAMANDI to learn and teach systems and cybernetics concepts and emphasize structured programming. This two-way path (of synthesis and analysis) is illustrated in Figure 16.3.

Materials

The materials are almost the same for all target audiences. In the beginning, solid squares (plastic, cardboard, or paper) are used. Texture, size, and shape may vary. As the number and variety of algorithms increase, the logical structures become more complex. Deterministic games become probabilistic. Younger audiences usually begin with concrete examples and then develop abstract concepts; this approach also works well with adults who have no programming experience. It is interesting to note that adults

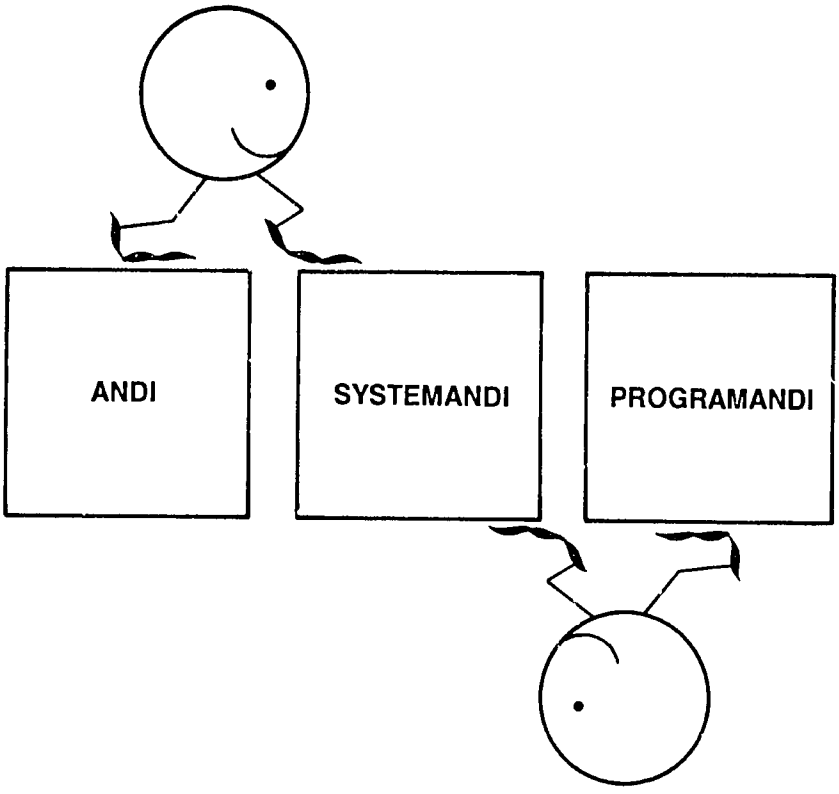

FIGURE 16.3 Visual aid for kindergarten students showing dual progression.

and/or students with programming experience have problems in converting abstract algorithms into concrete ones. Figure 16.4 illustrates a typical SYSTEMANDI game oriented toward structured algorithm analysis, using the structures and operators—IF, AND, OR, ELSE—that are also found in computer programming languages.

FUTURE PROGRAMS

The Teacher and Professor Computer Literacy Program has begun. System simulation, analysis and design is scheduled for 1986. Seminars and workshops about hardware and computer systems are under development. Practice with computer systems and languages emphasizes the systemic approach and structured programming in several computer languages, including structured,

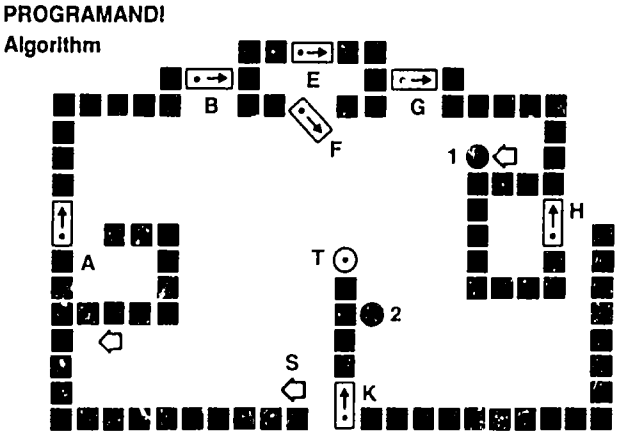

FIGURE 16.4 A typical SYSTEMANDI game oriented toward structured algorithm analysis.

graphic, and hybrid. Hardware suppliers have provided computers on temporary loan at no cost. Networking and access to databases are intermediate goals of the program.

The logistics and personnel of the Teacher and Professor Literacy Program follow here: coordinating institution: Ministry of Education, National Superior Education Direction; official coordinator: Prof. Eva Sarka, Head, Department of Informatics, Systems, and Education; seminars were held at the Escuela Nacional Normal Superior en Lenguas Vivas y Profesorado, Min. R. S. Naon, Pehuajo, Buenos Aires, Argentina. The Pehuajo educational system consists of the following educational institutions: kindergarten (11), primary (47), secondary (6), tertiary (2), adult education (1). The Institution Interdisciplinary Group Coordinator is Prof. M. V. Cosentino; the Methodology and Systems Advisor is Ing. Raul Dorfman.

Acknowledgments

The author wishes to thank the students, teachers, professors, and parents for their support, with special thanks to the Pehuajo School Parents Association for their support and funding. Particular gratitude is due Prof. Charles Francois, Prof. Alicia Gago, and the cooperating national and international organizations.

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APPENDIX 16.1
DRAFT OF AN INTERDISCIPLINARY SEMANTIC NET

Accommodation
Adaptation
Aleatory
Ambience
Amplification
Analog
Analysis
And
Art
Artificial
Arithmetic
Assimilation
Autonomy

Backward
Balance
Binary

Chaos
Clock
Closed
Coding
Complement
Complex
Computing
Communication
Concept
Connector
Continuous
Conversor
Cybernetics

Data
Deduction
Deterministic
Delay
Derive
Differentiate
Digital
Discrete
Drain
Dynamic

Efficiency
Element
Emittor

Equilibrium
Error
Etymology
Evolution
Exclusive

Feedback
Flow
Fluid
Form
Forward

Gradient
Goal

Idea
If...Then
Inclusive
Induction
Information
Integrate
Interdisciplinary
Interactive
Interruptor
Interval

Language
Left
Level
Line
Logic

Matter
Memory

Natural
Net
Noise
Not

Object
Observer
Operator
Or

Order
Organization
Output
Overt
Open

Parallel
Perception
Perspective
Plane
Point
Probability
Process
Proportional
Program
Ponder

Reference
Regulator
Repeat until...
Representation
Reserve
Right
Rhythm

Semantic
Serial
Sequence
Structure
Synthesis
System

Technique
Transduction
Transmission

Valve
Variety
Volume

While...Do

APPENDIX 16.2
A CASE STUDY OF STUDENT COMPREHENSION HELD AT THE BUENOS AIRES MUSEUM OF MODERN ART

The purpose of the study was to determine at what ages students were able to comprehend certain logical structures using PROGRAMANDI-style games.*

Target group: 850 children, four to twelve years old. They were organized in three categories by age and into groups of six to eight individuals.

Category	Ages	Number of Groups
A	4 to 5	30
B	6 to 9	30
C	10 to 12	30

The children engaged in games using both horizontal and vertical planes, and in free and guided play. The following logical structures were assimilated by the children. These give an idea of the success of different age groups in synthesis and analysis of the games.

CATE-GORY	PASS, DO NOT PASS	AND	OR	IF..THEN ELSE	REPEAT UNTIL	WHILE... REPEAT
A	x	x	x			
B	x	x	x	x	x	
C	x	x	x	x	x	x

The children had no previous experience with these games. These data have limited research value, since the situation was not controlled. They do, however, assist in refining the program and selecting the best games and techniques, based on the children's attitudes and observation of self-organized individual and group activities.

* The achievement levels and detailed observations of the participants as well as the methodologies used are provided by Araceli Monti in (Monti and Dorfman, 1984).

17

Introducing Logo to Teachers and Children

SAMUEL BERN

As with any good idea that requires implementation, the introduction of Logo concepts in schools can become a difficult task, especially if the teachers—even more than the pupils—are not adequately prepared. Different methodologies can be used to introduce pupils to the Logo language or turtle graphics, but all involve the prior preparation of teachers to help pupils cope with the new concepts and to develop pupils' ability to use computers as creative learning tools. Teachers in developing countries are aware of the increasing role computers play in society, but they are still unsure as to how the machines can help them improve student performance. This problem arises in public schools as well as in private ones in Panama.

The use of Logo introductory software can be visualized as a means of making teachers aware of potential applications of Logo in their educational plan. This introductory software can be considered as a first step before becoming involved in Logo's two-letter commands, rigid syntax, turtle degrees, number inputs, variables, and management routines—all of which are more difficult for young children to understand by themselves. Among the methodologies used to introduce Logo in the classroom, introductory software provides children at the preschool level with

the opportunity to control the computer and explore its capabilities, preparing them for using Logo language in a later step in the computer curriculum.

In a pilot project that started in June 1985 at the Albert Einstein Institute, a private school in Panama City, two groups of 20 five- and six-year-old children are successfully experimenting with the use of EZ Logo, a software program from the Minnesota Educational Computing Consortium designed to prepare children to use Logo.

Long before the use of the introductory Logo software was considered, all of the elementary school teachers in the school participated in a two-week instruction course on Apple Logo. Unfortunately, this course made but a poor effort at providing the necessary background of the theory behind the development of Logo language by Seymour Papert and his group at the Massachusetts Institute of Technology. Also, it did very little in the area of presenting possible applications of Logo to complement the learning process used in the school. This lack of adequate instruction caused some despair among teachers who could not really grasp the application of Logo in the school system.

The introduction of EZ Logo at a later stage of the program provided the practical orientation necessary for the teachers and pupils using simple sets of one-letter commands to generate turtle graphics. The following skills are taught by the use of EZ Logo:

- Recognizing left and right directions
- Estimating distances and degrees
- Drawing shapes
- Developing problem-solving strategies
- Gaining familiarity with the computer keyboard.

The software includes 24 activities where these skills can be combined in a variety of ways. EZ Logo requires a 64K Apple computer and the Apple Logo language software. The new EZ Logo Revised Edition can be run with the same equipment and does not require an upgraded version of Logo.

18

The Use of Computers in Teaching Mathematics

EMANUEL JINICH

The computer can be a tool of enormous importance in improving the teaching-learning process. It is therefore necessary that both students and teachers know how to profit from the advantages this machine offers.

There are two formats for interacting with the microcomputer: as users we can learn from the machine, or as programmers we can be its teachers. When computers are being used as teachers, their success in improving the student's grasp of mathematics depends on the software program. Many make the student a passive receptor of the information that is presented on the screen. However, by taking advantage of the graph-making capability of computers and its capacity for synthesizing musical tones, even these programs can have a major impact on the student. The user frequently has to answer multiple-choice questions on a topic. The immediate feedback the computer provides is important, and in some programs students have the option of going back for a further explanation, if they should need it.

As teachers of mathematics, however, we are interested in seeing that students come in closer contact with the material. We would like them to experiment with mathematics–to play with it. To accomplish this, we use another kind of program in which the students are active participants. With such a program they can

manipulate and apply the information that is given them; they can modify the values of variables; they can verify concepts presented in class or delve more deeply into them. Students can observe and analyze graphs; they can modify them and then make comparisons. They can make the computer draw an object in three dimensions, rotate it or move it, or have it do both operations simultaneously.

Let us see in detail how to take advantage of the microcomputer's capabilities in a mathematics class. If the program can display functions graphically, we could, for example, analyze polynomial functions and investigate the number of roots, or zeros, that the function has and determine what these values depend on. The computer could rapidly show (graphically) the functions of n degree that have n, $n-1$, $n-2$, up to 1 or 0 roots. The students could compare the graphs and perform iterations thereof according to the number of zeros in the function.

With this program we could study the linear function $y = mx + b$. The students could request the computer to make several graphs with different values of variables m and b, and thus to relate these letters with the concepts depending on and ordered in relation to the original. Also, one could view graphically a function $f(x)$, another function $g(x)$, and subsequently, the different curves that result from adding, subtracting, multiplying, or dividing $f(x)$ and $g(x)$. In addition, we could show graphically the composition of these functions, their inverse values, and so on.

The computer could also show the trigonometric functions for us graphically:

$$y = a * \sin b * (x - c * pi)$$

$$y = a * \cos b * (x - c * pi)$$

Students would experiment by looking at different graphs with different values for the variables, and could analyze the concepts of amplitude, frequency, and phase. In addition, it would be interesting for them to view graphically on the same screen the functions $\sin(x)$ and $\cos(x)$ to observe the points where they intersect.

This program also could serve to show us graphically how the Taylor series approximates various functions. For example, we could show a trigonometric function and then we would draw the graph for the first term of the series, then the first two, and so on, verifying that the graphed lines are increasingly closer to one another.

In analytical geometry we could command the computer to draw a cone for us. We could vary the base of the ellipse and the values of the semiaxes, and we could observe changes in the eccentricity of the curve. In addition, we could perform rotations and iterations of the cones. The computer would help us to find the limit of a function at a given value. For example, we would draw the function $f(x) = \sin(x)/x$, and we would analyze the graph at $x = 0$. The program permits us to vary the units on the axes and therefore we could analyze the graph at any level of detail desired.

Naturally, all of these graphs could be prepared and presented in a traditional class without computers. However, the time that this tool saves in the graph-making process is important. The student and the teacher are able to spend their time on the analysis of the mathematics rather than wasting it on the process of tabulation and making graphs, a task made tedious by constant repetition.

There are many other similarly constructed programs that strengthen the concepts presented in mathematics classes at all levels. Now, however, we will analyze the second format in which the computer can serve as a learning aid. In this type of program, the computer can be regarded as the student's student, in other words, as a machine that is going to learn exclusively what it is taught and that is going to obey our instructions to the letter. If the student has a full mastery of mathematical concepts, he/she can program the computer to apply these concepts correctly.

Let us look at an example. Suppose that a student has learned to program in the language BASIC. His/her objectives are first, to make a program in which the computer asks for the coefficients of a quadratic equation and second, to use a quadratic formula to calculate the results, if these happen to be real numbers.

In a first attempt, the student's program might be:

```
10 PRINT "DAME VALORES DE A, B, C EN"
20 PRINT "AX²+ BX + C = O Y YO TE"
30 PRINT "ENCONTRARE LOS RESULTADOS"
40 INPUT A, B, C
```

On reaching the next step, the student would have to translate to BASIC notation the formula "x is equal to minus b plus or minus the square root of b squared minus $4ac$ divided by $2a$." The student's first obstacle would be the meaning of "plus or minus."

If he or she has understood the concept that the square root of a number greater than or equal to zero has two results, then the student will conclude that the formula must be written twice, once for each sign.

```
50 X1 = -B + SQR(B² - 4*A*C) / 2*A
60 X2 = -B  - SQR(B² - 4*A*C) / 2*A
70 PRINT "LOS RESULTADOS SON"
80 PRINT X1
90 PRINT X2
```

At this point, we would ask the student to execute his or her program. Let us suppose that the student is working with the equation:

$$x^2 - 5x + 6 = 0$$

which gives the results $x = 2$ and $x = 3$. However, the student's program would indicate that the results are $x = 5.5$ and $x = 4.5$.

Next, the student who knows the order in which the computer does the combined operations would change steps 50 and 60:

```
50 X1 = (-B + SQR(B² - 4*A*C) / 2*A
60 X2 = (-B  - SQR(B² - 4*A*C) / 2*A
```

The student has corrected a very common mistake: the term 2*A divides the whole numerator, not just the square root. Moreover, the order in which the computer does the combined operations is also the order in which they should be done by the student.

When this program is run using the same problem, we will obtain the correct results. However, if we run the program for the equation

$$2x^2 - 10x + 12 = 0$$

(the results of which are the same), we will obtain the values $x = 12$ and $x = 8$.

Again we have to correct steps 50 and 60:

```
50 X1 = (-B + SQR(B² - 4*A*C) / (2*A)
60 X2 = (-B  - SQR(B² - 4*A*C) / (2*A)
```

and then we will obtain the correct results.

In the process of programming and verifying that the computer gives the student the expected results, the mathematical

concepts are reaffirmed. The student has created an object, and in manipulating it he learns from it. The student has become a teacher of the machine, and thus a master of knowledge.

Each of these ways of integrating the computer into the teaching of mathematics meets three objectives to some degree: it provides students with a basic knowledge of the principal characteristics of the computer; it teaches them a programming language; and it improves their understanding of mathematics. This last is, for the mathematics teacher, perhaps the main objective.

19

Computer Literacy Through Television

PEDRO HEPP

INTRODUCTION

This paper describes a course on computer literacy broadcast over television in 1984 and repeated in 1985. The course comprised 13 short programs aimed at teachers, parents, and students interested in microcomputers for education. People enrolled in the course had access to computers, courseware, and tutoring. The programming language Logo, which was translated into Spanish, was used. A number of other short courses for teachers and students have since been developed. A new course, based on applications, is now being developed and will be broadcast in 1986.

Television has always been regarded as a medium with great educational potential. Although education is the most important way for developing countries to improve people's lives in the long run, television's potential for education is, in general, barely exploited. In Chile, most of the people, including the poor, own or have access to television sets. Television can therefore be used for continuing education for large numbers of people of all ages and backgrounds, in their own homes and at their own pace.

The Catholic University of Chile owns a television network (channel 13) that reaches every major town in Chile. It devotes part of its transmission time to educational programs, which are

designed and implemented by a special department named "Teleduc" (TELevision EDUCativa). Each course consists of a series of 10 to 13 programs. Their underlying principles are that learning can be fun, that a great deal of learning happens by experimentation when people do things by themselves, and that television can be effectively used for education and promoting creative thinking. People who enroll in the courses participate in practical work, receive course material, and take examinations. For these activities, Teleduc has special purpose centers in ten of the largest cities in Chile.

Courses are broadcast on Saturday morning and repeated on Sunday. It is estimated that at that time, when no other channels are broadcasting in Santiago, 25 percent of the television sets are on. The courses are viewed by people between 8 and 85 years of age, but most are between 25 and 35 years old. Sixty percent of the viewers are females, 90 percent have completed secondary school and only 30 percent are professionals. Each semester, approximately 5,000 persons enroll in Teleduc courses.

Courses on history, arts, mathematics, photography, and theater have been developed by Teleduc with the cooperation of the appropriate university departments. A teacher is responsible for the content of each program. He or she prepares course material (in the form of a book or magazine) and supervises the entire process including scriptwriting, practical sessions, examinations, and assignments.

DESIGNING THE COURSE

In October 1983, Teleduc consulted the computer science department in order to design a course on computer literacy with the following objectives:

- To show that today's microcomputers are simple to learn (there is no need for any particular skill other than reading and writing), useful (their applications are limited only by people's creativity), and great fun (learning can be enjoyable)
- To show that microcomputers can be effectively used in education if teachers and parents are aware of and have had a personal experience with computers in an environment conducive to learning.

This second objective was particularly important because many schools and parents rush into computing, buying equipment and software labeled "educational" without knowing how they intend to use them. A survey showed that while 11 percent of Santiago's schools had computers in 1984, only 3 percent of the teachers had used them (Donoso, 1985). An increasing number of schools and parents need guidance because after a short period of uncoordinated attempts, they find that the technology does not match the promises. The same survey reported that 91 percent of Santiago's teachers want to enroll in computer courses (Donoso, 1985).

