Computers in Education in Developing Countries: Why and How?

by

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Preamble

This technical note deals with the subject of the introduction of computers as teaching and learning tools within the educational systems in developing countries, although many of the concepts to be presented here are of general validity and could be applied to any country facing the decisions related to this area. I have tried to avoid the usual pitfall of many transfer-of-technology projects, which is to "copy" in a developing country a project that was successful in a developed country. This note is the result of my experience in implementing educational projects in the very different situations that arise in developed and developing countries.

My experience in the three components of the title (computers, education and developing countries) is easy to identify. I was born and educated in Uruguay, and I spent the first 25 years of my professional career teaching at secondary and university levels, and making decisions as a member of university councils and committees. I was the Head of the National University Computing Center when I decided to move to Israel. During the next 25 years, I worked mainly in the area of computers in education, a topic where my interest started thirty years ago, with my MIT thesis for the MS degree. Israel was the ideal field of application, because there is a national commitment, expressed also in budgetary terms, to raise the level of education as a key element for the development of the country.

In this note I am not trying to tell other countries to use the Israeli recipe. What I have tried to do is to filter what we learned in Israel, through my Latin American eyes, selecting those aspects that may be of major importance for developing-country experts in the definition of their national projects.

The text will be organized in two parts: "Why?" and "How?".

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Part I : Why?

The Question

In developing countries, with large segments of the population living at extreme levels of poverty, the first question that must be asked is whether it is reasonable to invest money in technology for the educational system, instead of using the same money to improve the living conditions of those in dire need. I believe that these interests are not contradictory and that the only way to reach a long-term solution for the economic problems of the population is to raise the educational level, particularly for the low socio-economic groups.

The impact of educational level on economic development is more pronounced during recent years, with the influence of the information era and the global markets. Nevertheless, educational organization and practice has changed very little in two-hundred years.

For an extended analysis of these problems see Osin and Lesgold (1996). Here I will just mention the following points:

- Increasingly, competitiveness in international markets is based more and more on the educational level of human resources, and much less on raw materials.
- Automation of industrial and commercial processes has generated a migration of personnel towards more intellectually demanding tasks.
- Present educational systems, and not only in developing countries but also in the U.S., are not providing graduates at the levels required by the productive systems. The best sources for this assessment come from the United States. "*Adult Literacy in America*", a 1994-survey issued by the Educational Testing Service (ETS), reported that roughly 90 million Americans over age 16 - almost half that category's total population - are, as far as most workplaces are concerned, basically unfit for employment. That this state of affairs was approaching was already predicted ten years before in a report, issued by a presidential commission, under the suggestive title: "*A Nation at Risk*".
- In realistic terms, we have to assume that the output of the average educational system in developing countries is even lower than in the U.S. The consideration that a higher percentage of the population in developing countries works in the agricultural sector does not alleviate the problem, because today's agriculture, to be competitive in international markets, requires the usage of sophisticated methods and technology. This, again, requires a much better-educated farmer.
- I believe that the main reason for the failure of educational systems is that the individual needs of each student to sustain a successful learning process are essentially ignored in traditional classroom practice.
- Educational systems are resistant to change, and a transformation that purports to accelerate the solution of the problems just stated requires the support of educational technology.

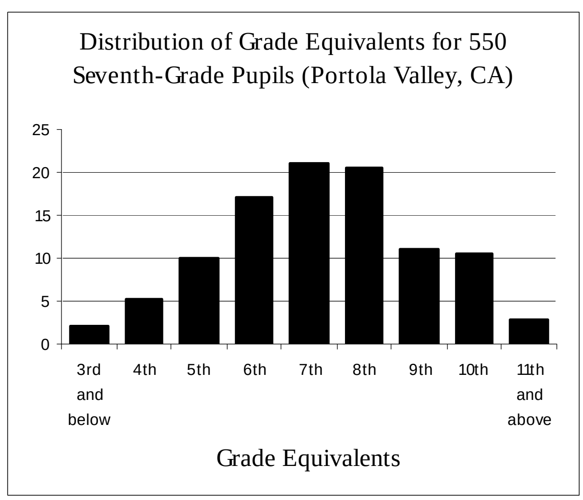
Problems of the Educational System

In this section I will identify some major problems of educational systems that the use of computers may help to solve.

System conception

- Present educational systems, inherited from a European conception that was created during the Industrial Revolution, group children according to age, in classes which are supposed to be relatively homogeneous from a cognitive development standpoint. Experimental measurements in real classes show that this conception is absolutely false. A good example is presented in Figure 1, built with data from Tyler (1962). In the excellent school district of Portola Valley, California, 550 seventh graders were classified according to what

Figure 1



they were able to accomplish in mathematics and English reading comprehension. The result is that only 21% of the students perform at grade level, with a distribution ranging from 3rd grade and below, to 11th and above. It is not surprising to find a normal distribution for a population of students (i.e., students are normal). What is exceptional in Portola Valley is that the distribution is centered at the level defined by the grade. In typical schools, for medium and low SES populations, only the best students in the grade would reach grade level (Osin, 1988).

