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Abstract

In the inaugural lesson for the academic year 2004-2005, the author reflects on the role of information and communications technology in education. He raises some fundamental issues and questions whether ICT is suited to transmitting knowledge, particularly to students who are not already highly motivated to learn or well versed in the art of using and interpreting information. For his analysis, he takes as a point of reference the world of business and offers a brief look at the changes brought to the sector by ICT. To date, the main application of ICT in the business sector has focused on aiding access and processing of large quantities of information for employees and management with the principal aim of increasing productivity. In the case of education, however, little or no information is being used to improve student performance, mainly because education managers are largely illiterate in information management tools. Likewise, despite schools having more and more access to ICT, new technologies are still scarcely used as part of the teaching methodology. Once again, it is the lack of training that creates difficulties: many teachers do not have the necessary IT skills and feel uncomfortable, nor do they have the specific training needed to be able to use the new resources in the classroom. In the university sector, ICT has already made an important impact, whether in terms of teaching, research or administration; however, despite some exceptions, there are few real examples with educational models that are based on this technology and there is still an important social preference for traditional educational models.

Keywords

ICT, education, school, university, educational management, teacher training

It is a great honor for me to present the inaugural lesson of the UOC for the academic year 2004. I want to use the lesson to review critically the role of information and communications technology (ICT) in education. I try to raise some fundamental issues about that role, even questioning whether ICT is particularly well suited to transmitting knowledge, particularly to students who are not already highly motivated learn and well versed in the art of using and interpreting information. Further, I suggest that, ICT's main application in the past generation has been to raise productivity in the business sector by making it possible for workers and managers to access and process massive amounts of information. This could also be the case in education, but little or no information is being used to improve student performance in the education sector, mainly because education managers are largely illiterate in information management tools.

Introduction

For more than forty years, innovative educators have been optimistic about computer uses in schools.[1] Their vision for computers—or better, their multiple visions—have not been realized to

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1. As early as 1962, business trainers were already describing the now familiar virtues of computer-based learning experiences: «they [computers] condense extensive decision-making experience into short periods of time; they emphasize the need of reaching decisions with the incomplete data at hand; they give role-playing experience; they make possible playback of training activities; and they induce feelings of participation» (Plattner and Herron, 1962).

nearly the extent thought possible, despite a rapid fall in the price of hardware, the exponential increase in computing power, and the development of the Internet, which has opened a host of new possibilities not conceived a decade ago. The main obstacles in education to incorporating ICT into the teaching-learning process are not obvious. In this essay, we try to understand better where the problems lie.

Although some analysts in the 1960s and 1970s dismissed computers as likely to go the way of educational radio and television, others anticipated future computer learning systems that integrate «material from a general cultural data bank, from the learner's own past responses and from the discontinuous symbolic storage» into holographic, multi-person learning dialogues (see Leonard, 1968, chapter 8, pp. 140-155).

Four independent threads have run through the vision of educational computing since its inception. The first, computer assisted instruction (CAI), grew out of early work on self-scoring tests and mechanical teaching machines by S.L. Pressey in the 1920s (Smith and Smith, 1966). Further development by Pressey and others was supported by the U.S. military and incorporated electronic components as they came along. The design of later CAI programs draws heavily on subsequent research on programmed learning materials implemented in a variety of media (see Smith and Smith, chapter 10).

Computer science, and specifically programming as a school subject, became a second major thread spun by proponents of computer use in schools. American educators such as Dwyer and Critchfield (1978) and Luehrmann and Peckham (1984) felt that students could not properly use a computer without learning to program it. This made programming and computer literacy synonymous—a reasonable position at a time when application programs were virtually non-existent outside of business data processing. With the rapid expansion of available programs, computer training evolved into many different levels, from elementary computer literacy to using various packages to programming. All of these can be lumped into «vocational» ICT education.

The third thread is cognitive development and problem-solving skill. Theoretical writings such as Brown and Lewis' «The Process of Conceptualization» (1968), and Seymour Papert's *Mindstorms* (1980) still influence thinking on ICT in education in spite of the research community's inability to demonstrate a measurable cognitive gain predicted by these writers (see, for example, Pea, Kurland and Hawkins, in Chen and Paisley, 1985).