The television course was called "The Logo Language: A Simple, Useful, and Enjoyable Way to Get into the Computer World." It was designed as a 13-week course, with the first television program being an interview with the author and an overview of today's computing technology and applications. A book, comprising 12 chapters, and a technical magazine were written. Each program consisted of short sketches in which actors tried to convey three or four basic ideas, extracted from one book chapter, and additional technical information from the magazine. Each program was planned to last 24 minutes.

It was expected that the general public not enrolled in the course would be able to follow the television programs without much difficulty and that they would be eager to try working on a microcomputer. Each program was designed to interest people in exploring ideas with the computer and to provide general support to the practical sessions for those enrolled. Each person who was formally enrolled was allowed to practice at least three hours a week with three different types of microcomputers.

The Logo Decision

We decided to use a programming language instead of an application software (such as a word processor or spreadsheet) as the learning vehicle because it was possible to get a standard subset of it working on all the different participating computer models. Also, schools and parents were already using programming languages, mainly BASIC, because it was readily available on their machines. However, we decided to use Logo instead of BASIC despite strong arguments against such a decision. It was said that BASIC was inexpensive and probably the language most used in

education. On the other hand, Logo was almost unknown in Chile, and no research had been done to support claims of its superiority over BASIC as a learning tool.

We had used BASIC at the university in the late 1960s and early 1970s to train programmers, and we were aware of the many benefits of BASIC for short and simple programming. However, as soon as code grew over approximately 100 lines and problems became more complex, BASIC would not provide adequate abstraction mechanisms and control structures to deal with the complexity. The longer the code, the more structured it became. It became much more difficult to debug, expand, and experiment with it. Code was difficult to share and to explain to others. At the university, we rapidly switched to Pascal as soon as it became available and overcame most of the problems found in BASIC.

Logo, on the other hand, was designed for learning (Papert, 1980). It has most of the benefits of BASIC, such as an interactive environment, including an editor; but it also has good abstraction mechanisms, elegant control structures (such as recursion) and the language is easy to extend. The integrated graphics capability makes it easy to begin with, allowing a smooth transition from simple to complex problems. It promotes experimentation, and as we rapidly observed by trying it on children and youngsters, it tends to stimulate programming in teams and code sharing. In brief, we consider that Logo has better underlying language design principles than BASIC; it has a strong educational appeal; and it has good supporting written material (Abelson, 1981; Abelson and DiSessa, 1982; Reggini, 1982; Ross, 1983; Thornburg, 1983).

Finally, Logo proved easy to translate into Spanish, and different versions had a large intersection, making it easy to standardize. At first, Logo was translated into Spanish for each make of computer by a commercial firm. This translation rapidly became a standard and further commercial versions were based on it. The university now has its own translation and is finishing its own Spanish implementation.

Courseware

The book, from which the television scripts were extracted, includes the following topics: turtle graphics, command and operator creation, editors, math operators, variables, if-then-else,

recursion, Cartesian coordinates, list processing, interactive programming, and file handling. Each chapter includes exercises and hints for experimentation. The final chapters describe projects such as building a simple database, playing with physics, geography, and motors. In writing the book, we drew heavily from ideas included in other books, which by now are standard examples, particularly those from Abelson, Ross and Thornburg.

The magazine includes topics on the history of computing, from the abacus, through the Inca Quipu, to the five generations of computers. It explains the basic principles of today's computers starting with components such as transistors and chips, and defines terms such as memory and CPU. A few pages are devoted to programming languages with brief examples. Finally, it demonstrates how computers are used in different activities, such as health care and administration.

The *television programs* are in a light comedy style. A special character called the "Logotipo" was created. He was responsible for presenting the main ideas, discussing them with the "Turtle," a character always ready to act and learn. Among other actors, the "Programmer" was in charge of representing the traditional view of computing as a difficult discipline, always in conflict with "Logotipo" and the helpful "Turtle." In essence, the "Turtle" was the medium through which the "Logotipo" learned and experimented.

THE 1984 COURSE

Computer and Human Resources

The computer industry was immediately interested in the course, and Teleduc obtained 74 microcomputers of three different types to be used during the course. Computer centers were established in ten cities. These centers were open twelve hours daily, six days a week, and were permanently staffed by teaching assistants. In each center, one person was in charge of assigning computers and practice hours according to demand and machine availability.

Teaching assistants were trained in only three days. Most of the assistants from Santiago were computer science students who already knew Logo. They helped prepare the others from provinces, mainly secondary school teachers. Their principal task

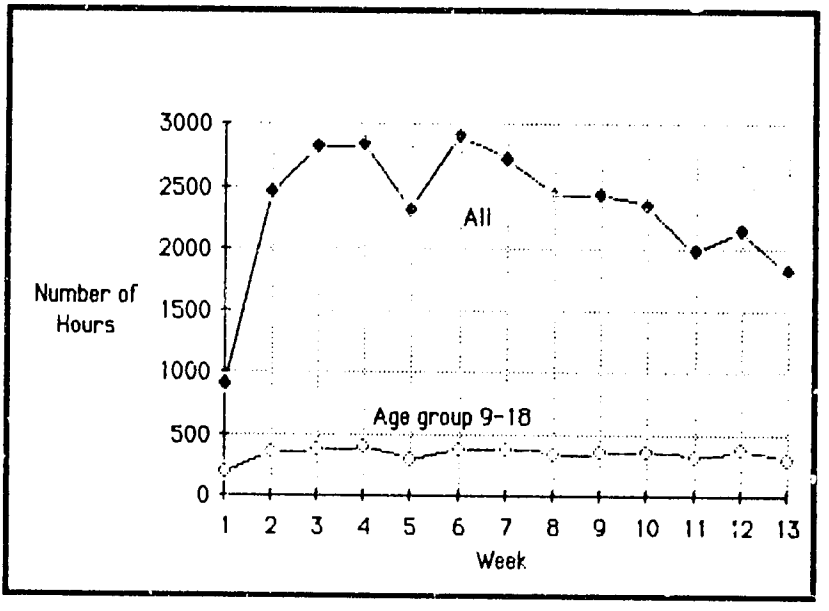

FIGURE 19.1 Practice room utilization. The 9 to 18 age group used 65 percent of their allowed time. Those over 19 used 54 percent. Weeks 5 and 11 were holiday weeks.

during the course was to observe and give guidance to students, stimulating experimentation and self-discovery.

Course Statistics

Of the 1,561 persons enrolled in the course, 1,343 (76 percent) used the computers in the practice centers. Of the total, 960 (61.5 percent) were male and 601 (38.5 percent) female. Only 534 (34.2 percent) were students. Figure 19.1 shows how the demand for practical work evolved during the course. The first week was slow mainly because people were still enrolling in the course. Later on, people found that they could finish the exercises in each book chapter in less than the three hours practice allowed each week and finished the course earlier. This was not the case with younger people, under 20 years of age, who also finished the course earlier but continued exploring other possibilities with the computers. This difference in attitude between ages was apparent in other short courses given after the television course.

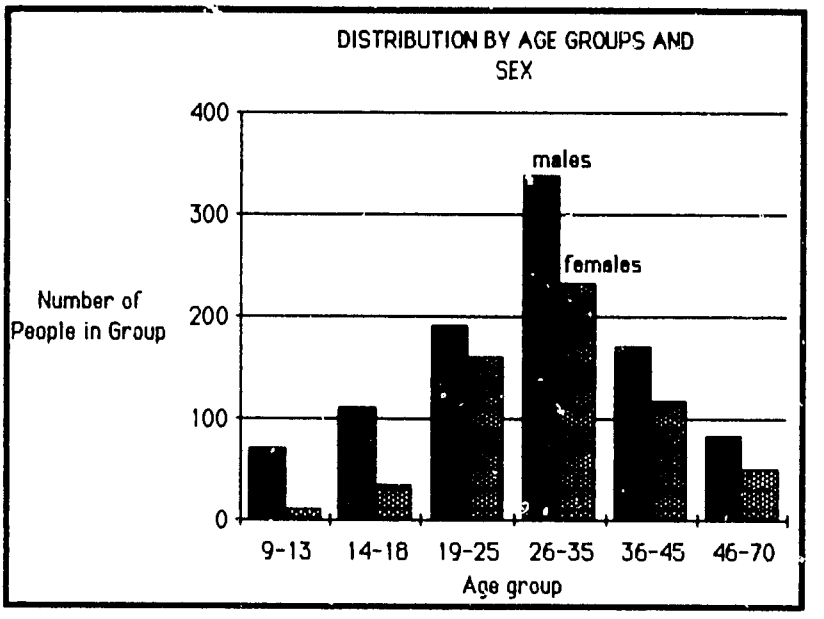

FIGURE 19.2 Percentages of students passing the course.

Only 70.5 percent of those enrolled took the examination, and 73.2 percent of this group passed the course. Figure 19.2 shows the distribution of course results. The group that passed the course was 74.7 percent male and 70.8 percent female. It was noted that when students and teachers were enrolled by their schools in the same course, the teachers generally did not take the examination.

EPILOGUE TO THE 1984 TELEVISION COURSE

In December, shortly after the 1984 course had finished, a two-week course for children between 8 and 14 years of age was implemented in schools and not shown on television for the general public. These children received seven sheets, in which a very energetic character named the "Supertortuga" introduced, in a comic-strip style, the Logo concepts. These concepts included only turtle graphics.

In January 1985, a two-week summer camp, with 60 children between the ages of 8 and 14 was held. It was a full-time course, combining recreation and computers. Each session began with one TV program and the children worked on those concepts for the

rest of the session. Children were filmed during these practices. As a result, Teleduc is now organizing more summer camps and short courses based on Logo.

Because of the pressure in schools to provide computer courses, it became apparent that courses for teachers were and are a growing necessity. After the summer camp, a two-week course for secondary school teachers was carried out. A permanent training course for teachers is currently available at the university (Donoso, 1985).

THE 1985 COURSE

The television course was repeated in 1985, with the following differences from the previous year:

The book was rewritten to include more exercises, a new chapter on the use of the editor, and changes in the order and content of chapters to provide a smoother transition from graphics to list processing. A *magazine*, written as a comic and featuring the Supertortuga was given to students under 15 years old instead of the book. The content of the book and magazine are similar but differ significantly in presentation. The *practice center* in Santiago is now twice as large, with 60 donated microcomputers. The new room includes space for group discussion and a second floor for demonstrations and exhibits for visitors

The Logo version now used has been translated by the computer science department, and our own Spanish version is currently being tested. We decided to implement our own version of Logo because present commercial versions are too expensive for most of the schools and parents. Also, we expect to improve the Logo syntax and add new features to it, according to needs and machine capabilities. For example, Logo versions for Apple's MacIntosh show many advanced features (such as three-dimensional spaces).

THE FUTURE

Teleduc now has a great deal of experience as well as computer resources and teaching material. It is therefore planning additional courses to be offered to the general public. There will be two new courses. One is based on Logo and will show how to use "microworlds" (Papert, 1980) in different subjects such as physics, history, and grammar. The other course will show how computers

can be used by people to do their current jobs in more productive and creative ways. This course is also intended to show that computers can modify the way people communicate, enriching the quality of their work.

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20

A Realistic Program of Computer Literacy for All Mexican Children

JORGE BUSTAMANTE

In countries that are highly developed technologically, it is estimated that within three years 75 percent of all work will directly employ computers. In our country, it will take several more years, but inevitably this will be the situation, at least in urban areas. Now is the moment to act intelligently, within our economic possibilities, and try to take steps that will benefit the entire population. For those who would question the arrival of computers in our midst, suffice it to say that in 1956 the ILLIAC, one of the first machines designed by Von Neumann, cost several million dollars, whereas today a $100 machine has more capacity than the ILLIAC ever did and can be used with greater ease. What will happen in another 15 years, considering that the rate of development is accelerating daily?

COMPUTERS IN MEXICAN SCHOOLS

Currently, schools for children and young people whose families have liberal economic resources have access to computer equipment and software. Some of these schools have comprehensive plans and are attempting to introduce them in different subject areas; others use computers in laboratories somewhat independently of the curricula. The Israeli and French schools in the Pedregal

are examples of these two very different approaches, although both schools use similar computer equipment.

Currently there are dozens of centers that teach computer skills to children from families that can afford to spend a great deal of money on education. Only the program at the Academy of Scientific Research and the one at the General Directorate of Libraries (the AIC-DGB Program) give computer courses free of charge for children at all socioeconomic levels. Unfortunately, the resources are limited to 20 stations; these are used all day long, Monday through Friday and half a day on Saturdays and Sundays. It is hoped that soon a major teaching program will be introduced in the third year of secondary school using 400 MICROSEP machines, as announced at a recent meeting in Durango.

If the current trend continues, in a few years there will be two classes of children: those who have had access to computers and those who have not. It could be said that there will be a further breakdown of these categories depending on the degree of mastery of the teaching methodology and other variables such as acceptance on the part of the teachers, the training they have had, and the quality and variety of devices available for the equipment being used. However, we firmly believe that the most serious difference will be between those children who have not had any contact with computers and those who have. It amounts to the difference between those who have learned to read and write and those who have not. Based on this analogy, we will use the term "computer literate" to refer to those who have attained a certain level of knowledge about the use of computers and "computer acculturated" to those with a fuller understanding of the technology.

ORGANIZATION OF THE PROPOSED PROGRAM

OBJECTIVES

The objective of the program described herein is to achieve computer literacy with a minimum investment for all Mexican children in the primary grades within a period of six years. Computer literacy occurs when people have had sufficient access to equipment and training hours to enable them to:

1. Use a computer keyboard directly, including the special function keys;
2. Write simple procedures;

3. Link these simple procedures in the development of increasingly more complicated procedures or programs;
4. Edit their procedures and correct their own errors to accomplish the proposed task;
5. Recognize that the computer does only what it is told and that it does not make mistakes or harbor any magic;
6. Understand that it is possible to do wonderful things with computers;
7. Recognize that these wonderful things are made up of small procedures just like the ones that they have already learned;
8. Pose problems and solve them correctly with the computer; and
9. Finally, it would be very desirable if they became motivated to continue working with computers whenever the opportunity arose.

Computer Acculturation

Experience with the almost 14,000 children in the AIC-DGB program leads us to the conclusion that with 20 hours of intensive work, two children per machine, it is possible to achieve the level of computer literacy described above.

To prevent a deterioration of this knowledge, which could soon lead to functional computer illiteracy, there should be equipment at the disposal of the computer literate children that has been set up for practical and useful applications. It is also necessary to give talks at the computer acculturation centers that will serve to carry on the sensitization process. The new applications that they will be working on daily will contribute to this objective. It would be very desirable if the Mexican television networks would do as the BBC has done in England and offer information programs on the uses of computers. Once people become computer acculturated, they can evaluate everyday applications in the markets, in shops, or on television, all of which will reinforce their knowledge and interest. It could be planned so that in the near future every television set will come with one or several additional electronic circuit boards and a small keyboard that will allow them to be converted into home computers. The additional cost of such equipment would not exceed that of a normal television set by more than 25 percent at this time, and, within a few years, by more than 10

percent. For this purpose, Mexican manufacturers should try to use a standard such as the MSX or the 16-bit MSX. This would mean that in the future all homes that have a recently acquired television set—and there are many—would have a computer. In those homes that have a telephone, the possibilities for communication would be enormous, and the process of full acculturation would be accomplished. If we discount the situation for the immediate future, given the economic crisis that we are currently going through, it is possible to plan for the teaching equipment to remain at the disposal of the children who have been trained so that they can practice what they have learned and use it in applications of collective interest. Further on, we will propose a practical way of accomplishing this. First we will address the task of developing computer literacy.

Methods to be Used in the Program

In a country the size of Mexico, the achievement of computer literacy in children would appear to be a superproject. But the printing of free textbooks for all primary schoolchildren was also once regarded as a project of unattainable dimensions, and this in fact was achieved within a very short time. My concrete proposal for computer literacy is that it be done through the network of the National Public Libraries Program and CONACYT'S "Casas de la Ciencia." The plan of operation would be similar to the one that has been used for the limited equipment of the Academy of Scientific Research (AIC). The effort would be to improve it with the provision that in each library the installation be permanent, secure, and adequate in size.

Personnel and Training

At each of these work centers there would be a person designated to be responsible for the equipment and the instruction. The training and technical selection of this person would, in principle, be done by AIC, either following the system that is now being used or by another mechanism described below under the heading "Supporting Organization."

Maintenance

A central unit would be created for maintenance of the equipment, and would be divided as the program grows. Persons already working in different parts of the country could take charge of the maintenance under contract, later on. An effort would be made to use small independent working groups to make the system efficient without increasing the permanent staff of the libraries or the Casas de la Ciencia. In our 20 months of experience with the AIC-DGB program, we have been able to verify that the equipment holds up well, even though the installations in the libraries are not the best for this purpose and the equipment is connected, disconnected, and packed up twice a day.

Enrollment of Students

The children would be enrolled at the libraries, on a first-come-first-serve basis; it would be emphasized to the parents and children that punctuality is an important part of the training, and that the program is ongoing. Cards will be made available for keeping attendance records, and rules will be set down in writing. In order to use the equipment without an instructor, the pupil will have to have completed 20 hours of supervised work. These are the rules that are already being applied under the current program.

Didactic Approach

We propose to use Logo as the basis of our educational philosophy; we have specifically avoided using the word "language" to emphasize the fact that Logo is more than a language.

During 20 hours of exposure to Logo, we plan to guide the children step by step toward the achievement of the objectives set forth in our definition of computer literacy. It is not a question of leaving the children alone to do what they want; this has not worked either in Mexico or in the country where the Logo movement has had its greatest development and acceptance. Logo is a language for both children and adults; to learn all of it requires a great deal of time and study. It is important to emphasize that it is useful for children and adults of all ages; no one can deny that it is not an intellectual challenge. The more advanced and clever children will be stimulated to find problems that are difficult to solve. In other words, Logo has no limitations that will hold back a child's development.

It is important to point out that the proposed scheme, which is outside the school system, should not create problems in the educational setting either for the teachers or for the children. On the contrary, the fact that it is free of charge will allow the children who are motivated to go the public libraries and, if they so wish, to see it through to the end. The scheme can be likened to an optional laboratory outside the classroom.

Equipment

We intend to use the most inexpensive equipment available that will enable us to attain the objective of computer literacy. We are aware that there is more expensive equipment that is more attractive and user-friendly, but we also know that the equipment we have selected or that is to be selected, even though it is inexpensive, is adequate for the job. Moreover, regardless of what the children use subsequently in the way of additional equipment (such as diskettes or printers), it will not represent a great change if they are computer literate.

In the later phase of acculturation there will be other applications at the children's disposal—such as word processing, database management, and the use of spreadsheets, to mention some of the ones that are best known and most useful.

Evaluation of the Program

The money spent in this program of computer literacy for children is justified if it helps to improve the quality of life of the Mexican people. Thus it is indispensable to evaluate the cost-benefit ratio of the project. In this research, it will be necessary to take into account any social changes that occur as a consequence of computer literacy and their influence on the development of creativity, logical and critical thought, intellectual ability, and problem-solving capacity in the children. Below we define, both operationally and in terms of computer literacy, the improvement in quality of life that we believe should result from a project such as the one proposed.

Improvement in the Quality of Life. We will refer to those aspects of quality of life that, as a consequence of computer literacy and subsequent acculturation, would be available to those who have had this preparation and without which they would face as many closed doors as now exist for the illiterate.

In general, I believe that Mexico will be a very different country when all the children are computer literate, perhaps in 10 to 15 years—when they will go to the public libraries to read and to use computers as a tool; and when they will see that there are other dimensions of thought and that they can break away from the constant alienation of a television set that makes them mere spectators of other people's lives. The computer can make it possible for them to create their own worlds and their own challenges, and to form user groups that have more in common than cartoons or Pac-Man.