- The assumption that all the students in a class are able to study the same curriculum in the same time contradicts experimental results. Gettinger (1984) cites findings of a 5:1 ratio among slow and fast learners in time to learn (TTL). In other words, what a fast learner learns in two months might require a whole school year for a slow learner.
- The emphasis in frontal presentation, or typical classroom teaching, with students listening to what the teacher tells, is not conducive to real learning. Each student must build his or her own models of knowledge. Learning theorists agree that we learn by doing and that schools should devote much more of students' time to project activities related to real life and to the application of curriculum contents.

Teacher preparation

- It is estimated that human knowledge (as measured by scientific publications) doubles every eight to ten years. Educational systems do not provide in-service training that suffices to keep teachers' knowledge adequately updated. In this state of affairs, many topics which students encounter in the media and arouse their intellectual curiosity - which would be ideal subjects for class discussion - will be avoided by the teacher, who feels insecure about them, and does not want to lose face in front of the students.
- Teachers colleges lack state-of-the-art educational technology, which could be a stepping-stone for positive changes in future teachers' behavior.

Developing-countries problems

- Overpopulated classes, often reaching beyond fifty students per class.
- Schools lack appropriate infrastructure, particularly in rural areas. Substandard classrooms, black of telephones, electricity, or lavatories.
- Very low teacher salaries, producing a flight of the higher intellectual levels to better-paid professions.
- Non-professional teachers are used to teach subjects where a credentialed teacher is not available.

Computer Uses in Education and their Benefits

Computers provide, for the first time in history, a key ingredient that was lacking in all the previous tools that raised high expectations when introduced in the educational system: **individualized interactivity**. From blackboard to television, the previous tools were presentation tools only. Computers, however, can not only present information with all the audio-visual expressive possibilities of television or film, but also can receive information from the user, and can adapt the presentation to the user needs, preferences or requests. Furthermore, in those schools where the Internet is accessible, the computer is the gateway to information without frontiers, and the catalyst for teacher and student dialogs beyond the walls of a single class or school. Today, when a major effort is being invested in the transformation of the classroom, moving away from frontal, expository, didactic presentations to environments where learners are active discoverers and builders of knowledge, the computer is the tool with the potential to help in reaching these goals. For a detailed description of different modes of computer use in the educational environment, see Alessi and Trollip (1991) or Venezky and Osin (1991). In the framework of this Technical Note, the following modes and benefits are summarized briefly.

- *Computer-Assisted Learning* The student learns by interacting with a program stored in the computer. This program is designed to react to the student's needs according to predetermined pedagogical criteria. In this case the student conducts a "distant dialog" with the authors of the educational program, who - in a well-designed program - will have considered the learning difficulties involved in the topics studied, and designed accordingly a set of remedial interventions. Enrichment units should have been included also, to attend to the interests of students who want to study in depth, beyond the curriculum requirements.

  Benefit Each student may learn according to his or her cognitive level and learning speed, independently of his or her classmates. Each student receives individual guidance, with explanations tailored to perceived problems, and opportunities for in-depth learning according to individual interests.

- *Simulation and Exploration* There are topics of study that deal with real systems whose complexity makes them hard to comprehend, operate, or predict. When we want our students to learn how to cope with such a system, the best pedagogical approach is not to provide a set of rules that describe the behavior of the system, but rather to let them explore the behavior, make decisions and predict their consequences or, in short, learn according to their own experience with the system. This is easier said than done, when the real system is a hydroelectric power station, or the economy of a nation, or a patient that requires medical treatment. Fortunately, for many real systems a **computer model** has been developed, i.e., the computer provides an output describing the behavior of the system, and the changes in this behavior produced by the input of diverse actions. Thus, a student may check the validity of decisions concerning the amount of water allowed to circulate in the hydroelectric power station in conditions of possible drought or flooding, or the effect on unemployment of raising taxes, or the effect of a certain therapy for a patient with given symptoms. All this without creating shortages of electric power for the population, or unemployment, or killing the patient.

  Benefit The student is actively exploring phenomena, instead of being a passive recipient of information. Thus each student builds his or her mental models of knowledge and develops the skills of searching information and creating hypotheses, which then can be verified or rejected using experimental results. The teacher may use simulations to generate class discussions and to stimulate students to generate hypotheses and critically analyze a phenomenon.

- *Computational tools* Teachers and students can use computer-based tools, such as text or graphic editors, databases, spreadsheets, or presentation packages, to help in processing information. Two important benefits that come to mind are: a) teachers' can enrich their presentations with rich graphics and tables, which can be stored in their computer, easily updated, and readily accessible for presentation to the whole class by means of a projection device; b) Students' papers may be of higher quality, particularly if, instead of just assigning a grade, the teacher requests that each paper be typed using a word processor and delivered on a diskette or through e-mail, thereby allowing the teacher to insert comments and suggestions and return it to the student for corrections until a satisfactory paper has been achieved.

  Benefit Teachers and students get used to working in the style and with the tools that permeate industrial, commercial and intellectual life.

- *Communication networks* Students and teachers can communicate with their peers and access data banks in different parts of the country and around the world, in order to develop joint projects, exchange information, or request advice. Instead of the expository presentation of a topic, the teacher may ask a student, or a team of students, to research the topic by exploring the Internet for relevant information. Not all the information on the Internet is reliable, but such is the information we gather in the real world, so that students will have to develop their analytical and critical skills. These skills are not usually developed in the restricted environment of the typical classroom, where most information has been filtered for them. Teams of students in one country can develop joint projects with teams of students in other countries by exchanging and comparing data on similar or contrasting phenomena.