The final, and most recent, strand is Internet use for gathering information, and the role of information itself as a tool for cognitive development and improving problem-solving skill. The Internet can be used as a major medium for accessing learning software, and for networking with other learners and teachers.[2]

Today, computers are ubiquitous in developed country schools and universities and are rapidly spreading to developing country classrooms. Many learning tools have been developed for these computers, from learning games to computer assisted instruction software to teacher assisting software. Schools are connected to the World Wide Web, and students even in remote areas can have access to increasing amounts of information previously available only to populations living near large city and university libraries. Through the Web, teachers and students can access curricular, teacher training, and other learning materials, some provided by their own central or state government administrations, and others through private providers. ICT is being used in distance education to replace earlier correspondence school and educational television. The new distance education is usually Web-based.

Computers are also ubiquitous in educational administrative offices. Even before desktop computers became widely used in business in the 1980s, ministries, state offices of education, universities, and school districts used computers to store information about students and school personnel. The World Bank and regional development banks recommended computer systems to developing countries for linking local, regional, and central administrative offices and for collecting and analyzing information about system performance.

With all this computer-based technology already in school systems and universities, shouldn't we be observing some major changes in the way education is managed, the way work is organized in the education industry, and the way young people learn? Most analysts agree that the changes are much smaller than expected, yet that the potential for change is great. In this paper, I try to assess why the changes are so small, and whether, given this assessment, the potential for change is indeed as great as many analysts claim. In particular, I ask whether institutional barriers in education are responsible for impeding greater gains from ICT and what kind of public policies inside and outside of education, if any, would stimulate greater use of ICT in education.

2. Kulik (1994) categorizes six program-specific computer uses within the classroom: tutoring, managing, simulation, enrichment, programming, and Logo. (1) Tutoring refers to those situations where the computer presents material, evaluates students' progress, and determines the next presentation topic accordingly. (2) Managing refers to situations where the computer uses students' evaluations to guide or direct them to appropriate educational resources, and maintains records of their progress. (3) When a computer is engaged in Simulation activities, it generates data that meets students' specifications, then displays it graphically or numerically to illustrate relations in models of social or physical reality. (4) Enrichment is defined quite similarly, as unstructured exercises of various natures - such as games, simulations, and tutoring - that enrich the classroom experience, stimulate and motivate students. (5) Programming as a category covers uses of computers to solve solely mathematical problems involving programming languages other than Logo, while the (6) Logo category refers to the engagement of students in Logo programming, with the expected or implied gains affecting more than the mathematical problem knowledge directly addressed by the programming activity. Even in 1994, Kulik did not include Internet computer uses. Taking into account the advances spurred by the popularity and growth of the Internet, Wenglinsky (1998) suggests classifying computer and supporting technologies educational uses in five categories - support for individual learning, group learning, instructional management, communication, and administration. Forced to analyze the effectiveness of different computer applications depending on the precise program used, within individual learning support, Wenglinsky differentiates «applications that stimulate higher order thinking» (defined as learning games for fourth-graders and simulations for eighth-graders) and «applications that stimulate higher order thinking,» (defined solely as drill-and-practice activities for eighth-graders) (Maldonado, 2000).

> «With all this computer-based technology already in school systems and universities, shouldn't we be observing some major changes in the way education is managed, the way work is organized in the education industry, and the way young people learn?»

The method I use is one of comparison with the private business sector. I review the changes that ICT has wrought in businesses, compare that to what has happened in education, and analyze whether the differences are the result of something that is inherently different about educational production, of differences in capacity between the business and the educational sector, or of more effective organized labor resistance in the education sector.

What changes has ICT made in business practices?

I divide this brief analysis of ICT's influence on business practices into three parts:

- The relationship of ICT to business organization—how production and business administration has changed because of ICT.
- Changes in work organization associated with ICT—how work itself has changed and its implications for labor markets.
- Changes in worker and manager training within business organizations.