It is hoped that there will be improvement in at least the following areas:

1. Equal job opportunities for all Mexicans, especially for jobs that are better paid or more attractive from other points of view;
2. Equal job opportunities for men and women, especially for better-paid jobs. We emphasize boys *and* girls because it has been widely noted that computers are regarded as a male preserve; we believe that this is due, in part, to lack of access for girls at an early age. In the program that follows, no distinction will be made between boys and girls; in all cases we will be referring to both sexes when we speak of "children";
3. Cultivation of a sense of security and emotional tranquillity compared with other children of the same age; and
4. Assurance of equal opportunity in the choice of career.

Some of these aspects will offer, in turn, other advantages for quality of life, such as better housing, better food, and better facilities for transportation and communication.

Estimated Program Cost

Before launching the program on a full scale, we would have a maturation period during which the necessary personnel would be trained. The annual cost, or better, the cash flow of the program, will depend on the size of the target population and the length of the maturation period.

As a rough estimate, we assume the following:

Size of the population:	15 million children in the primary grades
Literacy training period:	six years
Maturation period:	three years; each year the capacity will be increased in order to complete the project in six years.

Literacy program:	
First year:	1 million children
Second year:	2 million children
Third year:	3 million children
Fourth year:	3 million children
Fifth year:	3 million children
Sixth year:	3 million children
Total:	15 million children

Acculturation: 20 percent of the children trained each year.

Time necessary for literacy training:	20 machine-hours.
Time necessary for acculturation:	20 machine-hours.

Cost of Equipment and Necessary Programs:	
Cost of microcomputer:	U.S. $ 100
Cost of monitor, low color resolution:	180
Cost of cassette recorder (one for every five stations):	40
Cost of cassette with Logo program:	40
Cost of acculturation programs:	180

The cost of program administration and supervision is estimated at ten percent of the instructors' salaries.

Cost of Equipment Maintenance and Repair. We estimate that the equipment has a useful life of six years. Also, we consider that an adequate amount of funds should be set aside for its upkeep. Table 20.1 gives a sample of the percentages, based on the initial value, that are being considered for maintenance and for major repairs of the equipment. It could be a question of setting an upper limit, but we want to present a realistic estimate of the costs that can be expected.

TABLE 20.1 Cost of Hardware Maintenance as a Percentage of Initial Outlay

Year	Percentage
First year	7
Second year	17
Third year	27
Fourth year	37
Fifth year	47
Sixth year	57

TABLE 20.2 Cash Flow,[a] Stations, and Instructors Required

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	540.83	0.00	910.00	91.00	37.86	1,579.69	4,167	0	833
2	540.83	108.17	910.00	91.00	183.88	1,833.88	8,333	833	1,667
3	540.83	108.17	910.00	91.00	467.28	2,117.28	12,500	1,667	2,500
4	0.00	108.17	2,730.00	273.00	680.37	3,791.54	12,500	2,500	2,500
5	0.00	0.00	2,730.00	273.00	915.09	3,918.09	12,500	2,500	2,500
6	0.00	0.00	2,730.00	273.00	1,109.79	4,112.79	12,500	2,500	2,500
Total	1,622.50	24.50	10,920.00	1,092.00	3,394.27	17,353.27			

[a]Amounts are given in millions of pesos.

Cash Flow

Table 20.2 gives a summary of the cash flow needed in order to complete the program in six years under the conditions stipulated above. Appendix 20.1 presents the same table as alternative 1 and gives five other alternatives, with changes in the hypotheses regarding salaries, number of stations per instructor, and maturation period. Alternative 6 is the same as alternative 1 except that it is based on participation of only 50 percent of the children in the initial computer literacy program.

Instructors

For development of the program under alternative 1, it was considered that one instructor is needed for every five stations during the literacy phase of the program, while the acculturation phase could be carried out with the instructor together with volunteer tutors or teaching assistants. The rector of Universidad Nacional Autonoma de Mexico, Jorge Carpizo, and the director of social services, Rafael Valdes, looked favorably on the idea of assigning teaching assistants from some of the programs at this center to the teaching of computation to children.

The 20 percent annual increase in equipment and additional programs will be of greatest help in the acculturation process. The maintenance of knowledge, as it has already been said, will take place through the free use of computer equipment in applications that are valuable to students, such as word processing or database management.

Within the program, provision should be made for the participation of pupils and young tutors who can be of assistance to the instructors. In the current program of the AIC, tutors are being used with great success both from the standpoint of the assistance they provide and the motivation they have gotten from this work. In all cases, they have been told that they can work as much time as they want, but they have been asked not to leave the program once a cycle of sessions has started. The tutors have responded very well.

As can be seen, the human and material resources that this program requires would not be excessive for an economy such as Mexico's, and the cost per student would be very low.

Supporting Organization

For this program to have the dynamism that it requires, it is proposed to establish a Council for Free Computation for All Children, whose founding members might be the Ministry of Public Education, CONACYT, CONAFE, the Ministry of Trade and Industrial Promotion, the Academy of Scientific Research, parents' organizations, progressive firms such as the ICA, and all those persons or institutions that make a significant contribution to the financing of the project. The council would not have any employees or salaried staff; its functions would be to oversee quality control and research. For this purpose a technical committee

would be appointed consisting of ten members, two of whom would be replaced every two years. It would have a finance committee, similarly organized, whose objective would be to obtain funds for the project.

The council would not undertake any specific activity; rather, it would assign this work to third parties, preferably institutions or specialized enterprises. The council would be an advisory body, while the executive units, as previously mentioned, would be on the one hand, the Casas de la Ciencia, and on the other, the municipalities throughout the country and the SEP General Directorate of Libraries, as set forth in the agreement between the SEP and the Federated States for the installation of public libraries. In the expectation that the SEP could be depended on to give the most significant contributions for the equipment, CONAFE would be asked to place the international bids for the equipment and the corresponding contributions. Contracts for the work of coordination, evaluation, and research would be awarded through national bidding, while the specifications would be proposed by the council. Also, it would be the responsibility of CONAFE to contract for maintenance through national bidding. It would be the responsibility of the municipalities to contract for the personnel for the actual teaching. This personnel would be selected and trained by the companies responsible for coordination and evaluation, and the program would be carried out in all the municipalities as the opening of public libraries progresses. The council, depending on progress in computer instruction in the schools, could disappear or continue to function beyond the six years of the program.

CONCLUSIONS

The following conclusions may be drawn:

- The proposed program will remedy to a great extent the overwhelming social inequity being caused by the current elitist use of computers among Mexican children.
- In view of the financial and human resources that it requires, the program is feasible for a country such as Mexico.

- The proposed scheme is aimed at implementing a successful program under current circumstances and at preventing the intimidation of pupils and teachers. On a much smaller scale, it has already proven itself.
- This scheme does not interfere in any way with other computation and education projects planned by the SEP in the public libraries or in some secondary schools in the immediate or near future; on the contrary, it may complement them.
- It is proposed to institutionalize the project with the participation of all sectors involved in this project and others of its kind, for purposes of technical standardization, quality control, and research.

RECOMMENDATIONS

Twenty months ago the Academy of Scientific Research initiated a pilot project that was supported directly by the Ministry of Public Education (SEP), the Ministry of Trade and Industrial Promotion (SCFI), and CONACYT that has been an outstanding success. The project has reached maturity, and it is time to extend it throughout the country. For this to happen, it will be necessary to have the support of the rest of the political elements as well as of the economic sector. Only in this way can its continuity, its acceptance, and its success at the national level be guaranteed.

The concrete recommendation of this presentation is that a council be formed, with the participation of all the elements mentioned, in order to bring together the financial resources so that the project can be extended throughout the country. For this purpose, the infrastructure of the National Program of Public Libraries (which is opening a library in each municipality) would be utilized, along with the help of the federal, state, and municipal governments. In this way, equal opportunity would be made available to all Mexican children through free access to computer literacy, and the project would automatically have a federalist, participatory, and decentralized basis.

ACKNOWLEDGMENTS

On behalf of the Academy of Scientific Research and on my own behalf, I wish to express appreciation for the continued support that has been given to the project by the SEP, CONACYT, and the SCFI.

The plan outlined here has been discussed with staff from government and from the private sector, all of whom have found it both necessary and feasible. Among the persons consulted are Leonel Duran, Hector Mayagoitia, Daniel Resediz, Jose Warman, Gilberto Borja Navarrete, Fernando Espinosa, Horacio Lombardo, and Francisco Norena Casado. I wish to thank all of them for their enthusiasm and for the time they have spent listening to these ideas. We hope their support will continue so that the project will grow from its current pilot state into a program extended to children throughout the country and all social classes.

APPENDIX 20.1
SIX ALTERNATIVE SCENARIOS

ALTERNATIVE 1

Preliminary Data

Number of children (millions)	15
Number of years of program	6
Numbers of years since initiation	3
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	5
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	0.83333
2	0.83333
3	0.83333
4	4.16667
5	4.16667
6	4.16667

ALTERNATIVE 1 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	540.83	0.00	910.00	91.00	37.86	1,579.69	4,167	0	833
2	540.83	108.17	910.00	91.00	183.88	1,833.88	833	833	1,667
3	540.83	108.17	910.00	91.00	467.28	2,117.28	12,500	1,667	2,500
4	0.00	108.17	2,730.00	273.00	680.37	3,791.54	12,500	2,500	2,500
5	0.00	0.00	2,730.00	273.00	915.09	3,918.09	12,500	2,500	2,500
6	0.00	0.00	2,730.00	273.00	1,109.79	4,112.79	12,500	2,500	2,500
Total	1,622.50	324.50	10,920.00	1,092.00	3,394.27	17,353.27			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program.

ALTERNATIVE 2

Preliminary Data

Number of children (millions)	15
Number of years of program	6
Numbers of years since initiation	3
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	4
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	0.83333
2	0.83333
3	0.83333
4	4.16667
5	4.16667
6	4.16667

ALTERNATIVE 2 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	540.83	0.00	1,137.50	113.75	37.86	1,629.94	4,167	0	1,042
2	540.83	108.17	1,137.50	113.75	183.88	2,084.13	8,333	833	2,083
3	540.83	108.17	1,137.50	113.75	467.28	2,367.53	12,500	1,667	3,125
4	0.00	108.17	3,412.50	341.25	680.37	4,542.29	12,500	2,500	3,125
5	0.00	0.00	3,412.50	341.25	915.09	4,668.84	12,500	2,500	3,125
6	0.00	0.00	3,412.50	341.25	1,109.79	4,863.54	12,500	2,500	3,125
Total	1,622.50	324.50	13,650.00	1,365.00	3,394.27	20,156.27			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program.

ALTERNATIVE 3

Preliminary Data

Number of children (millions)	15
Number of years of program	6
Numbers of years since initiation	2
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	4
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	1.25000
2	1.25000
3	3.12500
4	3.12500
5	3.12500
6	4.16667

ALTERNATIVE 3 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	811.25	0.00	1,706.25	170.63	56.79	2,744.91	6,250	0	1,563
2	811.25	162.25	1,706.25	170.63	275.83	3,126.20	12,500	1,250	3,125
3	0.00	162.25	3,412.50	341.25	481.88	4,397.88	12,500	2,500	3,125
4	0.00	0.00	3,412.50	341.25	720.39	4,474.14	12,500	2,500	3,125
5	0.00	0.00	3,412.50	341.25	915.09	4,668.84	12,500	2,500	3,125
6	0.00	0.00	3,412.50	341.25	1,109.79	4,863.54	12,500	2,500	3,125
Total	1,622.50	324.50	17,062.50	1,706.25	3,559.77	24,275.52			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program.

ALTERNATIVE 4

Preliminary Data

Number of children (millions)	15
Number of years of program	6
Numbers of years since initiation	3
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	10
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	0.83333
2	0.83333
3	0.83333
4	4.16667
5	4.16667
6	4.16667

ALTERNATIVE 4 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	540.83	0.00	455.00	45.50	37.86	1,079.19	4,167	0	417
2	540.83	108.17	455.00	45.50	183.88	1,333.38	833	833	853
3	540.83	108.17	445.00	45.50	467.28	1,616.78	12,500	1,667	1,250
4	0.00	108.17	1,365.00	136.50	680.37	2,290.04	12,500	2,500	1,250
5	0.00	0.00	1,365.00	136.50	915.09	2,416.59	12,500	2,500	1,250
6	0.00	0.00	1,365.00	136.50	1,109.79	2,611.29	12,500	2,500	1,250
Total	1,622.50	324.50	5,460.00	546.00	3,394.27	11,247.27			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program

ALTERNATIVE 5

Preliminary Data

Number of children (millions)	15
Number of program years	6
Numbers of years since initiation	3
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	4
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	0.83333
2	0.83333
3	0.83333
4	4.16667
5	4.16667
6	4.16667

ALTERNATIVE 5 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	540.83	0.00	1,706.63	170.63	37.86	2,455.57	4,167	0	1,043
2	540.83	108.17	1,706.63	170.63	183.88	2,709.76	833	833	2,083
3	540.83	108.17	5,118.75	511.88	467.28	2,995.16	12,500	1,667	3,125
4	0.00	108.17	5,118.75	511.88	620.37	6,419.16	12,500	2,500	3,125
5	0.00	0.00	5,118.75	511.88	915.09	6,545.79	12,500	2,500	3,125
6	0.00	0.00	5,118.75	511.88	1,109.79	6,740.42	12,500	2,500	3,125
Total	1,522.50	324.50	20,475.00	2,047.50	3,394.27	27,863.77			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program.

ALTERNATIVE 6

Preliminary Data

Number of children (millions)	107.5
Number of program years	6
Numbers of years since initiation	3
Hours of annual instruction	20
Number of students per station	2
Number of students per instructor	5
Annual hours per station	2,000
Monthly wages for instructors (Pesos)	$60,000

Equipment Costs Per Station

Cost per computer	(US) $ 100
Cost per monitor	180
Cost per cartridge	40
Cost for illustrations	8
Cost for electrical installation	15,000

Year	Computer Literate Children (millions)
1	0.41667
2	0.41667
3	0.41667
4	2.83333
5	2.83333
6	2.83333

ALTERNATIVE 6 (Cont'd)
Cash Flow (Millions of Pesos)

Year	Equipment Literacy Program	Acculturation	Instructors	Coordination	Maintenance	Total	Stations Literacy Program	Acculturation	Total Instructors
1	270.42	0.00	455.00	45.50	10.93	789.85	2,083	0	417
2	270.42	54.08	455.00	45.50	91.94	916.94	4,167	417	833
3	270.42	54.08	455.00	45.50	233.64	1,358.64	6,250	833	1,250
4	0.00	54.08	1,365.00	136.50	340.18	1,895.77	6,250	1,250	1,250
5	0.00	0.00	1,365.00	136.50	457.55	1,959.04	6,250	1,250	1,250
6	0.00	0.00	1,365.00	136.50	554.89	2,056.40	6,250	1,250	1,250
Total	811.25	162.25	5,460.00	546.00	1,671.47	8,676.64			

Hypothesis: The expenses for coordination are equivalent to 10 percent of the teachers' salaries.

The equipment dedicated to acculturation amounts to 20 percent of the equipment dedicated to the literacy program.

Section 5
Special Education

21

Microcomputers in Special Education: Logo as an Educational Tool

JOSE ARMANDO VALENTE

INTRODUCTION

Even though our understanding of exceptional children has progressed enormously, in their education this knowledge has not been adequately applied in order to successfully tap their intellectual potential. Their needs have not been satisfied because the educational process in use today is a mere simplification of the educational method used with normal children. For example, a severely physically handicapped child has difficulty manipulating objects, hence the ordinary pencil and paper are not accessible educational tools. The exceptional child requires a new concept of education. Each child needs communicators, curriculum material, therapy programs, and physical spaces that are specially adapted for his individual needs.

The experience of utilizing the Logo methodology with special needs children (Goldenberg, 1979; Weir, 1981; Weir and Emanuel, 1976) has shown that the computer can provide a new approach to their education. The Logo methodology encompasses a computer language (Logo) and a learning environment consisting of children, computers, computer activities, programming ideas, and several learning principles. According to this methodology, the computer is a tool with which the special needs child can develop

his or her abstract thinking, can express ideas that were previously inaccessible, and can become a productive member of society.

The objective of this paper is two-fold: first, it describes the use of Logo as an educational tool for children physically handicapped by cerebral palsy. The result of this work demonstrates that combining information from a variety of Logo activities provides a powerful way of making a good analysis of performance in spatial, numerical, and writing domains—offering a magnified and "slowed-down" view of their cognitive processes. Second, it describes the ongoing work at our computer-based learning center for the education of special needs children.

THE USE OF LOGO TO EDUCATE CHILDREN WITH CEREBRAL PALSY

Cerebral palsied children have a disorder of movement and posture, caused by brain lesions, that limits their interaction with the physical world. They are known to have cognitive retardation as the result of reduced interactions with the environment because of their physical handicaps, or as a result of brain lesions that may affect motor areas as well as areas of the brain that support specific intellectual functions. These children's motor impairment makes understanding and evaluating their cognitive deficiencies a formidable task. It is difficult to create interesting and challenging activities that they can carry out so that their intellectual abilities can be evaluated. The computer can provide the means by which cerebral palsied children can perform engaging activities.

The Logo methodology meets the special needs of these children for the following reasons:

- First, the child does not have to manipulate physical objects. Instead, he controls a computer that, in turn, manipulates objects. The computer minimizes the barriers between the child and the physical world by moving the objects for him: executing the drawing and printing the words. Thus, children who have sufficient motor coordination to push a button can command the computer to do what they want, without being dependent on other people, and without being limited by their lack of motor coordination.

- Second, the activities the children develop in the Logo environment are determined by their own interests and imaginations. The children decide what to do and have control over their own projects. Thus children are transformed from passive observers to active participants.
- Third, the use of Logo demands the formalization of intuitive knowledge; this allows us to "see" the process the child uses to develop a particular activity and thus to identify the child's strengths and weaknesses. Education according to the Logo methodology consists of giving the children the power to channel their strengths to overcome their weaknesses.

A Case Study

This research started in 1978 as part of the project "Information Prosthetics for the Handicapped" developed at the Logo Laboratory of the Massachusetts Institute of Technology. It was tested in Boston at the Cotting School for Handicapped Children, a vocational school that offers a twelve-year academic program for physically handicapped children with normal mental capacities. A microcomputer from the Logo Laboratory was set up at the school, and the work started with Mike, a 17-year-old severely cerebral palsied boy, who was enrolled as a tenth-grade student.

Mike was selected as our first subject for several reasons. First, he had been at the Cotting School since the first grade and had shown a high degree of intellectual ability: excellent reasoning abilities, excellent memory, and an appreciation of being challenged by difficult tasks. This meant that he could not only exploit the intellectual power of the Logo environment, but he could also give us feedback in terms of the development of his ideas, the instructional techniques we were using, and his feeling about the use of the computer. Second, Mike's teachers were concerned that there was a gap between Mike's potential and the school's ability to meet his intellectual needs.

My first contact with Mike showed that traditional educational approaches had few chances of working. Although he had sufficient motor coordination to control his electric wheelchair, he had never used a pencil, and there were few things he could do with his hands. In the Logo environment, Mike was allowed to select the computer activities he wanted to develop. The computer was his

"scratch pad." He could draw, write, solve algebraic expressions, or keep notes about his programs. My function was to be his experienced colleague performing several roles: an observer trying to understand Mike's difficulties and working style, a facilitator providing the information necessary for him to reach his goal, and a critic asking for better structured and more elegant programs.

Mike's computer work lasted approximately three years, during which time he was offered unlimited access to the computer. Twice a week I came to the school and spent two to three hours working with him. Usually, he spent another five hours each week working by himself. During school vacations, Mike was brought to the Logo Laboratory at MIT, where he could continue his computer activities. Thus, for almost three years Mike spent approximately twelve hours a week working on the computer.