  Benefit Instead of isolated classes, students can communicate with people and gather information from around the world, thereby increasing their motivation to use higher-level analytical skills in their school work. In addition, communication among people from different countries helps to break down stereotypes and may expand intellectual horizons. Teachers who work in relatively isolated environments are able to exchange information with their peers, receive advice from experts around the world, and download an increasingly broad array of teaching and learning materials available on the Internet.

- *Pedagogical administration* Teachers can access a student database, where information about each student's knowledge map is stored. This information allows teachers to organize more effective learning environments for each student.

Benefit For the first time the teacher has the tools to make sophisticated and complex pedagogical decisions, based on appropriate information. Without computers, individualizing or personalizing instruction was quite difficult because it is impossible for a teacher to keep track of the different trajectories of all of his or her students in the universe of knowledge defined by the curriculum. A pedagogical administration system can show the topics mastered by a student, the topics where help may be needed, suggestions for topics and materials to be presented or assigned, and the possible groupings of students for team projects, selecting automatically students who have satisfied the prerequisites for each project being considered.

Another important consequence of wide dissemination of computer-based educational materials that have well-conceived pedagogical interactions, is that they serve as good examples for teachers who may be isolated. Based on such examples, teachers may expand their repertoire of strategies, and recognize the need for improvement in their classroom practices.

Warning!

The potential benefits just described may be wasted in practice. Installing computers does not guarantee that they will be used to improve the learning experience. As a matter of fact, they could also be used to perpetuate the negative characteristics of traditional instruction. As an example, if a teacher assigns a topic to be learned at the computer, but it is the same topic to be learned by all the students in the same amount of time, then, the investment is not justifiable. Similarly, if a teacher allows students to "surf the net", without any educational objective, and without a critical analysis of the information gathered, there will be more damage than benefit, and a waste of money and resources.

Benefit Analysis

In this section and the next, I will argue that a well-utilized system has a measurable benefit in learning outcomes that justifies its cost.

A recent benefit analysis of educational technology was published in a study prepared by the RAND Corporation for the Office of Science and Technology Policy and the U.S. Department of Education (Glennan and Melmed, 1996). The main results of meta-analyses of evaluations of technology programs were presented by James Kulik and Dexter Fletcher, well known experts in this area, during a workshop on "The Costs and Effectiveness of Educational Technology" (Melmed, 1995).

Major points in Kulik's presentation were:

- Students usually learn more in classes in which they receive computer-based instruction. The various analyses produced slightly different estimates of the magnitude of the effects of computer use, but all estimates were positive.
- Students learn their lessons in less time with computer-based instruction.
- Students also like their classes more when they receive computer help.
- Breaking studies of computer-based instruction into conventional categories clarifies the evaluation results. One kind of computer application that usually produces positive results in elementary and high school classes is computer tutoring. Students usually learn more in classes that include computer tutoring. On the other hand, precollege results are unimpressive for several other computer applications: managing, simulations, enrichment, and programming.

Dexter Fletcher, of the Institute for Defense Analyses, compared features related to the use of technology in military training to those in primary and secondary (K-12) education.

- Military training involves bringing individuals or collections of individuals to a required level of performance in the conduct of prescribed tasks.
- The time to reach competency varies considerably among trainees.
- The trainee is paid while in training. Thus, methods that reduce training time may substantially increase the cost-effectiveness of the instructional process.
- Repeated analyses have found that, on average, technology reduces by about 30% the time required to reach criterion levels of knowledge and performance. These estimates are similar to those reported by Kulik for reduced instructional time in education.
- The comparison of different approaches to improve K-12 education (peer and adult tutors, reduced class size, increased instructional time, and computer-based education), showed that peer tutoring and computer-based education are the most cost-effective approaches.

The results presented by both Kulik and Fletcher clearly justify the introduction of computer technology into the educational system. Kulik's observation that the only type of computer use with consistently proven results is what he calls computer tutoring (and I have called computer-assisted learning) should not preclude the experimentation with other uses listed in the previous section. The field is too young to try to fossilize it already. All the computer uses described offer high potential for an increase in student motivation and for the development of higher-level thinking skills. We may hypothesize that the success of computer-assisted learning, when compared to the other uses, results from the facts that: it is the one that blends more naturally with present teacher practices; provides teachers with a service, instead of requesting it from them; and is possible to implement after a relatively short training period, without requiring computer expertise of the teachers.

I will exemplify the type of successful results mentioned by Kulik with data from two experiments. One was conducted at the Centre for Educational Technology[2] (CET) in Israel (Osin, 1984, 1981), and the other a large-scale, controlled study was performed by the Educational Testing Service (ETS) at the request of the Los Angeles Unified School District (Ragosta, Holland and Jamison, 1982). Both studied programs that used computer-assisted instruction (CAI) for testing and practice in arithmetic.

The main result in the CET study was that 40 to 60 minutes per week of CAI in arithmetic sufficed to increase student progress by 121%[3]. The ETS result indicated a doubling of student gains with 100 minutes per week of CAI in arithmetic. One possible explanation for the substantially better results in the CET studies can be found in the greater investment done by the Centre for Educational Technology in the infrastructure, teacher training and teacher guidance provided as part of the services contracted by the participating schools. When the Centre's methods and technology were used in other countries, the experimental results were similar to those measured in Israel (Metrowich, 1984; Bordas, 1985, Echeverría, 1985).

In both cases, the results are not only statistically significant, but also of such an impact that it is hard to imagine such a change by conventional methods. The clue for the amazing increase in student progress lies in the individualization of the educational process.

Individualization generates another significant result, reported by Becker (1994) and Osin, Nesher and Ram (1994): the students who benefit more from the introduction of computer-based instruction are those in **both** extremes of the distribution, the low achievers and the high achievers. This means that the technology is providing something that conventional teaching does not: support for pupils who are falling behind, thereby helping to prevent early school drop out, and support for the intellectual development of bright students, who may progress well beyond the class average.

These results are particularly relevant for applications at the primary level, since in many developing countries, children start working after this stage and, in some cases, even without finishing it.

Cost Analysis

Let us analyze now what is today's cost to provide schools with the technological support required to obtain the benefits cited above. Accurate cost must be determined by analyzing the appropriate components in the Cartesian product shown in Figure 2.

Figure 2
Components of a Computer Learning System

Infrastructure	X	**Purchase**
Hardware		**Development**
Software		**Production**
Courseware		**Operation**
Personnel		**Maintenance**
		Administration

The following computations use Israeli cost figures, but readers can use the cost categories to compute prices for their own contexts, substituting local prices and salaries. Note, for instance, that Israeli prices include a 17% VAT. At the end of the computation I compare the obtained result with US and Latin American costs.

[2] The Centre for Educational Technology (CET), is the first and largest Israeli organization in the field of development, production, supply and evaluation of computer hardware, software and courseware.

[3] The average student progress in the experimental schools, when the system was installed, was of 38% of the progress expected (or hoped for) by the Ministry of Education. After four years of computer-assisted learning in arithmetic, the average student progress reached 84% of the Ministry's expectations.

To provide a specific cost, I assume an environment consisting of a primary school (grades 1-6) with two classes per grade, and 30 students per class. I also assume a LAN (Local Area Network) with a server, 30 PC's for the students, one for the principal and the secretary, one for the teacher's room and one for the library. The equipment is defined at the level being installed by the Centre for Educational Technology in such a school:

- **Server**: Pentium II 233 Mhz, 64 Mb RAM; disk SCSI 9.1 Gigabytes; magnetic tape drive (for backups) DAT 12/24 Gigabytes; diskette drive 3.5"; CD ROM; SuperVGA screen 1024x768 with accelerator; laser printer B&W; inkjet color printer; UPS (uninterruptible power supply); communication cards; modem. *Cost: $ 7,400*
- **Student Stations**: Pentium II 233 Mhz, 32 Mb RAM; disk EIDE 3.2 Gigabytes; SuperVGA screen 1024x768 with accelerator; diskette drive 3.5"; CD ROM (one for every four); mouse; communication card; sound card; earphones; operating system: Windows 95. *Cost: $ 1,850*
- **Auxiliary Equipment**: (for the administration, library, teachers, and authorized students): laser printer B&W; inkjet color printer; scanner; videobeam projector. *Cost: $ 7,300*
- **LAN Operating System**: Windows NT or Novell. *Cost: $ 2,000*
- **Courseware and Application Programs**: A library of 300 programs. Cost: $ 18,000
- **Internet**: Frame relay: Dedicated phone line ($ 250) and router ($ 1,500).

The initial investment cost will be annualized using an amortization formula, and recurrent costs will then be added to obtain the total annual cost.

Initial Investment Cost

- **Infrastructure**: Classroom[4] (7m x 7m = 23ft x 23ft) - $ 30,000; Furniture - $ 7,700; Air conditioning - $2,500; Electrical installation - $ 3,000; Communications: 10-Base-T cabling and connection boxes - $ 7,000. Total cost: $ 50,200
- **Hardware**: Total cost: 7,400 + 61,050 + 7,300 = $75,750
- **Software and Courseware**: Total cost: 2,000 + 18,000 = $ 20,000
- **Internet**: Total cost: 250 + 1,500 = $ 1,750
- **Teacher Training**: 60 hours at $ 55/hour. Total cost: $ 3,300[5]

Thus, the total initial investment cost is: <u>$ 151,000</u>

Amortization

In financial terms, more important that the initial investment cost, is the annualized cost of the investment. For a well-conceived national project in a developing country, it is reasonable to hope for an international bank or fund to help in financing the project.

To compute the annualized cost, estimates assume an expected life of 40 years for the classroom, 12 years for furniture and installations, and 6 years for hardware, software, courseware and initial teacher training. The yearly interest rate for the amortization is 6%.

Under these conditions, the annualized costs are:

Classroom: $ 1,990; Furniture and installations: $2,410; Hardware: $ 15,760; Software and Courseware: $ 4,070; Teacher training: $ 670.

This computation gives the real weight of each one of the components. The classroom cost, for instance, is dwarfed by comparison with the hardware cost.

In summary, the annualized cost of the initial investment is: <u>*$ 24,900*</u>.