In this learning environment it was possible to identify several aspects of Mike's working style. On the one hand, if we consider the degree of his motor handicap, it was surprising to discover not only how much knowledge he had acquired, but how creative and meticulous he was. On the other hand, his high degree of competence made it all the more surprising to find situations where he performed like a young child. His writing skills, for example, were an area of particular weakness. This is a sample of the first piece of writing Mike produced:

> I ment Dr. Sileva Where, Jose Valerte and Gary Drescher on October 5, 1978 at 9:32:47 AM. that the compuer I was so excized it like being it a waitting & maternace room at a hospital whiting to fine it oot's a boy or a grail.
> My fist and every day experreance with the compuer when it cash and it lost but it keep on losting all that I have tort it but keep no teaching it overy and overy agian when I bring back to live.

This example looks like spoken English that has been written down. There are many phonetic spellings, omissions of words and letters, reversed letters, and misconstructions of verb tenses. The question immediately arises of to what extent these problems are the result of lack of experience or of brain damage. To investigate and try to overcome this problem, we set up a focused remedial program. An English teacher designed a series of specific exercises based on weaknesses found in Mike's writing. All the lessons took place in the computer room, using the computer text editor, instead of having someone writing for him. Mike's use of this remedial program resulted in a gradual improvement, and he is

now writing papers at an acceptable level for college freshmen. This indicates that the deficiencies he showed may not be solely attributable to brain lesions and opens the possibility that some are the result of lack of experience.

Mike's programming skills also developed. They evolved from using simple programs to draw geometric shapes to programs involving sophisticated programming techniques such as ideas of recursion, data structure, and algorithms that operate on these data structures. The other change was in his conception of the purpose of the computer: he no longer saw it as a toy but as a tool. He learned to take advantage of the computer as an instrument that could carry out useful tasks, thus creating vocational options for himself.

Besides the development in Mike's programming skills, there was a noticeable improvement in his fine motor coordination as well as in his social interactions. The first improvement came because Mike was interested in using the computer and needed to attain the degree of dexterity necessary to manipulate the keyboard and insert the diskette into the disk drive. His social interactions developed because he had something interesting to talk about. His computer activities became a topic he could share with his teachers, colleagues, and with people interested in his work. This provided him with the means to interact with people outside of his immediate family, to make new friends, and to feel part of society. As he wrote, "The computer is a way that a disabled person can contribute to society" (Valente, 1983). Today he is an undergraduate in computer science at the University of Massachusetts and has a great interest in providing this training to other handicapped people.

The Cotting School also benefited from the project and acquired new educational and vocational tools. A computer center was established, and Logo was included as part of the high school curriculum. Computers were brought to the elementary classrooms so that the children could have a chance to develop computer activities.

From the researcher's point of view, the program showed that the computer can be an effective instrument to be used with physically handicapped children. It provided us with a way of understanding these children's intellectual disorders so that we could be truly helpful to them, giving them a way out of what seemed to be a hopeless situation. Our current objective is to

build upon this work, providing computer experiences to children in Brazil.

CENTER OF INFORMATICS FOR SPECIAL EDUCATION

The Center of Informatics for Special Education was established in January 1985 at the State University of Campinas, Sao Paulo, Brazil. The center is funded by private and government groups interested in education and the development of computer technology in Brazil. The primary objective of the center is to create computer-based Logo learning environments for children with physical handicaps, hearing impairment, and mental retardation and to develop educational methodologies that are suitable for these children's needs. To reach these objectives, we are developing the following activities:

- Research on cognitive styles. The Logo environment can provide us with the means to understand each child's problem-solving style. By analyzing the Logo work of the children in the center, we hope to be able to identify various landmarks or characteristics in their thinking process.
- Training programs. Professionals who work with exceptional children are trained to use Logo as an educational tool.
- Development of educational and training materials. Part of the center's funding is devoted to the development of educational and training materials such as floor turtle, a plotter, video tapes, and Logo booklets.
- A model school. The center has set up a model learning environment for the education of exceptional children. We believe that the best way to convince people about the power of Logo is to let them see Logo in action.

Training of Professionals

In a traditional two-week Logo workshop, the participants have a chance to develop only a superficial understanding of Logo and have no time to change their understanding of thinking and learning. In these situations, the computer never becomes the tool through which we can truly understand the exceptional child.

The goal of the center's training program is to produce educators who, in addition to having knowledge about computers and Logo, are willing to accept a radically different approach to learning; who are able to analyze learning situations and to reflect on their own experience; and who have developed an understanding of the psychological and intellectual issues related to their population of special needs children.

In this initial phase of the center, six professionals—two physical therapists, one occupational therapist, one phonologist, and two teachers—participated in an intensive six-month training program. The people selected were simultaneously continuing their work in the field with their respective special needs population. During the training program, the participants were involved in the following series of activities:

- Programming. The participants learned the Logo language in depth, including topics such as turtle geometry, manipulation of words, numbers, lists, and recursion, as well as some basic concepts about computers.
- Research in the literature. The participants were required to search the literature in order to develop an understanding of the intellectual and emotional problems related to their respective special needs population. This theoretical foundation can help to identify the potential contribution of the computer and to focus our attention on these issues as we work with the children.
- Using Logo with children. Under supervision, each participant was required to work with two children from their respective special needs population. The function of this activity was to create an environment where the participants were immersed in the theory and practice of Logo.
- Reflection on development. Participants were required to monitor the changes that took place within themselves as learners, as well as to analyze their behavior with the children as a teacher. This activity was supported by the use of personal notes each participant made of his or her own Logo activities, as well as his or her respective child's activities.
- Discussions. Weekly seminars were held to present new topics and to discuss problems and issues that arose during the activities.

This experience provided us with the means to understand some of the issues related to the training of adults and caused several changes in our participants' views of themselves as well as their role as professionals. The Logo experience radically changed the participants' concept of discipline from one of emphasizing conformity (behaving well, arriving on time, following formulas) to the discipline of critical thinking that includes playfulness and chaos. It shook the "owner of knowledge" mentality of our six professionals. They realized that to be a good Logo teacher they would have to, simultaneously, be a teacher, researcher, and learner. They had to reformulate their knowledge and reevaluate their learning style. Logo became a tool with which our trainees came to better understand themselves—the first step to using Logo as a tool with their students.

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22

Experiences in the Introduction of Computers in the Education of Hearing-Impaired Children

ALICIA MARIA GOYCOOLEA INCHAUSTEGUI

Basic education is administered at the national level in Mexico by the Ministry of Public Education (SEP). Within this ministry there is a General Office for Special Education in charge of the educational needs of atypical children such as the blind, those with learning problems, the mentally deficient, the hearing-impaired, and those with language problems.

In particular, the Coordination of Integrated Specific Groups for the Hearing-Impaired (GIEH) arranges programs for children who have hearing loss. Their psychological, pedagogical, and clinical characteristics are carefully studied so that they can be assigned to the most homogeneous groups possible with 10 children in kindergarten and primary school or 13 in technical secondary schools. The children attend public schools with normal-hearers using classrooms specifically designed for them. They take classes in Spanish, mathematics, social sciences, and natural sciences given by a teacher who specializes in hearing and language and who follows the SEP curriculum and programs, adapting them to the specific conditions of GIEH children. The normal school environment is used to encourage the socialization of the hearing-impaired; here they can interact with normal-hearing children in physical, artistic, technical, and school cooperative activities, and take these classes from the regular teachers, while the specialized

teacher serves as an assistant who explains to the hearing-impaired children what that they are not able to capture by lip-reading. To supplement their education, these children receive individualized language therapy according to a schedule that does not conflict with the regular class time.

Given the growing interest throughout the world in the use of computers in education, and with a view to providing hearing-impaired children with the advantages, means, and resources to utilize computers, we have undertaken a special extracurricular pilot project. This experiment seeks to give hearing-impaired children the opportunity to increase their personal development, to gradually become trained without missing out on technological advances because of their deficiency, and to become part of productive society in the future.

The experiment was initiated at the Universidad Nacional Autonoma de Mexico installation with a simultaneous course in BASIC for secondary teachers and students (in separate sessions) given by an instructor who, although experienced in computation for children, did not have any background in education of the hearing-impaired. However, since hearing-impaired children at the secondary level take most of their subjects with nonspecialized teachers, their understanding of the material (with the assistance of a specialized teacher) was similar to that of any another secondary subject. When the specialized teachers completed the course in BASIC, they were ready to try to develop simple teaching materials that, experience has shown, would awaken overall clear sensory perception in the children.

Next, thought was given to the possibility of introducing computation to hearing-impaired children (ages six to eight) in the first grade. A course in Logo was initiated simultaneously for teachers and students in separate sessions and was given at the Technological Museum of the C.F.E. with support from the Academy of Scientific Research. The group of teachers included participants from outside the GIEH who subsequently acted as assistants to the specialists in hearing and language.

It was clearly difficult for first grade children to carry out the orders given during training, since, even though they could read, they had limited knowledge of spatial relations. The teachers were forced to reduce the number of instructions and to carry out each of them step by step until they were sure that they had all been followed. The children's level of basic knowledge prevented them

from learning Logo effectively, since they did not yet know about angles, degrees, geometric figures (their names and the number of sides that they have), numbers above 50, and, in general, a number of concepts not taught until the third grade.

The teachers and assistants wrote a program, known as "The Maze," to practice instructions in Logo given in class. In it, a little turtle has to walk up to an apple and eat it, repeating the exercise until it has finished eating a total of three apples. This means that the child has to organize his thoughts so as to arrive at the goal as quickly as possible through trial and error. The Maze made it easier for the child to learn the right direction for the turtle to take. We think that is because the game has a goal, instead of having the child simply move the turtle without any objective. In addition, with this program it was more pleasant for children to learn the keyboard because, as a reward for their efforts, each time they came to an apple the machine made noises and flashed different colors, making children enthusiastic about going after the apple.

During the 1984 summer vacation, a workshop was held on the development of computerized educational materials in BASIC for teachers and assistants, and various exercises were developed in Spanish, social sciences, and mathematics. The program written for mathematics was designed to teach the basic geometric figures. Geared to first-grade children in the GIEH, it consists of the following: first, it shows the children three figures (a circle, a square, and a triangle) and asks them to name each of them. If the children recognize them, they must write the name of the figure as it is highlighted; they must write all three names correctly. If a child make three mistakes, he or she is sent to a subroutine where the names are written for each figure, and the child is permitted to copy them, before trying the test again. Once the first three figures are right, the child goes to the next level, where other figures are presented.

The program developed in the area of Spanish language is for third grade students on the subject of language structure. First, children are shown a conjugated verb and are given three alternatives from which to choose the corresponding pronoun. If they do not answer correctly, the program tells them why their choice is incorrect and gives them a second chance. If they answer correctly, they go on to the next section of the program, which involves choosing the circumstantial complement of place, and the

previous steps are repeated. Once they have answered correctly, the program writes the sentence and asks the children why this action happens. They are again given three choices as in the steps above. If the response is correct, the program congratulates the children and invites them to play with another sentence.

Finally, the program developed for the social sciences is for third grade students and aids in teaching the names of states and capitals of the Mexican Republic, and its federal entities and capitals. It gives the option of choosing between answering questions on federal entities or capitals, and the program sequence is identical in either case. First, the map of the Mexican Republic is shown, with random questions in the lower part of the screen concerning the capitals or federal entities. For learning purposes, if there are more than three wrong responses, the program highlights the capital or federal entity, giving its name and allowing the child to copy it three times, and after that returns to the previous step. Finally, once the program has performed all of its steps, a summary is given of successes and errors. Depending upon the number, the program invites the child to play again or to study the program again from the beginning.

During the 1985–86 school year, support was provided by the Arturo Rosenblith Foundation, through the Galileo Tlalpan Center, for a program in which a group of 15 students (who were also attending the center's regular secondary course) had 12 two-hour sessions on handling the following programs:

- Operating the electronic computer
- Understanding how computers work
- Using Karel the Robot
- Introduction to BASIC (this last was not completed).

In the course of utilizing these programs, some modifications were needed in the language to be used with the students, given their limitations in language abilities. Some difficulties were encountered in teaching the binary system and in converting the binary system to the decimal. The Karel program proved very complicated for our students, needed many additional sessions away from the machine, and required extra teaching material in order to be understood. For all of these reasons, it is clear that utilizing these programs with hearing-impaired children requires that explanations be given in simpler language with clearer examples in the theoretical sessions. It is also necessary to know

the skill-level of each of the students in order to begin working with the programs, and it is necessary to modify the teaching style or technique, since the students' achievements and activity will depend largely on this. Therefore, we believe that if we continue with this group, it would be desirable to have a plan of work that takes into account the characteristics, limitations, and possibilities of these young people.

During the course of this experience, the greatest limitations seemed to be the lack of human and financial resources. Even though we have been given access to equipment at UNAM and the Galileo Tlalpan Center, it has only been for very short periods that are barely enough time for the instruction of the children. As a result, the development of materials has virtually stopped. However, through this experiment, we have benefited from the interest and cooperation of persons completely outside our program of Integrated Specific Groups for the Hearing-Impaired in the General Bureau of Special Education, Ministry of Public Education, who have helped us to the extent that they were able. This provides a very great incentive for us because it has made us realize that people from outside our group have appreciated the value of our work solely for its value in assisting in the rehabilitation of hearing-impaired children.

CONCLUSIONS

I have taken the liberty of listing many of the conclusions that have been reached by the teachers in the Integrated Specific Groups for the Hearing-Impaired who have participated in this experience.

- Through computers, it has been possible to expand the horizons of new teaching aids in education that can provide a solid basis for strengthening instruction in the classroom.
- The intellectual development of a child can be channeled through logic and the use of the computer. This opens unexpected paths for people who simply need a chance to demonstrate that their deficiency lies in their hearing and not in their intelligence.
- The computer can become a great ally of the teacher, since an educational program carried out in accordance with the interests of special education can be repeated

again and again, thereby guaranteeing immediate feedback, and reinforcing the successes of the students at the right moment. If they are not successful, they proceed through corrective subroutines that can be repeated until they have achieved the objective.

- In no way is this a substitute for the specialized teacher; on the contrary, it is a valuable teaching resource.
- It has been observed that computer graphics facilitate the teaching of vocabulary, set theory, maps, perceptual visual exercises (depth perception, visual discrimination, spatial relations), series, and associations.
- The software can be written so that it does not accept spelling errors, inversions, substitutions, or omissions in the text—all common problems for hearing-impaired children. The program gives immediate corrections, and the children will become more careful in their writing.
- In interpreting the instructions given in the programs, the children can practice their reading skills.
- Because of its characteristics, the computer can provide valuable assistance in teaching mathematics.
- By means of software programmed for the drafting of texts, it is possible to strengthen the areas of Spanish, language structure, social sciences, and natural sciences.
- The time required to learn a new word or a new concept is greatly reduced, since the computer is faster than using slides, pencil and paper, or blackboard and chalk. Moreover, constant repetition of the same exercise favors the formation of habits and thus the exercise of memory and basic learning skills.
- Most children find working with computers interesting. This gives them a positive attitude toward learning.
- Use of the computer provides hearing-impaired children with an additional means of communication.
- The organization of computer programs is one more exercise in organizing the thoughts of hearing-impaired children.

- Computer education has a positive effect in overcoming the prospect of a dark occupational future for the hearing-impaired. It offers new hope for personal satisfaction, career development, and improved earning potential.

Section 6
Advanced Education

23

Experiences with Computers at ICESI

RODRIGO VARELA V.

Instituto Colombiano de Estudios Superiores de INCOLDA (ICESI) is a private university, founded by a group of businessmen who decided to join efforts with the Instituto Colombiano de Administracion (INCOLDA) in search of an institution academically strong in the areas of business and management. Its main objective is to provide students with integrated training—academic, moral, spiritual and ethical—under the political ideology of free enterprise, the democratic system, and the Colombian social, economic and legal environment. Its mission is the search for leadership, excellence, and honesty in all of its students and in their activities.

ICESI has three undergraduate programs:

- B.A. in business administration (day program)
- B.A. in business administration for people already working (evening program)
- B.S. in system engineering and informatics with a major in administration.

The ICESI graduate school offers a M.S. in business administration, with majors in marketing, industrial relations, agribusiness management, and management of information systems. This presentation focuses on the work done with undergraduate business administration students in specific areas.

PHILOSOPHY OF THE PROGRAM

In December 1982, when ICESI was a very small school with academic programs only in business, the president of the school decided to introduce microcomputers in order to modernize teaching techniques and increase the skills of ICESI students. Based on his training in education and in systems engineering, he established the following policies:

- All ICESI students should be able to use the microcomputer in their work, and ICESI should provide them the means to reach that goal. Therefore, the academic program should include training in microcomputer applications.
- ICESI professors should become acquainted with the microcomputer and gradually begin to use it as a teaching device and/or in support of the learning experience.

In April 1983, 15 NEC 8000's were purchased and the process began. In February 1984, the Systems Engineering and Informatics Program started, and 20 additional NEC 8800's were purchased. We have now decided to purchase another 25 microcomputers from IBM and Hewlett-Packard.

Software Development Schemes

At the beginning of the program the decision was made that software should be developed by and for students. We did not expect to produce high-quality software, but instead to produce software (with all its limitations), that could be developed by undergraduate students. The goal, then, was to train students in software development and application rather than to develop professional quality software. Additionally, we were looking for software that could be useful for the academic process, that would help in the solution of problems, and that would also help the students understand the procedures and the steps required to solve problems.

However, we found that in order to interest the students in learning to use the microcomputers, we needed to allow them access to high-quality software related to the course they were taking at the time, engineering economics. Thus we decided to adapt five programs on the IBM 1130 and B5900 that were directly related to the course (FAECO, MAIA, MAII, SENSE and EVAP) to be used interactively on microcomputers.

After the students learned how to use these programs, the second phase started. Each student was assigned a program that in most cases, was already commercially available. The main sources were programs that I had in my Apple II+ and programs published in *Industrial Engineering*. In some cases, students were asked to develop their own software in a defined subject area. For academic credit, the final paper of the course required each student to describe the goals and limitations of the program, present the flow diagram, and test the program under working conditions.

Usually the results of this exercise were not fully satisfactory because the students lacked prior experience not only with adapting or developing software, but even with using it. Although the students had taken a BASIC course, they did not realize the full potential of microcomputers until they became involved in the software development program.

After the first phase of development and adaptation was completed, three or four students in the course who had shown a high level of interest and ability were chosen to work on a detailed approach to a problem. They were able to continue with the next level of training and to have the opportunity to check with all their classmates about any doubts they had about the preliminary exercises. During this second phase, the professor played a larger role, providing the students with ideas about the final version. Special attention was to be directed toward a clear phrasing of commands to avoid user-errors, to the printing, to providing a general description of the procedure followed by the program, to the general information provided about the scope, and to the limitations of the program.

In the final step of the second stage, the students prepared a condensed user's manual. Finally, the programs were released to students taking the engineering economics course the following semester for their use and evaluation.

We expect that as the systems engineering and informatics students become more experienced, there will be a third stage that will be oriented toward refining the products and improving the efficiency of programming. We plan to start this third stage in about a year, after information about the difficulties found in the use of each of the programs has been collected.

Uses of the Software

The software developed has been used in two ways: as a complement to classroom activities and as a teaching device inside the classroom.