Recurrent Costs

- **Maintenance**: The major maintenance costs correspond to electromechanical equipment, hardware, software and courseware. A reasonable estimate is 6% of the initial cost. This results in: *0.06 x (2,500 + 7,000 + 77,500 + 20,000) = $ 6,420*
- **Upgrading software and courseware**: This may require another 10% of the initial cost per year. Thus: *0.10 x 20,000 = $ 2,000*

[4] The cost of building a classroom to host a computer laboratory is included because it is needed in many cases, and because, if a classroom is available now, it may be needed at a later date due to increased student enrollment. The cost of a specially-built computer room should not be included when the decision is to distribute the computers in classrooms, but this approach, despite its pedagogical appeal, provides inadequate security and makes community use more difficult.

[5] Instructor hours are listed (at CET's rate of $ 55 / hour), and it is assumed that teachers will appreciate receiving computer training (instructors and equipment), and not demand payment for the hours they attend training.

- **Teacher Training**: There are always new teachers, new educational materials, and new problems, and this may require 60 hours of instructor time per year. *Cost: 60 x $55 = $ 3,300*
- **Personnel**: I have not budgeted for a full-time person to be in charge of the computer lab, but instead assume that each teacher will bring his or her students to the lab at scheduled hours, and will interact with the students according to their needs. It is very important for the teacher to consider the computer interaction as one of the tools of the trade, feel responsible for the activity in the computer lab, and enjoy its benefits. On the other hand, one teacher with affinity or qualifications for the task should be made responsible for the system, to solve minor technical problems, be in charge of the system disk backup, provide advice to teachers less acquainted with the system, and request maintenance when a technician is needed. This task could be assigned (and paid) 8 hours per week. I also propose that three teachers in major subjects be assigned 3 hours per week each, in order to explore and try new educational materials that may be particularly appropriate for the school curriculum. Finally, administration and cleaning may require 8 hours per week. At an average salary of $20 per hour, this results in an annual cost of: *$20 x (8 + 9 + 8) x 52 = $ 26,000*
- **Internet**: In Israel schools pay flat monthly rates of $100 for the phone line, and $400 for the ISP (Internet Service Provider). *Annual cost: ($100+$400) x 12 = $ 6,000*

Total Annual Cost

The sum of the annualized amortization plus the recurrent costs is:

24,900 + 6,420 + 2,000 + 3,300 + 26,000 + 6,000 = $ 68,620. Adding an additional 10%, to cover general expenses, insurance, materials and unforeseen expenses, we reach finally a:

Total Annual Cost = <u>$ 75,480.</u>

Annual Cost per Student

In the case study used here, the number of students in the school is:

2 classes x 6 grades x 30 students per class = 360 students per school.

Thus, the *annual cost per student* is $ 210. This value fits very well in the range determined by Keltner and Ross (quoted in Glennan and Melmed, 1996), for technology-rich US schools, from a low of $142 to a high of $490, and even in the range determined when the two extremes are excluded — $182 to $453. Another comparison comes from Potashnik and Adkins (1996) who, in the two cases studies presented in Tables 1 and 2, compute annual costs per student of $367 and $333. It seems natural that US costs are higher than Israeli costs, mainly because of their higher salaries. In developing countries, the annual cost may be reduced significantly, as estimated below.

Cost Per Hour of Student-Computer Interaction

The value of greatest interest is the cost of one hour of student interaction with the computer. This is determined by dividing the total annual cost of $ 75,480 by the number of computer hours available in school. Assuming 200 days of operation, 4 hours per day (standard Israeli school day), we have: 200 x 4 x 30 = 24,000 student-computer hours. This results in an hourly cost of interaction of $ 3.15.[6]

Adjustment for Developing Countries

The value just computed, of $ 3.15, is probably acceptable by US standards, but it is very high for developing-countries standards. However, there are certain adjustments that are possible and desirable for almost any developing country. Consider the following factors:

- Teacher salaries are, on average, one order of magnitude below those of industrialized countries.
- Building costs are less than half.
- Life expectancy for the equipment should be estimated at 8 years, because equipment renewal is not easy to obtain.
- It is possible to sign agreements with large (and prestigious) computer manufacturers, in order to purchase equipment of a previous model, instead of the most recent one. From an instructional standpoint there is almost no difference in working with equipment with an average age of 4.5 years, instead of equipment with an average age of 4 years[7]. But in terms of cost, this decision may halve the price.

Based on these considerations, the yearly cost can be estimated at 40% of the original estimate of

[6] This value is computed under the assumption that the students work individually at the computer. In the cases where it is possible to work in pairs, the cost of the contact hour is halved.

$30,340. This results *in an annual per-student cost of $84*, very similar to the costs presented by Potashnik and Adkins (1996) for Jamaica ($89), Chile ($104) and Belize ($78).

And now, a specific consideration for developing countries. This important investment should not be utilized only during school hours, but should be considered as a community resource and used by students and their families, to raise the education and skill level of all the members of the community.[8] If the system is used 300 days per year, 10 hours per day, and referring to the 30 student PC's only, then the number of interaction hours would be 90,000, and the cost for one hour of interaction comes down to *30,340 / 90,000 = $0.34*. There is no alternative system known that may provide the benefits possible by integrating computers in the educational system, while at the same time serving the whole community, at a cost of 34 cents per hour of interaction.

Summary

In this first part, I argued that the introduction of computers into developing countries' educational systems is not only justifiable, but also financially feasible. The second part of this paper will deal with how to avoid pitfalls, and with the proposal of a carefully considered sequence of steps to maximize the probability of success for this complex endeavor.

Part II : How?

Causes for Failure When Introducing Computers to the Educational System

It may seem strange to start with the "don't" instead of the "do", but the proposal will be more clear if the reader knows the pitfalls to be avoided.

- **Don't start your project by buying computers**. It is true that installing computers is very attractive from a political standpoint: they can be shown; they are modern; they give a feeling of progress; there are highly sophisticated demonstration programs; parents are happy; the school principal will declare that his or her school is computerized; but . . . when buying the equipment is the first step, the second step will be to discover that the teachers are not prepared to integrate the computer activities with their current educational practice. Thus the equipment will be under-utilized, a feeling that the investment was useless will start to develop, and from there it is only a small step to generaling that computers do not help in the educational process and are a waste of money that could be put to a better use.
- **Do not decide on a national project that is based on an "equalized" distribution of a small number of computers per school**. In such a situation, the time each student may spend using a computer is negligible compared with his/her total study time. The consequence will be that there are no measurable differences in student learning when compared with the previous situation, and again, the perception will be that computers do not help in the educational process.
- **Do not start a project before assuring long-term budget coverage**. Without long term budget support for operation, maintenance, upgrading, and training, the initial investment inevitably will be wasted.

Some Advice for the Successful Introduction of Computers

The following recommendations are meant for the definition of national or regional projects whose purpose is to introduce computers into the educational system in developing countries.

For reasons of simplicity, and due to the multiplicity of situations that may be encountered in practice, I will standardize the vocabulary. I will use the word **Region** to refer to the country, state, province, city, district, etc., where the computers will be introduced. This Region is ruled by an **Authority** (government, council, etc.), part of which is an **Educational Authority** (Ministry, Secretary or Department of Education).

The tasks defined here assume the existence of local talent in computer science, and local experience in computer use, but relatively little experience in the use of computers in the educational system.

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[7] When a school buys new equipment, it starts with equipment that is 0 years old and finishes using it when the equipment is 8 years old, because we estimated the life expectancy of the equipment at 8 years. In consequence, the average age of the equipment during its utilization period is 4 years. In the case proposed here, the school starts with equipment that is 0.5 years old, and finishes using it when it is 8.5 years old. Thus, the average age of this equipment during its utilization period is 4.5 years.

[8] Senior students, and experienced members of the community, whose only "payment" would be the use of the computer resources, could volunteer to teach less advantaged members of the community to use the computer and to access educational materials and other sources of information on the Internet.

Task 1: Provide a structure for the decision-making processes

In the assumed scenario, where the objective is to *introduce* computers into the educational system, we have to suppose that there are few local experts with personal experience in the area of computers in education. The first recommendation relates to the gathering and development of this local expertise. This step is critical for two reasons: first, weighty decisions will have to be taken, and the wisdom required for these decisions, upon which the success or failure of these projects depends, cannot exist without serious knowledge of the subject matter; second, without this high level of knowledge on the buyer's side, the influence of the professionals employed by the sellers (whose advice may be biased for commercial reasons), may be undesirably high.

The first step towards defining a regional plan (the **Plan**) for introducing computers into the educational system will be the appointment, by the Educational Authority, of an **Advisory Committee**. This Advisory Committee should include local experts who will contribute their knowledge and expertise in the areas of education, computers, computers in education, evaluation, economics, planning, etc. These experts should represent a wide range of organizations (i.e., the Educational Authority, related branches of the Authority - particularly in the financial aspects, universities, teachers colleges, schools of education, and educational institutions with experience in the use of computers for instructional purposes). The Educational Authority may choose to include in the Advisory Committee, on a temporary basis, members who are international consultants of recognized expertise in the area.

The first activity of the Advisory Committee should be to reinforce the knowledge of its members in the area of computers in education. This can be done by means of conferences provided by those members able to contribute to this task; by inviting local or foreign experts to give lectures or seminars; by attending relevant conferences; by creating a data bank of information that will support the decisions required to define the Plan; and by sending some of the Committee's members to visit successful projects in the Region, in neighboring regions, or even in foreign countries with long-term experience in the area.

Task 2: Prepare a plan

Once the Advisory Committee feels mature enough in terms of having developed a common base of knowledge, and has reached consensus about the main objectives to be achieved, its second activity may begin: the definition of the Plan. The Plan should define stages with short, middle and long-term objectives, with each stage of implementation adjusted according to the experience learned from the previous stages. The first stage is the most difficult from a conceptual standpoint. Additional stages deal mainly with the expansion of the previous ones to larger populations, and are usually constrained by budgetary considerations.

The first stage should cover at least the following seven points:

1. Define pilot projects
2. Create cadres of instructors
3. Provide in-service training for teachers in the schools to be computerized
4. Introduce computers in teachers colleges
5. Plan experimental evaluations of all of the above
6. Attract community support.
7. Write the terms and conditions for the submission of tenders for:
   a) supplying equipment, software, courseware (i.e., educational software), and corresponding maintenance;
   b) providing ad hoc personnel training;
   c) building or completing the necessary infrastructure.

Having listed what has to be done, it must be clear that the Advisory Committee will have its say regarding these points (and others that may be appropriate to the needs of the Region), but the actual implementation requires the intervention of executive and administrative bodies. It will be up to each Educational Authority (or even to the Authority) to decide whether to create an organization that will take care of all the tasks mentioned in this note, or whether those tasks will be distributed and assigned to different branches of the Educational Authority.