Software as a Complement

In the first case, the software is used after the student has learned to solve the problem by other means (analytically, graphically, numerically) and with other resources (mainly calculators). This procedure is used because we believe that a university educational process is more a process of formation than of information, and that learning is an educational experience that should provide several alternative ways of solving a problem and not "the" solution. In addition, we realize that not all the students will have microcomputer and software facilities in their professional lives. Furthermore, real-life problems will not permit all the simplifications and assumptions required in most existing mathematical models, and the student should have a wider vision of the problem. Finally, we believe that the software makes sense only when the student knows what the software is doing, what amount of time he or she is saving, what kind of difficulties could arise in the solution, and the complexity of the problem. Even though it may seem to be a strict attitude, we believe that students should know how to do things by themselves before turning on the machine. They should learn how to add before using a calculator, how to solve a problem before using a microcomputer.

The main advantages to the students who have learned to write and critique software have been as follows:

- The programs provide a new learning experience, increasing students' motivation and interest in the academic subject.
- The students have quickly developed an understanding of the interactions among the variables, and a disposition to attack more complex problems.
- The students have used the programs to refine their algorithmic approach to the solution of problems, because most of the programs will print the solution step by step.
- The students have better grasped the decision procedure involved in each situation, and they have been able to understand the role of the decision criteria.

- The students have been able to devote their time to analysis, interpretation of the meaning of the results, and decision making, rather than to mechanical calculations.
- They have overcome their fear of microcomputers, and many of them find this the starting point for a new skill in computer programming and use.
- Academic results have improved because the students are able to consider many problems and possible situations, and they begin to recognize that alternative procedures can be used to reach a solution.
- Many of the student users return to the school after graduation to use the student-written software, and some of them are interested in buying the software for their companies.
- All the students realize that the microcomputer is a great help to the learning process.

Software as a Teaching Device

In the second case, software is used by the professor in the classroom, mainly to show the students certain procedures and/or to show the students how to use a specific software. The main experience in this area had been in the linear programming courses, in which we bring to the classroom a microcomputer and a giant video screen to show the students how to use the software, how the simplex method works on large problems, and how to do sensitivity analyses. It should be understood that this activity is done after the basic explanation about the simplex algorithm has been given in class and after the students have worked a small simplex problem by hand.

The main advantages of this application have been the following:

- It reduces the time spent teaching the subject because all the mechanics that were traditionally written by the professor on the blackboard and were subject to mistakes and student inattention have been replaced by an innovative scheme that solves the problems quickly.
- It is possible to solve several times as many problems and to better illustrate the technique.
- It is possible to solve bigger and more complex problems. This possibility has been especially useful in the graduate courses in which the final paper relates to a real problem of

the student's company that usually has so many variables and constraints that it becomes impossible to solve without a computer.

- The professor and the students are able to dedicate their time to the analysis and interpretation of the solution and to making a decision, rather than to solving the problem, where they are subject to making time-consuming mistakes.
- Some of the concepts (such as shadow prices) and some of the procedures (for instance sensitivity analysis) can be explained and understood very easily and without resorting to mathematical jargon.
- After running the software, the students have a good understanding of the algorithmic scheme of the simplex method.

The Software Developed

The following is a very concise description of the programs we have developed in each area.

Engineering Economics—Project Evaluations

TASCO	It finds the real cost of a loan using several schemes for interest and capital payments, including the effect created by the concept of commission.
EQUIVALENCIA	It does all the calculations required to handle the time-value of money using the equivalence concept.
INTERES	It makes conversions among interest rates expressed in several ways.
PRESTAMOS	It calculates the payment schemes for a home loan under the UPAC system, using any of the five most common schemes.
ELECTRO	It finds the real cost of money for people who have to borrow because they do not have enough money to pay cash.

DEPRE	It calculates the depreciation and the book value for each period of fiscal life using any one of six methods.

In addition, we use the programs FEACE, MAIA, SENSE, and EVAP. Their instruction and scope are presented in the textbook by R. Varela, *Evaluacion Economica de Alternativas Operacionales y Proyectos de Inversion.* (Editorial Norma, fourth edition, second printing, 1985.) These last programs are available from Varela Software.

Operations Research

LINEA I	PROGRAMACION LINEAL It solves a linear programming (LP) problem using the simplex method. It allows sensitivity analysis and data modifications.
PROGL	It solves an LP problem, adjusting itself to standard form. It does sensitivity analysis but data modifications are not allowed in the same run.
PROLIN	It solves an LP problem using a data statement to feed the data.
ASIREG	It uses the Hungarian's algorithm to solve the assignation problem.

Production and Economic Analysis

PUNEQ	It calculates break-even levels for several situations including several kinds of costs.
FACTI	It determines the economic feasibility of improvements in a production line.
SEGUI	It does the follow up of financial statements of the projects studied by FACTI.
ARBOLES	It solves a decision tree including, if necessary, the time-value of money.
INFLA	It studies investments for the productive sector under inflationary conditions.

Production

INVPRO	It finds the optimum inventory policy for demand and replenishment times that follow a Poisson, normal, or exponential distribution.
MINDES	It finds the optimum purchase level under discount conditions.
INVCO	It finds the optimum policies of spare parts using Park's Algorithm.
C.O.C.	It calculates the O.C. Curves.
COFIB	It calculates reliability indices.
MEZCLA	It finds the optimum sequence of operations in an assembly line.
SECUENCIA	It finds the optimum sequence of "j" works through "n" machines using Johnson's Algorithm.
EMPA	It finds the optimum scheme to locate several boxes in a crate.
PRONOSTICOS	It does the main calculations to estimate demand based on historical data.
NEQUIP	It determines the number of pieces of equipment needed to fulfill a production requirement.

New Projects

Approximately ten additional programs are now being refined, and we expect to continue our production rate of about ten per semester. In addition, several new projects in the following subjects are planned.

- Mathematics. With the systems engineering students, we are starting a process similar to the one used in engineering economics. We expect to have about six programs of Calculus III by the end of the year.
- Production. Two professors at our institution made the decision to develop programs to help in the teaching of Production I and Production II. It will be their master's thesis and will have a larger scope than the programs already developed, covering the whole subject.

- Numerical Analysis. Next year will be the first time that this course will be taught. Work to provide our microcomputers with enough software will be started early in 1986.

CONCLUSIONS

For the academic life of ICESI, and mainly for the quantitative area and the project evaluation courses, the microcomputer software development program has been a complete success—without major conflicts, without complex bureaucracy, and extremely inexpensive.

ACKNOWLEDGMENTS

This work is mainly the result of the deep interest in learning of my ICESI students in the project evaluation courses. Thanks are due to the administration of ICESI that has allowed us to develop this program without the red tape of bureaucratic procedures.

24

Teaching General, Tropical, and Nutritional Epidemiology with Microcomputer Support

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INTRODUCTION

A statistical package has been developed at the Universidad Peruana Cayetano Heredia, based on the relational model, that includes interactive operation with graphic output, complete parametric and nonparametric coverage for uni-, bi-, and trivariate analysis, and messages in Spanish. It has special routines for computing derived variables and anthropometric indices. The initial version was written in BASIC for the Apple II. Development was entirely local.

The package has been employed since 1983 in courses on nutritional epidemiology (undergraduate medicine and nutrition, postgraduate hospital administration), tropical epidemiology, and nutritional epidemiology for medical students, interns, and residents. Students receive actual data sets together with questions about the data. Within a given time limit, they can make data processing requests. The results are prepared for public presentation. The package is also used in actual research and thesis work.

This approach allows concentration on the analysis rather than the mechanical aspects of the calculation, without losing the "feel" of real data. The use of graphics is central to the perception of relationships among the variables. Learning by practical

experience rather than passive reception seems to result in more enduring knowledge.

Teaching Epidemiology

Epidemiology deals with the interpretation of health phenomena at the population level. It is mostly based upon statistical thinking and systems analysis (Morris, 1975). It is clear that solving the complex health problems of developing countries, and indeed of any country, is a task that requires much applied epidemiology. Therefore, training in this area merits a high priority in the curricula of the health sciences.

Two issues are important in teaching epidemiology to the health professions: (1) making the topic palatable to people who find their primary interest in individual patient care or practical community work, and (2) achieving the kind of analytical thinking that makes the difference between mechanical behavior and enduring knowledge. The importance of solving these issues can be better assessed from a position of understanding of the current status of public health training in undergraduate health schools and of the way health professionals deal with public health problems in developing countries (OPS, 1984).

Our group was able to obtain an 8-bit microcomputer in 1981, when software was neither cheap nor powerful (Carpenter, 1984). Since we were faced with the practical needs of data analysis for research, we thought that the cost-effective decision lay in developing some kind of integrated statistical package that would provide a subset of mainframe packages (Dixon, 1972). Actual software development started in 1983, when the team began to assemble. At the same time, we took over the responsibility of teaching epidemiology at the medical school.

In the course of developing and applying this software to the educational situation presented in the previous paragraphs, we have had some experiences we would like to share. This, however, is not the report of a planned educational experiment or a full-scale software development project, rather it is an account of some particular experiences and our reflections on them.

DESIGN OF THE PACKAGE

Computational Aspects

Two data structures were chosen to implement the package:

- A rectangular matrix of real values: (1) representing the data in memory as a real array of cases versus variables; (2) ignoring the decimals for analysis, using them only for display purposes; and (3) assigning for each variable a missing value, to represent the absence of data.
- A relational file organization: (1) standardizing the data files as sets of fixed-length, fixed-format ASCII records (FORTRAN-like, without using delimiters); (2) defining for each data file a dictionary file describing the variables; and (3) making an entry into a catalogue file recording record length and file length. Both the dictionary files and the catalogue file have the same format as data files; they have their respective dictionaries and are recorded in the catalogue.

The algorithms to be implemented were divided into four groups:

- Data entry procedures: (1) keypunching emulation (both initial and verification pass); (2) correction of individual data items; (3) data listing; and (4) dictionary definition.
- Interactive description and analysis: (1) univariate parametric and nonparametric descriptions; (2) graphical procedures (uni- and bivariate scatter plots); (3) editing, filtering, and transgeneration; (4) bivariate analysis (linear regression, analysis of variance, two-way tabulation, and their nonparametric counterparts); and (5) analysis of three variables (multiple regression, two-way ANOVA, ANCOVA, and multiway tabulation). Standard techniques are implemented (Armitage, 1971; Sokal, 1981).
- Out-of-core analysis: currently only multiway tabulation and breakdown of means are available.
- Relational operations: currently a set of independent programs that must be tailored to perform selection of variables (vertical projection), selection of cases (horizontal selection), top-bottom merge, left-right merge, and join (Date, 1981).

The software development was organized so that modules could be developed independently and integrated using a menu skeleton supported by overlay management. Structured programming techniques were employed throughout the whole project. A consistent menu-driven user interface was provided so that the user deals only with three programs, and all the capabilities are options in those programs.

The initial implementation of the software package was made on an Apple II+ (rev 7) microcomputer with 64 KB (kilobyte) RAM, 280 KB dual $5\frac{1}{4}$ inch floppy disk storage, an ALF 8088 co-processor board, and Videx Ultraterm and Enhancer cards, using Applesoft BASIC under DOS 3.3, plus an Epson MX-100+ dot matrix printer attached through an Orange Micro-Buffered Grappler+ interface.

Educational Aspects

Various ideas for the application of the package in actual training have evolved during the training courses. Naturally, conventional microcomputer applications were used to support technical aspects of teaching: word processing for writing monographs and exercises, spreadsheets for managing students' grades, and database programs for storing references.

The way in which microcomputer support was employed can best be illustrated by the activities of the main epidemiology course in the undergraduate medical school:

- Lectures (10 hrs): one-hour lectures on the main topics of the course
- Discussions (15 hrs): one and one-half-hour group sessions about written exercises distributed in advance
- Examinations (15 hrs): Objective assessments given every week before lectures
- Study design exercise (20 hrs): Each group receives a question of practical importance for which an epidemiologic study needs to be designed
- Literature review exercise (20 hrs): Each group receives a theme, usually a disease, for which a concise summary of facts about the epidemiology and control must be prepared

- Data analysis exercise (20 hrs): Each group of five to ten students receives a data set (which is available on computer). The group has three weeks to request processing (batch mode) and to present the discussion to the class. If the class shows interest, some of the computer runs are performed.

Attendance is not compulsory, but the grades received on exercises count together with the examinations for the students' final marks. The overall objective is to promote rational thinking on the health problems at the level of human societies. Specific objectives are targeted to key epidemiological concepts, basic types of study, common sources of error, and essential elements of design (Barker, 1982; MacMahon et al., 1970).

The course is offered each year during the first term (12 weeks) to each cohort of about 80 students in the UPCH medical school. After this course, another course, also 100 hours long, is offered on the actual performance of an epidemiological study. During this activity, students are further exposed to computerized data analysis

Teaching for the special sectors of nutrition or tropical diseases follows the same outline, emphasizing the actual meaning of the information in public health terms as supported by the available evidence.

Within this educational frame, computers are seen as tools that students must be acquainted with, but they are not the focus of teaching.

RESULTS

The software developed has been used in the following courses shown in Table 24.1.

The following are examples of the more interesting topics that have been analyzed with the package:

- Comparision of Diagnostic Techniques for Strongyloidiasis in the Field (Lumbreras, Guerra, et al., 1983).
- Diseases at a University Hospital (Iturri, 1983).
- Risk Factors for Intestinal Bleeding in Typhoid Fever (Gubbins, Gutuzzo, et al., 1984).
- Evaluation of Diagnostic Techniques for Typhoid Fever in Children (Vallenas, Gutuzzo, et al., 1985).

TABLE 24.1 Computer-Aided Courses

Course	Students	Hours/ Studied	Teacher Time	Level
Epidemiological Method	80	100	400 h	4th MB
Nutritional Epidemiology	80	20	100 h	5th MB
Nutrition in Public Health	40	10	50 h	DPH
Tropical Epidemiology	80	10	100 h	4th MB
Epidemiological Studies	80	100	400 h	4th MB
Thesis Seminar	1	240	variable	6th MB and MR

DPH: Diploma in hospital administration
MB: Undergraduate medical students
MR: Medical residency training

- Nutritional Assessment of Children in San Pablo, Loreto (Tambini, 1985).
- Case-Control Study of Risk Factors for Hepatitis B among Hospital Workers (Deville, 1985).
- Case-Control Study of Risk Factors for Typhoid Fever in the Northern Area of Peru (Gotuzzo, Black, et al., 1985).
- Follow-up of Family Contacts of Typhoid Fever (Gotuzzo, Black, et al., 1985).

These examples cover approximately 10 percent of the overall data processing performed with the package. The size of the data sets varies between 20 to 130 variables and 150 to 1,200 cases.

Software was developed over an 18-month period, using approximately 1,000 programmer-hours for the production of about 64KB of BASIC code in 6,000 BASIC statements. Special tailoring of programs for particular data sets was kept to a minimum. No special purpose programs were written for individual users.

Since this program was designed as a teaching tool, numerical accuracy has not been as important as the data management problems. Nevertheless, the arithmetic errors inherent in the hardware and the BASIC interpreter required some attention when designing the algorithms (Conte and de Boore, 1980).

While programming effort was directed to general purpose software development, some degree of "baby-sitting" was necessary to help users with (1) the strategy of statistical analysis, (2) actual operation procedures that were not "friendly" enough, and

(3) handling some bugs that cropped up in actual use. These tasks consume analysts' time, reducing the cost-effectiveness of the computerized data processing.

Discussion

Was the micromputer helpful? Our answer is a qualified "yes." Advantages that have been clearly perceived are these:

- Focus on analysis and interpretation of real data, and its meaning for public health, therein combining social relevance and technical rigor
- Visual examination of data, comparing the statistical results of various approaches, and understanding the concepts of p, confidence interval, and biological significance
- Rise in teachers' productivity, allowing the same time to be used in higher quality work, creating the opportunity for a better use of qualified human resources
- Increased stimuli to students' participation, resulting from the availability of higher quality learning activities
- Learning experience with exercises that are very similar to real epidemiological analysis, rather than made-up examples
- Multidisciplinary integration through actual cooperation resulting in local development of software engineering capacity and in bridges between mathematical abstraction and health problems.

There were also some disadvantages noticed. While considerably cheaper than mainframes, microcomputers are still expensive. In addition, they produce an uncomfortable dependence on foreign technology and private funding. The risk of misuse is present, particularly the waste of computer-time in analyzing useless data. Special care has to be taken since mistakes can often yield spectacular results with computer technology. Users must also keep clearly in mind that programming is neither a necessary requirement for teaching nor a straightforward activity.

Prospects for the future

Microcomputer use is growing. The collection of real data sets available on magnetic media has to be increased, and data entry techniques have to be improved. The use of powerful spreadsheets

and commercial statistical packages in training should be considered, since they are now more easily available. (Carpenter, 1984; Dean, 1985).

Our efforts in software development will not cease. The design ideas developed for the package are being used as the kernel of large health information systems. This work will be developed in Pascal under MSDOS. The design ideas are also being used to tailor specific data handling applications. The role of simulators has to be explored, as well as the increasing amount of "intelligence" built into the systems.

The training of teachers on computing tools has to be reinforced. At present, teachers are not able to complete their university education without knowing how to use word processors, spreadsheets, relational database systems, and statistical packages.

SOME REFLECTIONS ON COMPUTERS, TEACHING, AND DEVELOPING COUNTRIES

Computers are part of the development process. They have a large potential, but there are also risks, particularly of increasing dependence on developed countries and of creating inequity in a society. One important lesson that can be learned is in the orientation toward general solutions. Independent sets of programs with customized data entry and file management represent a considerable development burden in exchange for only minor gains in efficiency when compared with general purpose packages. The search for general structures also forces understanding of the problem. Epidemiology is an area where general solutions can be developed and taught.

However complex, the key impact of microcomputers seems to be in the way they allow us to think when we use them. This effect is not inherent in their use. The concept of significance and the importance of relevance can be learned better if one is freed from mechanical tasks, but they still need to be actively learned.

Computers, especially small ones, have limitations, so priorities need to be considered when their use is being planned, both in education and in research. The tendency to overload studies just because the computer will take care of the extra work is not

warranted. Learning how best to teach (and learn) these concepts seems to require the fertile terrain of multidisciplinary work targeted toward relevant objectives.

The trend that goes from the ancient core dumps to the graphics and the actual calculation of the p values has to be extended to achieve knowledge level output. Attention must be paid, however, to a possible exaggeration of the black box concept. Users must understand the relation between input and output, otherwise they are just operating the machine while someone else thinks and reaps the benefits of knowledge. Understanding is best derived from making a tool rather than from simply owning it.

Human resources capable of optimal use of microcomputers are scarce. Therefore, the multiplicative role of those who acquire the knowledge has to be emphasized. Early identification of the students who pick up the statistical concepts and their relationship with decision making in health will allow a more effective concentration of teachers' time, as those students will in turn help others. Learning epidemiological concepts is an active process. Teachers are to provide exercises and very little steering.

Finally, a few words need to be said about a method for assessing microcomputer projects. Comparative trials could be designed for measuring gains in knowledge or in faster acquisition of some skills when microcomputers have been used to support training. The data from these studies could indeed be analyzed with computers and tested for significance. The resulting conclusions are unlikely to be useful. Society has already been taken over by computers and our universities are following the path. There is a place for careful, scientific evaluation of the experience, but technicians must be careful not to misuse techniques.

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Training in Knowledge Engineering for Medical Practice

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Largely because of ineffective mass education developing countries produce a pseudo-expert physician: a professional stuffed with an undigested feast of unrelated facts and who has almost entirely forgotten basic medical knowledge. This paper offers a "postmortem" solution to this pseudo-expert production.

The Two Kinds of Medical Knowledge

The nature of medical knowledge includes case-specific (correlative) and deep (theoretical) information; the professional needs to blend them in his practice. At first, medical knowledge is taught in medical schools as organized knowledge with a nearly scientific structure: laws, models, deductions, and experimental support are taught. This kind of knowledge is classified as "deep" in the field of artificial intelligence (AI) (Koton, 1985).