Once a Plan has been defined by the Advisory Committee, it will be presented for approval to the Educational Authority (further authorization from the Authority, particularly in the budgetary aspects, might be necessary).

Task 3: Define pilot projects

A risk that no Region should take is to rush into total regional coverage, with large-scale introduction of computers in the educational system. There are several reasons to avoid such an approach:

a) Developing cadres of instructors and training teachers is a process that requires a relatively long time, regardless of budgetary considerations.
b) Because the equipment required is relatively expensive, compared with traditional investments in education, budgetary considerations will require pacing the installation rate. In developing countries, salaries constitute most the budget, whereas equipment receives a very minor part.
c) Hardware, software and courseware should be piloted under local conditions before going to scale.

It is preferable to initiate the Plan with several small-scale pilot projects. Each project should try a different approach in a different environment. Pilots should test all the combinations of equipment (hardware, software and courseware), pedagogical approach (free, guided or mixed activities) and type of installation (laboratory-concentrated or class-distributed) in schools of high, medium and low socio-economic-status students. At the same time, the pilot projects would serve to evaluate the reliability and efficiency of the suppliers of equipment and services required. The relatively large number of pilot projects should open the opportunity for different vendors to win at least one tender in an area where each one has a relative advantage.

Each pilot project should include a carefully-designed formative evaluation, to discover the pitfalls to be avoided in the large-scale implementation, and in what measure the materials supplied by external sources satisfy the regional requirements. Furthermore, it is no less important to design a summative evaluation, which will be critical in deciding which of the pilot projects (one, several, or a combination of some of them), should be adopted as a basis for the next expansion stage.

Task 4: Create cadres of instructors for teacher training

Teacher training in the new capabilities required by the introduction of computers is a long-term process, because it must be done in a sequence of progressive stages. A “multiplier effect” is needed to reach the whole population of teachers in the Region. I suggest the following stages:

a) Select a high-level group of instructors to be the **Nucleus** upon which future generations of instructors will be developed. This Nucleus will be relatively small (as a guideline, the initial number of instructors in the Nucleus could be equal to the number of schools in the pilot projects - with a minimum of 5 and a maximum of 20). It is important to develop a common conceptual base and an agreement on the programs of study for additional instructors and for teacher training, This can be done by providing the Nucleus with a series of in-depth seminars in the areas of knowledge that will be included in the program of studies for the instructors (which will be a superset of the program of studies for the teachers). These seminars can be offered by local and foreign experts. Areas to be covered are: computer and communications systems, uses of informatics for the improvement of teaching and learning processes, evaluation of student achievement, evaluation of educational software, methods of adaptive or personalized education, authoring systems, and other topics to be decided by the Advisory Committee.
b) The Advisory Committee, supplemented by a selected group of members of the Nucleus, will define the program of studies for additional instructors, and the programs of studies for the training of the teachers working in the schools to be computerized (a part of these programs will be common to all teachers, with a second part varying according to the type of educational institution, and a third part varying according to the subject matter taught by each teacher).
c) If the number of schools in the pilot projects does not exceed a limit compatible with the number of instructors in the Nucleus, they themselves will train the teachers in the schools being computerized in the pilot projects.
d) The members of the Nucleus, individually or grouped, will conduct courses and seminars, according to the program of studies defined in b), for additional groups of instructors.
e) The instructors graduated from d), and the members of the Nucleus who want to do so, will train the teachers in the schools being computerized in the pilot projects, if the number of such schools exceeds the limit mentioned in c), and in the expansion stages of the Plan.
f) At the end of the pilot-projects stage, with more schools being computerized, some of the best instructors formed in d), with practical experience from e), will be incorporated into the Nucleus, to expand the body of instructors for additional courses and seminars.
g) The instructors will provide courses and seminars to train all the teachers in the schools being computerized, according to the expansions determined by the Plan.

h) An important piece of advice, according to our experience, is for the instructors to serve also as supervisors of the school activity in some of the schools where their trainees are teaching, not only to provide guidance, but also to verify the effectiveness of the instruction provided, and to reflect on what improvements should be introduced in the training courses.

Task 5: Introduce computers into teachers colleges

I strongly recommend giving priority in the pilot projects and in the first expansion stage to computerizing the institutes where future teachers are being educated. Most inservice teachers have not had any formal education on computer use. Inservice training for these teachers includes the difficult task of unlearning acquired teaching habits, and learning to use a tool foreign to their culture. On the other hand, if the future teachers are formed in an environment where the computer is totally integrated, they will enter gracefully into computerized schools and will serve as catalysts in those schools not yet computerized, creating an atmosphere beneficial for the expected change.

The computerization I have in mind does not consist of listening to lectures about the uses of computers in education. Future teachers should *live* the type of learning experiences that we want their future students to have. This means that the first group to be trained in the integration of computers are the faculty at the teachers colleges. These faculty should use computers in their classes, instead of talking about how they should be used. When a relevant part of a course is learned through "computer dialog", the student is developing the real experience that will guide him or her in the teaching practice.