Thereafter, when the student enters a hospital, the training switches to a massive input of correlative knowledge, largely unwritten, almost unconnected with the "theory of medicine." This knowledge is "abductive" (Pople, 1973) in nature and oriented to problem-solving by the use of "rule-of-thumb" decisions. The student thereby becomes a correlational expert (a "surface knowledge" expert, in AI terms). This expertise is not without value

because it can be used to solve a certain percentage of cases; however, it has no means of questioning the already acquired correlations, is unable to find new, meaningful correlations, and is handicapped in the capacity to transform rule-of-thumb decisions into strategies to deal with contingencies. We call this kind of expertise "pseudo-expertise."

A RESTATEMENT OF THE PROBLEM

What we would like to do is to transform this pseudo-expertise into expertise. The real aim is to "engineer" the already existing knowledge into a blend of theoretical and correlational knowledge. This knowledge engineering should ideally take place in the pseudo-expert's mind, without the need for a human tutor, since one is generally not available.

The Use of Microcomputers to Implement the Solution

The restatement of the problem implies the use of expert systems for this retraining, with emphasis placed on the personal use of the computer for auto-revision of the trainee's personal knowledge.

A First Strategy

The problem of implementing this training is mainly microsociological. Any attempt faces resistance from the medical establishment. In this sense, as with any other attempt of this nature, it is subversive. Our solution to this resistance was to offer a course on awareness of the nature of the knowledge to be engineered for those physicians who were sufficiently interested to pay for the course.

Specification of the "Poetic" Nature of the Training

The awareness course is one in which the nature of the program is explained at the instructional level in BASIC and at the "information-flow" level in LISP. The physician is expected to change some parts of the programs, but is not expected to program (this is the so-called programming for poets). The core of the awareness is not programming; it focuses on the nature of the knowledge involved. It deals with the distinction between

TABLE 25.1 Outline of the Awareness Course

Session	Pedagogical Perspective	Medical Knowledge Correlation vs. Theory	Problem Solving Algorithmic vs. Heuristic	Math and Computation Background
1	The computer as an organism	Theory	Algorithm	Computer literacy
2	Health care decisions under risk	Correlations	Algorithm	Hill-climbing
3	Therapy decisions under uncertainty	Correlations	Algorithm	Math expectancy
4 & 5	Diagnosis as an epidemiological problem	Correlations	Algorithm	Bayes' theorem
6	Training in deduction	Theory	Algorithm	Biophysical models
7	Training in backward reasoning	Correlations and theory	Algorithm	Biophysical models plus rules for translation of variables into symptoms
8	Training in clinical backward reasoning	Correlations and theory	Algorithm	Rules of translation of etiological "hints," and variables into parameters
9	Qualitative biophysical reasoning	Theory	Heuristic	Artificial intelligence; Qualitative physics
10	Polishing correlative medical knowledge	Correlations	Heuristic	Production rules for expert systems
11	Training in pattern recognition of diseases and medical strategies of interviewing	Correlations	Heuristic	Artificial intelligence; Patient simulation
12	Training in medical decision making	Correlations	Algorithm	Decision theory

correlative and theoretical medical knowledge and algorithmic as opposed to heuristic problem-solving. It also involves the distinctions between the pedagogical perspectives that the different systems offer.

Organization of the Awareness Course

Table 25.1 describes an awareness course already given consisting of 12 two-hour, hands-on sessions.

Second strategy

> It is essential that the curriculum of the first two years be planned so that students know enough pathophysiology to learn clinical skills efficiently. . . . Logical clinical reasoning should be an explicit high priority goal of the medical curriculum with more emphasis prior to clerkships on the logic of clinical diagnosis . . . and to use computer-based exercises that explain the logic of diagnosis.

> . . . Students should learn principles of probabilistic reasoning as applied to medicine and should understand how decision analysis can contribute to patient care. . . . [they] must have adequate access to costs, risks and benefits of procedures. . . . [I]ntroductory clinical experiences should be coordinated with basic science courses (Sox et al., 1984).

These are some of the recommendations of the subgroup report on clinical skills for the "Physicians of the Twenty-First Century," submitted to the Association of Medical Colleges on the question of the future of medical education in the United States. They could, however, be well taken as the theme of this paper if the new goal in medical training were added to our operational commitment. Our awareness course is a concrete example of these new trends.

In order for a student to pass from a state of awareness to the effective training required, it is necessary to offer in our medical schools a parallel training option by expanding every session of the awareness course into an open-ended training program. What we have in mind is a drop-in, twenty-four-hour-a-day "micros hall" for every school of medicine. The hall should be equipped with organized tutorial software for every semester. Random access tape recorders, voice and noise synthesizers, and video disks should be driven by the resident software. Among the software packages available should be expert systems on different subjects.

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Section 7
Future Developments

26

The Contribution of Machine Translation: Present Status and Future Perspectives

MURIEL VASCONCELLOS

THE BROAD PERSPECTIVE

The reality of the translation of natural language by computer opens up new perspectives for the exchange of knowledge among cultures. The costly overhead associated with human translation—in terms of both economics and time delays—can now be greatly reduced thanks to recent advances in machine translation (MT). Rough, or "raw," output for purposes of information only is already available at dramatic savings, and polished translations are produced in as little as one-third or even one-quarter the time it takes to complete a human translation at approximately half the expense. These savings create the very real possibility of equal accelerations in the transfer of information: for the same amount of money, volumes can be doubled, trebled, or quadrupled while delivery speeds improve in the same proportions. Machine translation, because of its increased flexibility, is already being used for the processing of information that was not being translated previously. It is not an exaggeration to say that wherever there is a need for the transfer of knowledge between cultures with different languages, there is a potential application for this new and powerful technology.

Microcomputers, to some degree, are already extending the reach of MT, bringing it within the capabilities of the small investor and even of the single individual working independently. The microcomputer is used both as a word processor for text that is being translated on a larger computer and as the host itself of the MT system. The low cost and ready accessibility of the microcomputer, combined with the savings to be effected through the use of machine translation, hold promise for quantum increases in communication across language barriers.

The Present Status of Machine Translation

The concept of machine translation actually dates back more than half a century (Zarechnak, 1979). Two fairly detailed processes were proposed simultaneously in France and the Soviet Union in 1933, but they were far ahead of the technology of the time. For the two decades following the invention of the digital computer in 1946, scientists tried a multitude of approaches in their search to automate the principles of translation, while suggesting that computers would soon be capable of translation without any need for human intervention. The linguistic assumptions that fueled this effort have since been proven to be somewhat simplistic. As research progressed, the real complexity of language became more apparent; the problem was that at that time linguistic formulations, programming techniques, and computers were not yet equal to the task. Still, the need and the interest remained, and isolated initiatives, including commercial ones, continued to be pursued.

Improvements in programming techniques were gradually matched by increased knowledge of the syntactic and semantic rules that are involved in the analysis of natural language. By the 1970s, computers had acquired the speed and efficiency that made it possible to handle the enormous and deeply coded dictionaries that are needed for machine translation. Miniaturization in turn, brought personalization and made it possible for the linguist to be his own programmer. Word processing provided the routine availability of text in machine-readable form.

The advent of word processing was a watershed for production machine translation. Not only did it facilitate input, it provided the translator with an efficient tool for postediting. The importance of having fully automatic high-quality (FAHQ) output was

no longer as great, and the translator was now incorporated into the process. By 1980, systems were in place at a number of sites around the world. In 1983, Ian Piggott reported at the annual Aslib meeting in London that 400,000 pages had been run in production environments over the preceeding 12 months (Piggott, 1985:98), corresponding to the output of approximately 230 full-time translators working in the traditional mode. Four systems (ALPS, Logos, Weidner, and Smart) were by then available in bureau service, and one of these, Weidner, was being offered on microcomputers. Logos was on the Wang OIA/140. Since then, a new system, Textus, has been developed by the inventor of Systran, and is available on an IBM PC.

THE EXPERIENCE OF SPANAM AND ENGSPAN*

Milestones

The Pan American Health Organization (PAHO), regional office for the Americas of the World Health Organization (WHO), entered the machine translation picture in 1976, just at the threshold of the linguistics and technological advances that were to make MT a more feasible concept. Since that date, PAHO has developed two in-house mainframe systems using its own resources. The first system to be undertaken was SPANAM, which has been translating from Spanish into English since early 1980 (sample output is shown in Figure 26.1). ENGSPAN, which tranlates from English into Spanish, was developed with partial support from the U.S. Agency for International Development (AID) and became operational in 1984. (Sample output is shown in Figure 26.2.)

SPANAM began to provide machine translation to internal users at PAHO in 1980, shortly after a network of Wang word processors was introduced at its headquarters in Washington, D.C. Since that time, word processing documents, usually produced in the secretariat for other purposes, have been submitted from the Wang to the IBM mainframe, where the translation algorithm is run against the system's large dictionaries, which are stored on permanently mounted disks. After the translation program has

*SPANAM and ENGSPAN are trademarks of the Pan American Health Organization.

LA ESTRATEGIA DEL ILRAD

Las dos enfermedades mencionadas son causadas por parásitos que son transmitidos por insectos. La mosca tsetsé transmite los tripanosomas y la teileriosis es transmitida por las garrapatas. En ambos casos las relaciones entre parásitos, huéspedes y vectores son complejas y sutiles, y por tanto la intervención es difícil. Además, en ambos casos, otros animales salvajes y domésticos sirven también como huéspedes de los parásitos, creando así reservas de infección prácticamente inaccesibles a las medidas de control.

THE STRATEGY OF ILRAD

The two diseases mentioned are caused by parasites that are transmitted by insects. The tsetse fly transmits the trypanosomes and theileriosis is transmitted by the ticks. In both cases the relations between parasites, hosts and vectors are complex and subtle, and accordingly the intervention is difficult. In addition, in both cases, other wild and domestic animals serve as well as hosts of the parasites, creating thus reservoirs of infection practically inaccessible to the measures of control.

FIGURE 26.1 Sample translation by SPANAM.

Among the 20 known virus diseases of the potato, the two OK
that significantly affect production- potato virus Y and
potato leaf roll virus -have received the most attention at
CIP. Good resistance to virtually all major viruses is now NO
available and in the process of incorporation into national
breeding populations.

CIP researchers are also screening germplasm for OK
resistance to the insect vectors that transmit viral
diseases. The principal vectors are the green peach aphid OK
and the potato aphid; others include leafhoppers, leaf OK
miners, potato tuberworm moths, and weevils. On certain OK TU
hybrid potato plants, CIP researchers have noted glandular
foliar hairs with sticky tips that trap insects -mainly
aphids, but also flea beetles and mites- reducing epidemic
infestations.

Entre las 20 enfermedades conocidas víricas de la papa,
los dos que significativamente afectan la producción- virus
Y de papa y virus de enrollamiento de la hoja -han recibido
la mayoría de atención en el CIP. La resistencia buena
a virtualmente todos virus principales es ahora disponible
y en el proceso de incorporación en poblaciones nacionales
de mejoramiento.

Los investigadores del CIP también están examinando el
germoplasma para resistencia a los insectos vectores que
transmiten enfermedades víricas. Los vectores principales
son el áfido verde del durazno y el áfido de papa; los
otros incluyen saltarillas, minadores de hojas, polillas de
papa, y gorgojos. En ciertas plantas de papa híbrida,
investigadores del CIP han notado pelos foliculares
glandulares con puntas pegajosas que atrapan insectos-
principalmente áfidos, pero también pulgillas y ácaros -
reduciendo infestaciones epidémicas.

FIGURE 26.2 Sample translation by ENGSPAN.

run, the resulting document is returned to the Wang for postediting on the word processing screen (Figure 26.3). SPANAM has always been what Lawson (1982) would call a "try-anything" type of system: the vocabulary and syntax of the input are entirely free, and the text is not pre-edited at any point. As of the end of September 1985, it had produced a total of 2.5 million words (about 8,500 pages) for more than 90 requesting units under some 830 separate work orders. The service is provided to offices and programs not only at the headquarters in Washington but also in the field and to WHO in Geneva.

ENGPSAN, the counterpart system, became fully operational in August 1985. It operates in the same mode and has already produced more than a half-million words of Spanish text, most of it for publication. It is linguistically more sophisticated than SPANAM in a number of respects: its English analysis uses an augmented transition network (ATN) to parse the entire sentence based on 175 types of syntactic and semantic information; idiomatic expressions are highly context-sensitive; and special rules for Spanish, based on an additional 101 criteria, operate at the synthesis stage to generate structures that do not exist in English—for example, certain uses of the subjunctive.

Over the next year, the plan is to provide SPANAM with a parser for Spanish similar to ENGSPAN's parser for English, as well as with many of the other features that have been developed for the newer system over the last two years.

Cost Effectiveness

Even though SPANAM is slated to undergo improvement, its practical efficiency has already been demonstrated repeatedly. One of its early applications, carried out over two months starting in January 1981, showed how much money could be saved. The task called for the translation of 101,296 words of Spanish-language contributions to PAHO's large biennial budget document, which by regulation must be published in both languages. This was felt to be a particularly appropriate application since much of the retyping and proofreading that have traditionally been involved could be reduced or eliminated with MT. Also, the transfer of numerics would be guaranteed to be accurate. The results exceeded expectations.

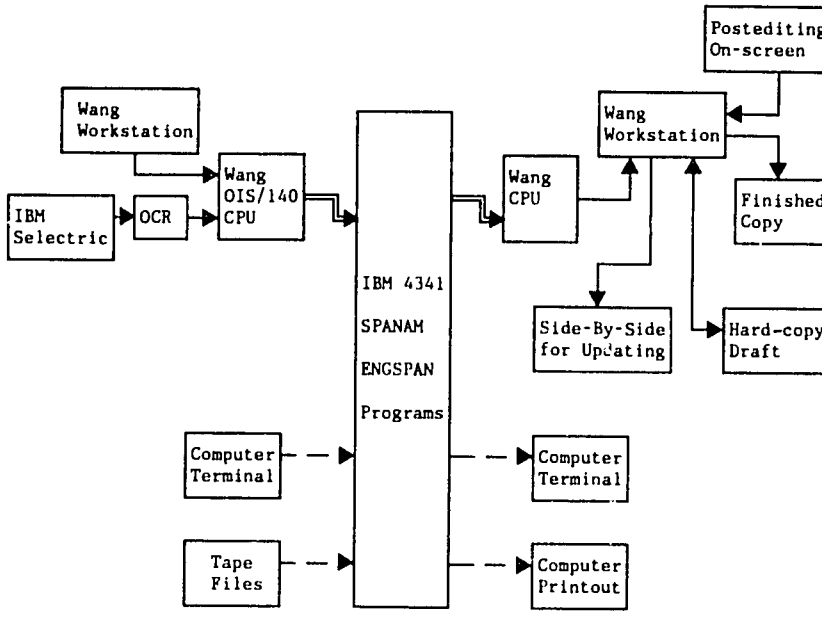

FIGURE 26.3 The PAHO Machine Translation System, 1980.

It turned out that SPANAM cost 61 percent less than contract translation for the same number of words at the then prevailing rate of $55 per thousand words (Table 26.1). There was a monetary savings of $5,078.48. In terms of time, a job that would traditionally have taken 66 days was accomplished in 36, for a savings of 45 percent. This calculation takes into account all factors of overhead for both modes, including a hypothetical cost for machine time, for which in fact there is no charge at PAHO.

The effectiveness of SPANAM, and now ENGSPAN, can also be measured in terms of daily output per posteditor. The overall figure for both systems averages between 6,000 and 6,500 words in an eight-hour day. On one occasion, it was possible to postedit 11,376 words of SPANAM output in eight hours. It should be kept in mind that this is finished, machine-readable text that does not have to be recopied. These figures compare with the traditional standard in the United Nations agencies of 2,000 words a day per translator, to which must be added the cost of transcription. At the latter rates, translation would remain a luxury for the elite.

TABLE 26.1 Example of Cost Savings with SPANAM

	Amount in US $	Staff-days
TRADITIONAL PROCEDURES: Contract translation at $55 per 1000 words; Processing; Cross-checking; Keying of translation; Proofreading, adjustments:	$8,296.18	65.75
SPANAM: Postediting of 101,296 words; Supervision; Submission, Retrieval, formatting of text; Proofreading, adjustments; Machine-time:*	$3,217.70	36.25
SAVINGS ACHIEVED:	$5,078.48	29.50

*A hypothetical figure, since PAHO does not have a job accounting system for charging the use of the computer.

It has been our experience that the contract translators, who earn twice as much at human translation as at postediting MT, will in most cases prefer to do a machine translation. Since the contractors have the option of going either route, and since it is in their interest to make as much money as they can, it must be assumed that at the very minimum they are able to work at least twice as fast using the machine output. They have also commented that they prefer to use machine translation because they feel more rested at the end of the day.

The Working Environment

The posteditors of SPANAM and ENGSPAN are also responsible for enhancing the system dictionaries. They are trained in applying the codes that are required in order to activate appropriate decisions by the parser and to trigger special, context-sensitive equivalents in the target. As they postedit, they follow a side-by-side printout that shows the source language on the left, the target on the right, and a series of diagnostic flags that appear in the center column between the two texts. These flags will indicate, among other things, words that were not found in the source dictionary, sentences that are longer than 70 words, and, in the

case of ENGSPAN, the status of the English analysis. The last will show whether there was a complete parse, a partial parse, or no parse—in which case there will still be a translation, but it will be based on only a phrase-by-phrase analysis rather than on the actions taken by the ATN parser. The output will also have an indication of translational equivalents that are found in the specialized microglossaries and of terms that appear in PAHO's own database of standardized terms (WHOTERM), or of terms that carry a high rating for "reliability."

All this information demonstrates to the translators ways in which the glosses and the coding in the dictionaries can be improved. As they work along at the screen, they use the hard copy to mark all the changes that they will be making in the dictionaries later. The benefit of working in this way is that all the contextual cues are fresh in the translator's mind at the moment the notes are made. This saves much time later on in deciding how the entries should be coded. The translator also jots down problems related to the translation algorithm itself, and these are communicated to the computational linguists, who are usually able to correct them promptly.

As of September 1985, the SPANAM dictionary had a total of 61,252 source entries (94 percent base forms, 6 percent full forms), and ENGSPAN had 45,185. The relatively large size of these dictionaries means that more than 99 percent of the words from a randomly selected text in any of our health-related fields will find a match (about 99.85 percent for SPANAM and 99.53 percent for ENGSPAN). Under these circumstances, all the analysis and synthesis that the system is capable of will be performed. Smaller dictionaries would give many more "not-found" words, and this would mean that the analysis could easily break down.

Our experience has shown that the combination of production, terminology retrieval, dictionary and program maintenance, and advanced development makes for a highly effective environment in which each function supports—and actually potentiates—the others.

FUTURE PROSPECTS FOR SPANAM AND ENGSPAN

The future of machine translation at PAHO is unfolding in three major directions: (1) the porting of ENGSPAN, and eventually SPANAM, to other mainframe sites, especially where it can serve the community of Third World nations; (2) the development of additional language pairs; and (3) the adaptation of the different systems to the microcomputer environment.

The mainframe version is soon to begin operation on the computers of the U.S. Agency for International Development, where it will process texts that are submitted either at headquarters in Washington or, via telecommunication, from field offices around the world. Similarly, field offices of PAHO, and perhaps national ministries of health, will soon be linked in a network through which the MT systems can be used. At a later date, it will be important to locate ENGSPAN and SPANAM at computer centers that serve the sister organizations of the United Nations system. And finally, serious inquiries are already being received from other areas of the public sector and from the private sector, where there is also interest in obtaining these systems.

For additional language pairs, the first priority is English into Portuguese, an official language of PAHO. With the English analysis and Spanish synthesis that have been developed for ENGSPAN, we already have about three-fourths of the system in place, and ENGPORT, as we now call it, could become a reality, with only a small investment, in less than 18 months. Another combination that would be relatively easy to develop is English into Haitian Creole. WHO is committed to publishing more information in vernacular languages. The application of MT to such an effort could help to boost both literacy and employment among people whose mother tongue does not have a strong written tradition.

The third direction that lies ahead is adaptation to a microcomputer. Some of the factors involved in this step are discussed in the next section.

Machine Translation and Microcomputers

It is certainly inevitable that machine translation will migrate increasingly to the microcomputer environment. Already, the micromputer is a word processor at both the input and the

output end of MT. To some extent, it also provides access to lexical databases, both the translator's own and large ones for which the microcomputer can serve as an on-line terminal. The latter technology—being exploited for example with SUSANNAH, a microcomputer environment that has been developed for translators by the University of Saarbrucken—is bound to be maximized as telecommunication networking expands and as windowing technology becomes more widely available.

What is of interest now is the microcomputer as host to the MT system itself. All the major commercial vendors are moving in this direction, and one of them, Weidner, has had a microcomputer product on the market since late 1983. From the beginning, Weidner ran on a minicomputer, and Logos has been running on a minicomputer and a Wang OIS/140 for nearly two years. Another minicomputer product is METAL, developed at the University of Texas and launched by Siemans in 1984. Textus, the only system so far to make its initial debut on a microcomputer, has been on the market for a short time.

There is no doubt that it is now technically feasible to port a major MT system to a microcomputer. However, there are limitations. The processing of translation is slower by several orders of magnitude. Certain complex operations may have to be sacrificed. For example, Textus does not have the powerful routines for the handling of idioms that are characteristic of its mainframe predecessor, Systran. Parsing, depending on the technology used, may take up large amounts of CPU and slow down a system considerably. In order to fit within the strict confines of space allowed, the programs may have to employ extensive overlays. Another consideration is that the programming languages which offer the best utilization of microcomputer capabilities—for example "C"—are not the ones used originally to write the mainframe versions. In the case of PL/1, the language in which SPANAM and ENGSPAN are written, the compiler for the microcomputer has dispensed with some of the functions that are heavily used in our systems. Workarounds are possible, but in the long run it may be better eventually to rewrite the code to maximize the features offered by a language specifically geared to the microcomputer.

As far as the dictionaries are concerned, the latest hard and not-so-hard disks are now capable of providing up to about 30 MB of on-line access. This space is barely adequate for dictionaries such as ENGSPAN's with 40,000 entries or more, and a dictionary

that is much smaller will limit the overall power of any MT system. The disk must be of a medium that is easily updatable. It is possible—indeed more than likely—that disk capacity will increase substantially in the very near future. The main problem is to find a fast and efficient way to perform the dictionary lookup, which with ENGSPAN may occur as many as five times for a single word.

If a microcomputer is being used for production, it cannot be used at the same time for postediting. Thus, if any degree of intensive production is envisioned, it may be necessary to choose between running the jobs at night or having one unit devoted solely to the translation program itself. In either case, it may be desirable to have several additional units networked for purposes of postediting.

On the positive side, the microcomputer is excellent for user-friendly on-line updating of the MT dictionaries. Weidner has devised interactive facilities for a microcomputer, and Logos has a sophisticated on-line program that runs on a minicomputer. Atamiri, a new system yet to be fully developed, is programmed to update dictionaries interactively in several languages at the same time.

The foregoing considerations all seem insignificant, however, they become extremely relevant when they are weighed against the heretofore undreamed-of advantage of having a microcomputer MT system available at a minute fraction of mainframe cost for use in small operations or by single individuals.

CONCLUSION

There is no doubt that machine translation has a major contribution to make in bridging the isolation gap between cultures with different languages. In the Americas, for example, there is need to greatly accelerate the exchange of experience between the countries that speak Spanish and Portuguese, on the one hand, and those that speak English, especially in the Caribbean. Throughout the world there is knowledge to be exchanged, and this exchange has been held back by the slowness and high cost of traditional human translation.

In the time that it takes for word processing to become the universal mode for the capture of human language, machine translation systems will become even more clever than they are today.

We will truly see the dissolving of language barriers and the worldwide exchange of information that has been the dream of so many.

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27

Microcomputer Simulation: Economies in Curricula Choice

ANITA NAZARETH

INTRODUCTION

The Economies in Curricula Choice (ECC) model is available in two forms and is designed to serve two functions: (1) as a tool for illustration to demonstrate the relative cost implications of each subject in a set curriculum; and (2) as a simulation model that requires specific data concerning a curriculum of the user's choice (Heyneman, 1985). Four examples of the EEC model's use for finding relative costs are available. Appendix 27.1 shows the data generated by EEC for Malaysia.

The objectives of the ECC model are both political and pedagogical. The political aim is to generate a new attitude toward curriculum choices among decision makers in developing countries. That is, the atmosphere currently surrounding this issue is tense. Developing countries understandably feel defensive when choosing what they want their children to learn, and they are rightfully suspicious of the efforts of development assistance agencies to have them economize. External efforts in this regard are often interpreted as ethnocentric, as though development assistance agencies might have an ulterior motive of perpetuating inferior education. The political objective of this project is to allow officials from developing countries to visualize the sacrifices being made within their own education systems as a result of curriculum breadth.

It will allow them to see, through the use of graphics, the order of magnitude of these sacrifices. Through the judicious use of these computer-aided illustrations, officials from developing countries might, for the first time, be expected to raise the issue of curriculum costs at home.

The pedagogical objective is to test the possiblity of using computers as a tool for illustration. At present, the Economic Development Institute (EDI) is assessing the circumstances under which computer-aided instruction is optimal. The most common use of computers in EDI training is to facilitate analysis—cost models, planning models, and decision models. EDI uses illustration as opposed to analysis in its teaching, along with slide-tape units, the common overhead projector, or simply written material.

The model is currently set up on Lotus 1-2-3 for use on the IBM 3270, a microcomputer commonly in use throughout EDI. The next stage is to develop the same model with its series of graphic illustrations on "Jazz," an integrated package now available for use on the MacIntosh.

The analysis of the differences in using these two microcomputer models is critical. This is because the instructions for utilizing a MacIntosh are basically visual. If this is truly the case, then officials unfamiliar with microcomputer use should be able to manipulate variables in the model utilizing visual instructions more quickly than if they were using the IBM coded instructions. At some point, we would like to test and analyze the potential difference by actually measuring the response effect of Lotus and Jazz with the same target group.

USES OF THE ECC MODEL

The model allows the user to study various alternative scenarios created on the basis of a set curriculum. It provides a means to visualize or analyze the curriculum's cost, piece by piece—the annual per student cost for each subject and for each unit period of a subject; the excess or cost wastages due to employing specialized teachers versus teacher equivalents; and, for the more ambitious, the marginal costs of increasing the number of periods offered per week for each subject.

The key concept on which this model is based is relative cost. Actual cost data are difficult to obtain and, if not treated with

caution they can be misleading. They are difficult to obtain because of the "traditions" of educational architecture that build programs by levels of education and by size of student cohorts rather than by subject matter. Since subjects are not traditionally considered substitutable, subject costs are rarely identifiable. The data used for these illustrative purposes had to be located by subject specialists from long and undifferentiated lists of equipment. It is hoped that the concept of relative costs will give the planner better leverage for comparison among different categories of subjects, e.g., academic non-science, science, vocational, and extra-curricular subjects.

Relative cost data obtained in this manner could be used in evaluating the entire program and justifying expenditure. However, such information must be coupled with information regarding program objectives and program output. Attainment of objectives and consistency of that output with student and manpower needs are other factors that must be considered (Thomas, 1975).

POSSIBLE USERS

National Curriculum Planners

Imagine that a policy is suggested to "diversify" the curriculum in order (among other reasons) to meet the need to produce graduates with certain skills. The ECC model can help planners study various combinations and see overall implications with respect to capital and recurrent costs.

Questions one can analyze include:

- What if we increase the number of science or technical workshop subjects?
- What if we reduce the proportion of laboratory sessions within the science subjects?
- What if we include some extra-curricular activities such as music, art, and physical education?
- What if we emphasize language subjects?
- What if we include more teaching periods on civics and good citizenship?

How would each of these alternatives affect costs and hence, how would each affect the national education budget allocation for a school offering such a curriculum?

School Architects

Even when the subject matter in a curriculum is fixed, the model enables the user to study variations in costs based on different utilization options. Questions that can be asked include:

- How many classrooms, laboratories, and special rooms are needed to run the program optimally?
- How many more class periods can be conducted in each facility to increase its use and minimize downtime?
- How would per-subject costs vary if some facilities were shared among subjects?
- What is the optimal school population needed to justify the proposed curriculum?

Teacher Trainers

In the section of the ECC model entitled "Teachers," the teacher equivalents needed to conduct each subject are calculated based on the weekly teaching loads.* If the curriculum selected is a national curriculum for, as an example, secondary comprehensive schools, then graduates of teacher training colleges could be trained to teach optimal combinations of subjects instead of specializing in only one. This obviously could reduce recurrent costs and potentially alleviate the specialized-subject teacher shortage common in developing countries.

School Administrators

From the cost information derived from the ECC model, administrators would be able to more clearly differentiate items on school budgets, including salary and nonsalary expenses. For example, the model could provide information about the economic implications of:

- Employing teachers who can teach subject combinations instead of employing subject specialists
- Cutting down on the use of consumable materials

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* Teacher "equivalents" mean teachers in the statistical sense where teachers are quantified in fractions, 1/10 of a teacher, 1/3 of a teacher, and so on.

- Delaying the replacement of deteriorated furniture and equipment.

World Bank Staff

At the pre-appraisal stage of a project, education project officers can use the ECC model to run alternative scenarios. They can study costs relative to school size (enrollment); facilities required; construction, furniture and equipment for each facility; teacher salaries; and non-teacher recurrent costs. From these figures the number of schools that can be built with a fixed budget can be calculated or total costs can be computed if the number of schools required is predetermined.

CONCLUSION

The ECC model can be used by various levels of personnel in the planning hierarchy, depending on the type of available information and data and on the user's ability to operate Lotus 1-2-3 package. The model has a customized menu that may allow users who are not familiar with Lotus to utilize various sections and enter or change data in "non-protected" cells. However, whether it can be taught to non-Lotus users is as yet untested, and we suspect that many pedagogical problems remain.

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Thomas, Ruth G. A Method for Recording-Keeping and Analysis of Equipment and Related Costs by Educational Program. University of Minnesota, St. Paul, July. 1975, p. 10 (unpublished paper).

APPENDIX 27.1
CASE STUDY OF RELATIVE COST IMPLICATION OF A CURRICULUM (MALAYSIA)

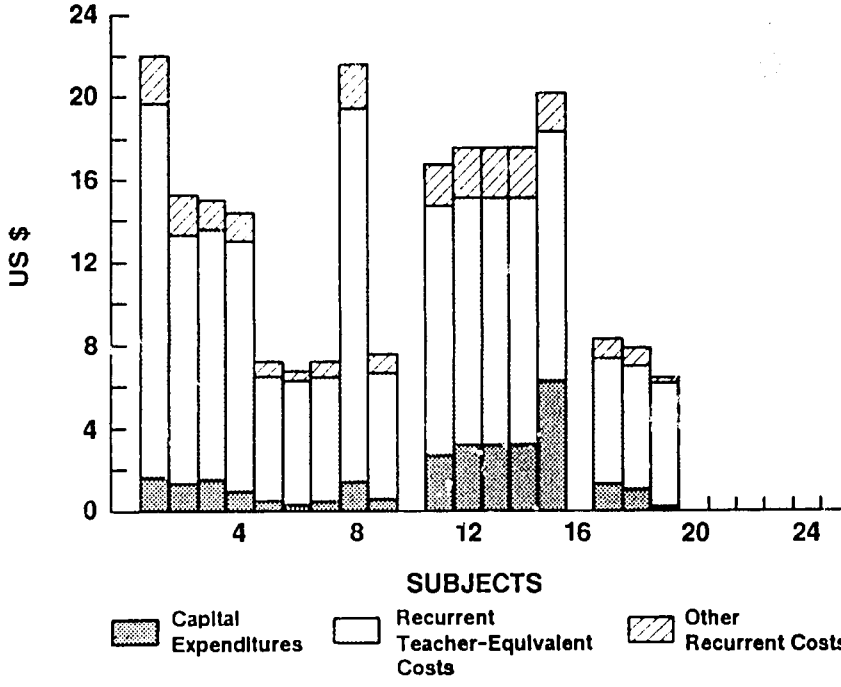
TABLE 1 Minimum Recurrent Costs

NOTE: IN THIS SECTION WE USE TEACHER EQUIVALENTS INSTEAD OF ACTUAL NO. OF TEACHERS FOR RECURRENT TEACHER COSTS.

	COSTS/STUDENT/SUBJECT/YEAR (M$)								/PER'OD (M$)					
(P=B/STU) Teacher/ Student	(Q=E) Annual Teacher Salary	(F=P*Q) Teacher-Cost/ Student	(S=I+A) Other Costs/ Student	(T=R+S) Total Recurr. Cost	(U=I) Capital Cost/ Subject	(V=T+U) Capital+ Recurr. Cost/Subj	(W=P/A) Teacher-Cost/ Student	(I=L) Other Costs/ Student	(Y=W+I) Tot.l Recc. Cost	(Z=N) Capital Cost	(A'=Y+Z) Capital + Pecc. Cost		SUBJECTS
0.0039	3840	15.00	2.40	17.40	1.65	19.05	0.19	0.03	0.22	0.02	0.24	1	BAHASA MALAYSIA
0.0031	3840	12.00	1.92	13.92	1.32	15.24	0.19	0.03	0.22	0.02	0.24	2	ENGLISH
0.0023	3840	9.00	1.44	10.44	1.56	12.00	0.19	0.03	0.22	0.03	0.25	3	RELIGIOUS STUDIES
0.0023	3840	9.00	1.44	10.44	0.99	11.43	0.19	0.03	0.22	0.02	0.24	4	GEOGRAPHY/SOCIAL SC
0.0012	3840	4.50	0.72	5.22	0.49	5.71	0.19	0.03	0.22	0.02	0.24	5	HISTORY
0.0008	3840	3.00	0.48	3.48	0.33	3.81	0.19	0.03	0.22	0.02	0.24	6	CIVICS
0.0012	3840	4.50	0.72	5.22	0.49	5.71	0.19	0.03	0.22	0.02	0.24	7	LITERATURE
0.0035	3840	13.50	2.16	15.66	1.48	17.14	0.19	0.03	0.22	0.02	0.24	8	MATHEMATICS
0.0016	3840	6.00	0.96	6.96	0.66	7.62	0.19	0.03	0.22	0.02	0.24	9	ADDITIONAL MATHS
0.0000	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10	
0.0020	3840	7.50	2.00	9.50	2.78	12.28	0.19	0.05	0.24	0.07	0.31	11	GENERAL SCIENCE
0.0023	3840	9.00	2.40	11.40	3.19	14.59	0.19	0.05	0.24	0.07	0.30	12	PHYSICS
0.0023	3840	9.00	2.40	11.40	3.19	14.59	0.19	0.05	0.24	0.07	0.30	13	CHEMISTRY
0.0023	3840	9.00	2.40	11.40	3.19	14.59	0.19	0.05	0.24	0.07	0.30	14	BIOLOGY
0.0023	3840	9.00	1.92	10.92	6.34	17.26	0.19	0.06	0.25	0.13	0.38	15	AGRICULTURE SCIENCE
0.0000	0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16	
0.0016	3840	6.00	0.96	6.96	1.39	8.35	0.19	0.03	0.22	0.04	0.26	17	COMMERCE
0.0008	3840	3.00	0.80	3.80	1.09	4.89	0.19	0.05	0.24	0.07	0.31	18	ARTS/CRAFTS
0.0016	3840	6.00	0.32	6.32	0.19	6.51	0.19	0.01	0.20	0.01	0.20	19	PHYSICAL EDUCATION
0.035	65280	135.00	25.44	160.44	30.34	190.78							