It is true that some "computer courses" have to be included, if we want the future teachers to have a deeper understanding of the possibilities of these tools, but the objective of these courses is not to create specialists in computer science. The two courses that should be included are *Computer Literacy* and *Uses of Computers in Education*. But it is essential that when a student is learning mathematics, part of the learning process will be in front of a computer, and when studying literature, his or her essays will be typed using a word processor, probably incorporating information gathered on the Internet, and the teacher or professor will receive a diskette with the assignment, will insert comments using the same word processor, and will return it to the student for corrections. In physics, simulations will be used in class and on assignments to explore possibilities and develop hypothesis. Similarly, computers should be used as learning tools in most other subjects.

To complete the richness and the validity of this experience, each of these pilot projects should also incorporate the computerization of at least one neighboring school. Such schools would constitute "practice schools" where students and faculty of the teachers colleges would have the opportunity to experiment, to analyze the improvements introduced by the change, and to discover the pitfalls that may wait for them in the classrooms.

A pilot project in such a rich environment may become a focus of attention for university professors and researchers in the areas of education, cognitive development, informatics, evaluation, etc. This is a positive form of reinforcing the intellectual contributions to the national Plan, expanding at the same time the local expertise that will be required for the future development of the educational system.

Task 6: Plan formative and summative evaluations

This is an area where there is usually local expertise, and the task of the Advisory Committee will be to identify the best teams for this task which, in most cases, will be found within the universities. As was already mentioned, the main objective of the formative evaluation studies is to detect the weaknesses in the transformation processes while it is still possible to correct them. With this support, the summative evaluation studies, which must present the achievements of each project, will not be clouded by minor problems or unnecessary failures, which could obscure the potential of the approach being tested.

The objective of the summative evaluation of the pilot projects is to decide which, if any, of the pilot projects being tested is worth adopting for expansion. The design of this evaluation should precede project implementation and should be initiated when each project begins. Experience shows that, lacking this evaluation, the decisions at the end of the pilot projects are arbitrary and without scientific basis.

Summative evaluations should include a careful computation of all the costs incurred, because expansion of the population of users must be justified on both student achievement increases and cost-effectiveness. In other words, an approach may be rejected if the cost required for its application is too expensive compared to the educational gains obtained.

Summative evaluations are necessary, not only for the pilot projects, but also during all stages of expansion, and this for political reasons. Political change often brings about extensive changes in the administration. Usual casualties of the change are the projects initiated by the preceding Authority ("all what was done before is bad, now we will start making the correct decisions"). It is important to avoid the educational system becoming the victim of such an approach, and the best defense of a project is to demonstrate that what was done was justified on the basis of serious evaluation results.

Task 7: Attract community support

An important factor for the success of computers in a school is community support.

- Parents should be incorporated into the decision-making process. This will encourage them to feel responsible for the project success and to cooperate with project implementers and planners. Even in the case of a Regional plan, it is possible to encourage local discussions and analysis to help in establishing priorities, equipment needs, and scheduling of the installations.
- For schools in high socio-economic-status areas, it may be possible to ask for financial support from parents to purchase some of the equipment, or to add components not provided by the Educational Authority.
- The school computers may be used to provide community courses, thus enriching the variety of educational and training opportunities available to the entire community.
- The use of the computers by community members increases the contact-hours, thus improving the cost-effectiveness of the system. This, in turn, helps to justify the investment.
- Computerized diagnostic methods introduce an objective measure that may provide parents a more realistic vision of the capabilities and needs of their children and of the efforts that are needed to resolve learning difficulties.

Task 8: Requests for tenders

Once the Advisory Committee has selected a set of pilot projects, organizations or companies external to the Educational Authority will need to be contracted to provide equipment and services. This requires defining a request for tenders from regional and foreign companies. The definition for each pilot project should be as precise as possible in functional terms, but should give freedom to prospective suppliers in terms of implementation, even allowing for alternative solutions. Particular emphasis should be placed on the reliability of the equipment (electrical and communications infrastructure, hardware, software, courseware), including the response time allowed for repairs. When training of personnel is included, the tenders should determine the courses of study and the number of hours that will be assigned to courses.

With respect to the courseware, i.e., the educational software, it would be wise to start with programs that have been used extensively, have been experimentally evaluated, and have proved their success in augmenting educational achievements. In the first stage, it will be necessary to start with programs that are culturally transferable (like mathematics, science and English-as-a-second language). Once enough experience has been developed, and during the expansion stages, it will be possible to open opportunities for local development of educational software of specific interest for the Region (such as for geography, history, or the social sciences).

The final step of this last task is the analysis of the tenders received, and the selection of winners. The most delicate aspect is the assignment of weights to the different factors, because the proposals may differ in equipment, cost, conditions for payment, experience and prestige of the company, level of the personnel assigned for implementation and training, and other factors that will be discovered once the tenders are open.

Final words

The introduction of computer technology within the educational processes is unavoidable, but there are questions related to the most beneficial modes of use, how this process should start, and the rate of introduction. The steps proposed here, based on my extensive experience at the Centre, allow for a cautious and self-regulating process, where successive steps are based on the feedback received from previous steps. In this way, the possibility of the Plan to be successful is maximized, while minimizing possibile pitfalls. I have presented many of these ideas in lectures and seminars, and the reactions of the audiences indicates that teachers are ready, mature, and willing to make an effort to improve education by introducing computer and communications technology into their classrooms. The authorities must remember that success depends on high-level commitment and long term support.

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