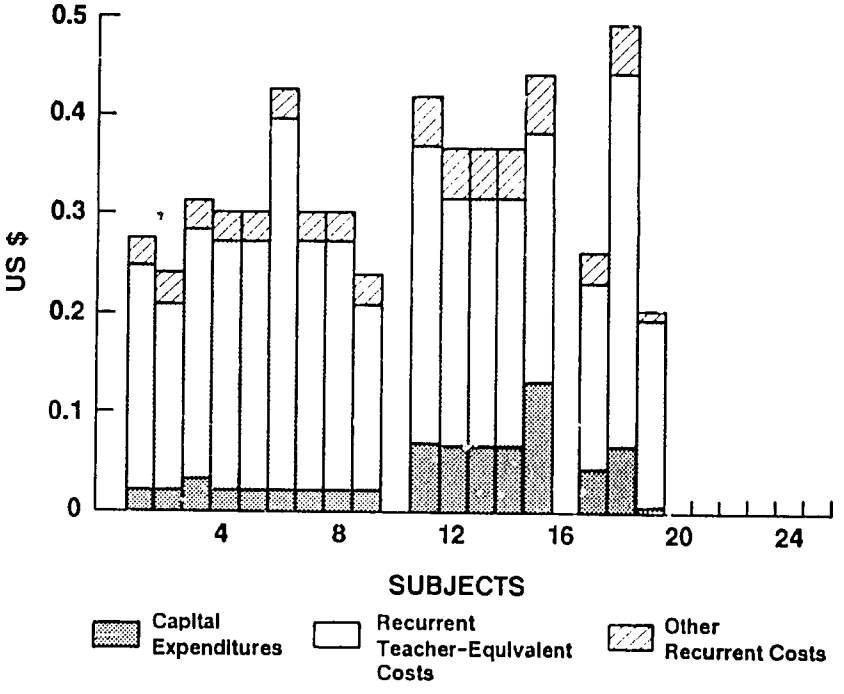
GRAPH 1

Costs per Student per Subject per Year



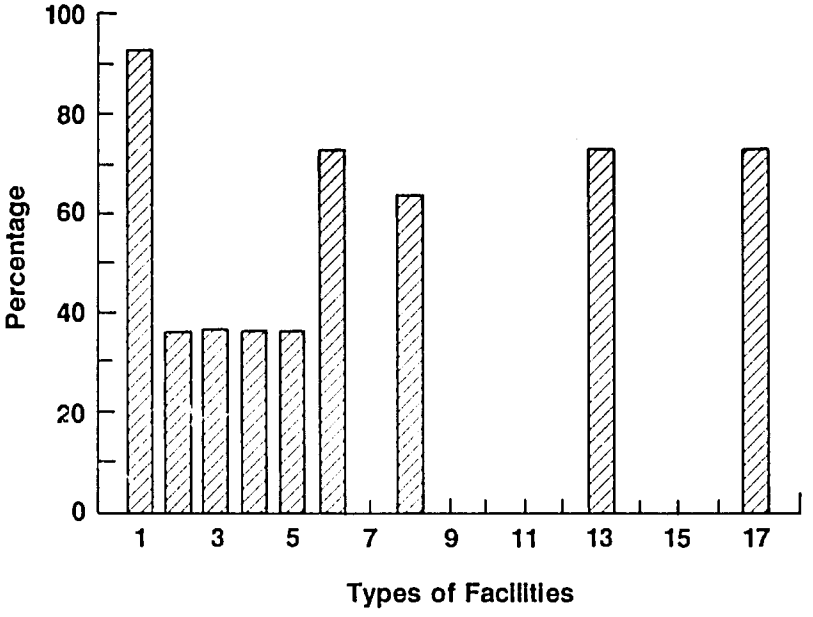
GRAPH 2

Costs per Student per Subject-Period per Year



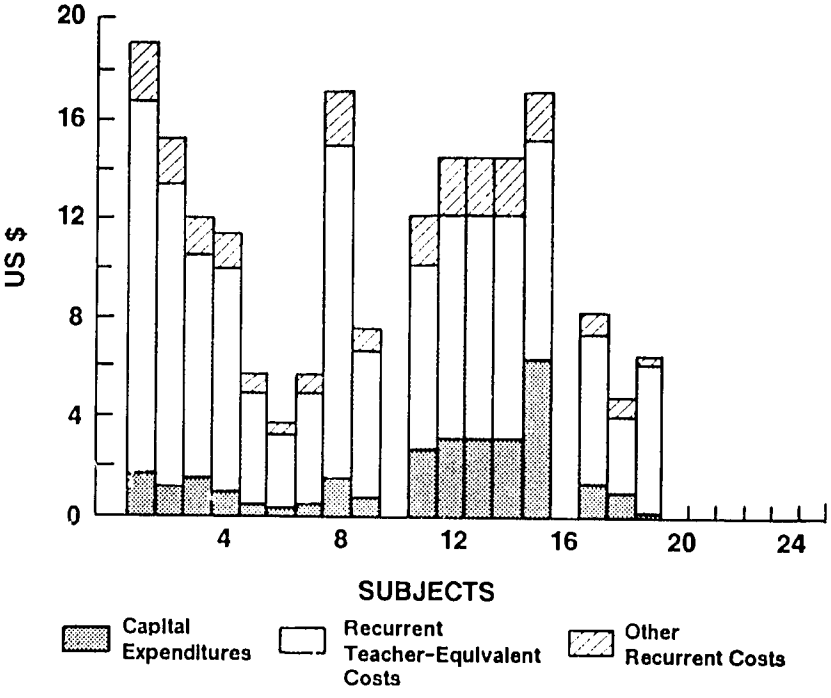
GRAPH 3

Facilities Use Factor



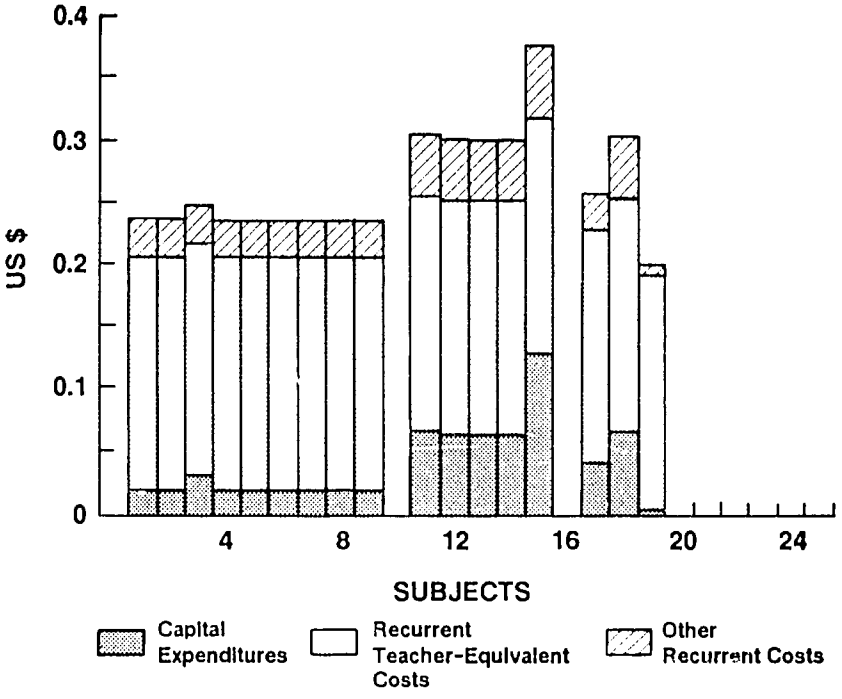
GRAPH 4

Minimum Costs per Student
per Subject per Year



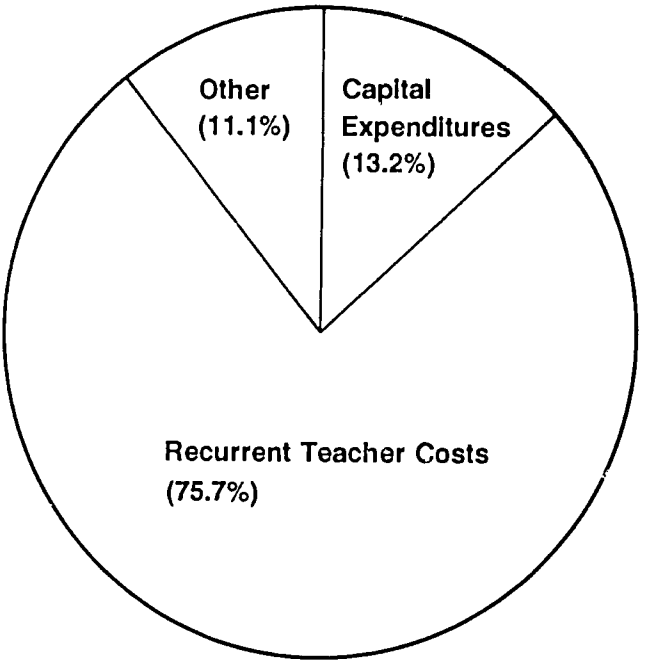
GRAPH 5

Minimum costs per Student
per Subject-Period per Year



GRAPH 6

Capital and Recurrent Costs per Year
(in US $)



28

A Software Exchange System for the Americas

WILLIAM L. HUGHES

This paper presents a preliminary proposal for setting up a software exchange system for the Americas based on the discussions held at the symposium. It suggests the organizational and operational decisions that need to be made and outlines alternatives that should be considered.

PRINCIPLES OF OPERATION

The Software Center of the Americas (SCOTA) should have a well-defined purpose: to make its software resources available to anyone in the Western Hemisphere, essentially at cost of operational overhead. It would make resources equally available to commercial, nonprofit, and governmental organizations, as well as to individuals. There should be no screening of beneficiaries as long as they pay the small overhead fee. For those developing countries with rigid foreign exchange prohibitions, some type of voluntary fund or grant (perhaps from one of the private foundations) could be established so that a reasonable amount of accommodation may be provided.

The word "software" ultimately should be taken to include both computer programs and educational video and audio tapes,

since a major fraction of the center's effort would be related to education. The video and audio tape software should be accompanied by a considerable amount of reading matter.

Software sources should be essentially voluntary, since SCOTA simply will not have sufficient funds to buy software (except for one possibility mentioned below). Users would be expected to contribute to the software pool when they have something worthwhile to give. If some individual, company, or funding agency is willing to pay for the development of software to contribute to SCOTA, it would, of course, be accepted. The sharing of software cannot be made a requirement because it can not be enforced, but once the users understand how the group works, they will make significant contributions.

The principle media of exchange of computer programs, at least initially, will be either through floppy disks or hard copies. As there are nearly one hundred floppy disk operating systems, it would make sense for the center to accept hard copies only on 8 1/2" x 11" sheets, or floppy disc copies only in MSDOS or CP/M. It will also have to accommodate the Brazilians if they have a DOS of their own. With these restrictions, the copying equipment requirement for the center is minimal initially—a duplicating machine and a dual disk-drive microcomputer. Ultimately, of course, the center will have to be equipped with conversion capabilities. This is not very difficult because most machines can convert data files to ASCII files, to be transferred by a modem to another system that can read ASCII files. The fabrication of more elaborate conversion systems is a good project for electrical engineering students.

ORGANIZATIONAL MATTERS

Location

One of the first questions to be answered is, Where should SCOTA be located? In this matter, I think we need to be extremely practical. First, it must be somewhere where mail is reliable and fast. This is not to discount the possibilities of transmission of software by satellite, because I think SCOTA would ultimately be doing that, but the primary gathering and distribution systems will be by mail for a long time to come. Second, it must be somewhere where the government has a history of stability. Otherwise,

the temptation to politicize and control the operation would be irresistible, resulting in censorship problems and other operational disruptions. Third, it should not be in the United States because in order to be recognized as a Latin American center, it must be located in the region. Fourth, the language of the country should be Spanish simply because that will be the native tongue of at least half of the users. This does not imply that all of the software should be in Spanish. It simply means that SCOTA headquarters should be located in a country with the same primary language as the majority of its users. Several countries, including Brazil and Belize, should not be considered precisely because of their languages.

In my view, SCOTA should probably be in Mexico City. If Mexico clearly does not want the center and if Interciencia is willing to be the coordinator, Caracas is a possible alternative. Mexico has strong industrial ties to the northern countries and would be in a good position to solicit support. If it is in Mexico City, then the question is, Under whose auspices should it be? Possible sponsors include the National University (UNAM), Metropolitan University (UAEM), or the Mexican Academy of Engineering (ANIAC).

Scope

What should be the scope of the software to be exchanged in SCOTA? A rough grouping of software categories that could be extremely useful, particularly to developing countries, follows:

- Software developed to enhance primary education in the language, cultural, and quantitative skills. Computer, video, and audio software are vitally important here. In addition, software to teach language and cultural skills must originate in the cultures that will use it. That fact was stressed at the symposium, and this is probably the single most important area of endeavor for SCOTA.
- Software developed for various subjects in secondary education. Since desired cultural patterns should be well established, it would be possible to make use of a much wider variety of software sources.
- Software developed for post-secondary education of all types—university, technical training, and so on. Software could be from anywhere.

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minimize its usefulness. If SCOTA is to be effective, there must be some initial source(s) of funding to (1) set it up, (2) establish a basic library, and (3) make itself sufficiently known that it begins to attract users.

To obtain sufficient funds (which will not be an inconsequential task), a governing body (board of directors) must be established consisting primarily of Central and South American representatives but also a few from the United States and Canada. A small committee led by a Latin American should then prepare a preliminary conceptual proposal and visit a variety of U.S., Canadian, and Central and South American funding organizations to seek a number of small cooperative effort grants to get started. Perhaps the U.S. Agency for International Development could also contribute. Organizations such as the Ford Foundation and those oil company foundations whose sponsoring companies conduct business in Central and South America could be approached.

Perhaps a sum on the order of a half-million dollars could be raised. This amount could pay for the establishment of a central staff consisting of a young, eager, and a modestly paid director and some support staff; the purchase of a computer, a duplicating machine, desks, and chairs; and overhead expenses—salaries, postage, and telephone—for three or four years. Perhaps the director might be a half-time university professor devoting the other half of his time to this project. In addition, perhaps the facility in which the operation is housed (two or three rooms initially) could be provided by the host university or other organization free of charge. Ultimately, the center must be self-supporting, either through levying nominal charges for its services, through the establishment of ongoing grants, or through some combination of both.

Outreach

Making itself known to those for whom it is established will not be a problem for the center. The simple issuance of a one-page bulletin describing the center (to be posted in libraries and at educational, industrial, and governmental locations) should be sufficient. All that needs to be written is that software in the appropriate categories is available for nominal fees and that users are encouraged to share their software as well. In addition, an annual listing of what is available along with quarterly updatings should be available in the libraries of all institutions where the bulletin is posted.

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A Proposed Latin American Society for Computers in Education

ACADEMIA NACIONAL DE INGENIERA

One of the principal recommendations emanating from the Symposium on Microcomputers in Education called for the creation of an agency that will implement the general conclusions of the group. Pursuant to that recommendation, it was proposed that a Latin American Society for Microprocessing in Education be created whose principal objective is described below.

OBJECTIVE

The objective of the society, as we see it, will be to promote the exchange of information, ideas, and experience in the application of computers in education in Latin America by means of a bulletin, a database accessible through a computer network, and periodic meetings encompassing all countries of Latin America. Although the society would focus on the countries of Latin America, in view of prevailing opinion in the Latin American countries and in view of the opinions expressed by the participants at the symposium in Cuernavaca, membership would not be limited to Central and South America. People from other countries with similar problems, even if non-Spanish-speaking, would be admitted as individual members. In addition, it would be reasonable to admit countries such as Spain and Puerto Rico as well as certain

Spanish-speaking groups in the United States, for example those in California and Texas. These latter groups could be of great benefit to the society through their close contact with sources of technology and information.

INSTRUMENTS

To achieve our stated objective, it is proposed that we establish a number of instruments to facilitate information exchange and feedback. First, a quarterly bulletin should be established, to be circulated among individuals in Latin America who are interested in the subject of computers in education. The bulletin will publish a list of persons interested in microcomputer use in education, along with their interests, addresses, and telephone numbers in order to facilitate direct exchange between individuals with common interests. Articles of various types will be published: some giving details of achievements by groups belonging to the society, articles on various aspects of computers in education, reviews of software, descriptions of software available for exchange, program listings with instructions, reviews of computer hardware for use in education, news from participating and other countries of meetings and events in the field, and other information of interest.

To ensure that the bulletin will be available as quickly as possible, an initial editorial committee will be established, made up of members from the committee elected at the symposium along with Mexicans prominent in this area, several of whom participated in the symposium. Among the first materials to be published in the bulletin will be the list of participants at the Cuernavaca symposium, the conclusions of the three working groups at the symposium, and summaries of the papers presented at the symposium. Afterward, the bulletin will publish news obtained from or submitted by members concerning progress in their countries, the by-laws approved for the society, lists of new members, and the materials mentioned above.

Second, periodic meetings should be held in various Latin American countries for the purpose of ensuring that the individuals who are working in the area of microcomputers in education are known to each other and that they have the opportunity to discuss topics of common interest, as well as to exchange information, programs, and experiences. In particular, the first annual meeting could, among other things, serve to formally establish the society,

approve its by-laws, and establish a program of work for the first officers elected. For this purpose, it would be necessary to make an intensive effort prior to this meeting to have all the elements in place, ready to launch the society.

Third, chapters of the society should be established in all those countries where there are people interested in the society's activities. Some of the members of these chapters will act as correspondents for the bulletin as well as for its editorial committee. They will also form part of the local organizing committee for meetings held in the country. Fourth, the society should have at its disposal a computer network connecting the different groups in Latin America that are working in the area of computers in education. The network would greatly facilitate communication in this vast geographical region and would permit the ready exchange of programs and other educational materials. Lastly, a database would be connected to the network and be available for storage and ready access of information on methodologies, materials developed by the different groups in Latin America, and on individuals interested in the field, as well as other information that requires regular updating.

ORGANIZATION

It is proposed that the Latin American Society for Computers in Education have a permanent secretariat with its headquarters initially located in Mexico until the society is fully stabilized. Once this has been achieved, a more suitable site can be selected for its permanent headquarters. The reason for choosing Mexico as the initial headquarters site include, first, that that was where the idea was born, and second, that two of the committee members elected to implement the recommendations of the Symposium on Microcomputers in Education (including its president) live in Mexico. It is proposed that the committee elected in Cuernavaca be charged with initiating the activities of the society by writing to all the participants in the Cuernavaca symposium, encouraging them to form chapters in their countries, and making contact with people in countries that were not represented in Cuernavaca so that chapters are established in those countries as well. Each chapter will send data to the permanent secretariat on the people they wish to include in the society so that a directory of these names, to be published in the bulletin, can be generated. Membership will be

regulated by a set of by-laws that will be proposed by the committee members to the chapters established in the different countries. These by-laws, in addition to regulating membership, will stipulate how the society is to be organized, how it will operate, how its leaders are to be elected, as well as other details.

FINANCING

Ultimately, the society should be financed by the individual contributions of its members; by contributions from private, academic, or governmental institutions in the participating countries; and by contributions from international institutions such as the Organization of American States. However, during its initial launching it is proposed that the activities of the society be financed with contributions from interested Mexican institutions (to be arranged by the National Academy of Engineering of Mexico) and by similar institutions and organizations in other member countries. These contributions will serve to defray the operating expenses of the permanent secretariat as well as the cost of terminal connections in the network, integration of the database, and preparation, publication, and distribution of the bulletin, for the extent of the period in which financing is limited. Additional expenditures that need to be covered are trips to the bulletin's editorial committee meetings and other committee meetings. It will also be necessary to obtain financing for the attendance of representatives of the society's chapters at the inaugural meeting.

Section 8
Conclusions and Recommendations

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Conclusions and Recommendations

REPORT OF THE WORKING GROUPS

In separate sessions, each of the three working groups—Teacher Training, Pre-University Education, and University and Professional Education—prepared a report of their conclusions and recommendations. Many of the recommendations made by the working groups that were basically policy-oriented proved to be similar. All three groups stressed that developing countries that take an early and active role in the information revolution will narrow the gap between themselves and the industrialized countries. They noted that because information technology does not require a large and expensive infrastucture, trained individuals in developing countries can make contributions on the same level of expertise as their counterparts in developed countries. This training, however, depends on the introduction of microcomputers into education at an early level and the continuing use of this technology in education at all levels.

The participants agreed that information technology makes a useful contribution to the education process. The third working group suggested that students must go beyond programming to be able to use the computer as an extension of their capacity to think and to solve problems. The computer can then enhance educational productivity in teaching students to be creative, to

think critically, to make valid decisions, and to explain and present their ideas.

Participants in each group cautioned that since the microcomputer must be introduced early in the educational process, the software used must be appropriate for the particular culture of the country. A widely shared experience of cultural problems with imported software, even when it had been translated, led the participants to recommend strongly that educators in each country develop software appropriate for their needs or, at least, review and modify software developed elsewhere. The group on pre-university education underlined the importance of this review particularly when software is to be used by noncritical students in the elementary grades. The participants who teach technical subjects to high school and university students were more concerned that software be reviewed to ensure that the sequence of instruction is compatible with the syllabus being followed by the class.

All the participants supported the recommendation that it is important for each country to take part in the development of microcomputers whether by building hardware and writing software, or by modifying imported technology. They added, however, that although each country should have a significant degree of autonomy in the process of introducing microcomputers into education, the process of sharing information that extends across national borders is beneficial in that it provides guidance and permits cooperation among programmers and users with common interests. Because educational material should be relevant to the cultural and intellectual context of each country or region, however, it is essential that even these shared programs be tailored to reflect local priorities.

A number of recommendations were addressed to government officials charged with setting policy. The participants agreed that the general public must be made aware of information technology so as to share in its benefits. Local school and community leaders must be given enough training to become informed consumers, so that hardware and software selection can reflect community needs. Teachers, as the front line in spreading the use of computers to the next generation, must be given training so that they will understand the technology and be comfortable with it. They should see information technology as a valuable resource that they can command. To ensure that this attitude prevails, teacher

training institutions must make computer training an integral part of the curriculum, and continuing education in this technology must be provided for teachers currently working in the schools. The group agreed that the more widely information technology is spread to the people of a country, the more that country will be able to control the technology and guide its own economic and social development.

Inherent in the nature of information is the attribute that sharing information does not diminish, but rather increases the amount available to each individual. All the working groups recognized the value of cooperation to this end and emphasized the need for mechanisms to enhance communication at all levels. They suggested holding frequent conferences and publishing newsletters or magazines to diffuse microcomputer technology. These might be organized for teachers at various levels and in various regions, for researchers, for programmers, and for administrators. Technology centers within countries and regions could enable technical personnel to cooperate and might provide a place for novice computer users to try new software and find assistance with technical problems. It was strongly recommended that a standing committee be elected from among the participants at the symposium to investigate methods of improving international exchange of educational applications of microcomputers. The committee was asked to explore the development of an international newsletter or journal and to initiate planning for an annual conference on microcomputer applications in education and training.