ICT and Business Organization

ICT has contributed to major changes in how enterprises organize themselves internally and externally. The most significant of these is firms' capacity to network among departments and individuals in the firm (sharing information, coordinating activity, performing operations in real time), networking among firms, and between firms and consumers. New information technologies facilitate the decentralization of work tasks and their coordination in an interactive network of communication in real time, be it between continents or between floors of the same building (Castells, 1996). Technology also contributes to increased competition because it compresses time and space (Cairncross, 2002). This has accelerated spinning off pieces of business activities that firms used to do in house, business-to-business sales, and direct business-to-consumer sales (Cairncross, 2001; Strassman, 1997). ICT has also helped make firms more efficient by making possible better control of inventories and product delivery. Just-in-time inputs and outputs have thus greatly reduced interest costs. Communications with customers is also facilitated: Cisco Systems claims, for example, that it has saved hundreds of thousands of phones calls per year because of the availability of its web site (Cairncross, 2002).

Networking has produced a new logic of the firm, where changing hierarchies and organizational forms are based on interactive connections between different layers and positions within the firm, between firms, and within the market. New information technologies allow for greater flexibility and networking that emphasizes interdependence, interaction, and constant adaptation to an ever-changing environment (Castells, 2001, chapter 3). This environment affects workers in firms, creating a culture of individual networking across companies. Individual networking is a way both to learn about working conditions, projects, and innovations in other firms and to make strategic job moves in a flexible labor market. With e-mail and the Internet, individual networking has no spatial or temporal limits. Employees of one firm, if they have the capacity and choose to do so, can access employees of other firms without ever leaving their workplace or home computer. The better networking firms are more likely to flourish because of their better information and contacts (Breshnahan, et al, 1999).

E-mail alone has made it possible to communicate in real time between far-flung sites in the same firm and among firms, their suppliers, and their customers, exchanging data and making decisions on-line. E-commerce has had its problems, but there is little doubt that the Internet has revolutionized the possibilities of doing business between firms and between firms and final consumers, particularly in creating much more efficient markets (Cairncross, 2002). Consumers can much more easily find the lowest-cost provider of goods and services. E-Bay's business model, for example, is based on creating markets through the Internet between millions of consumers and sellers.

Firms not only do more networking, they use ICT to reduce inventory costs and to raise the productivity of capital and labor through much closer control of product quality, data analysis of sales, marketing, and production process, and closer control of labor processes. The speed and comprehensiveness of collecting data on and analyzing sales and costs, combined with more flexible production structures, allows firms to move much more quickly in response to economic change (Strassman, 1997).

ICT and Work Organization

ICT has contributed to greater work flexibility in firms. Besides the famous but only partially realized concept of computer commuting, in which workers can work effectively off site, flexibility on-site means that work tasks and work time can be constantly adapted to changing products, processes, and markets. This makes workers increasingly autonomous in the work process (Castells, 1996). Firms demand higher skills, self-programming ability, individual responsibility, and a willingness to follow a flexible schedule and to work longer hours. Firms also reduce the ties that bind the firm to the worker. The goal is a «just-in-time» labor force that allows firms to increase the number of hours (and workers) when demand rises and to reduce hours when demand falls

(Carnoy, 2000). By enabling tasks to be simultaneously divided into sub-tasks, but at the same time providing the information-sharing capability needed to reintegrate tasks, employers can parcel out many jobs as they are required to be done. In practice this means more temporary and part-time work, as well as more independent contracting to the self-employed. Some workers also seek weaker ties to the firm, preferring contract work and the freedom to contract with several different companies. Flexibility pushes workers to be «agile» in their work and in their movement from job to job (Carnoy, 2000).

There is a spate of popular business books on the market today about the «best» U.S. companies and the business practices that make other countries, such as Japan, Germany, and Italy, produce such high-quality products. This growing literature makes it seem that the most effective way to increase flexibility is worker-centered, training-intensive, productivity-enhancing organizational innovations designed to make workers feel secure and part of a company team (see, for example, Peters and Waterman, 1982; Pfeffer, 1998; Johnson, 1982; and Piore and Sable, 1984). High quality work places are more attractive to highly-skilled core workers (Pfeffer, 1998). But, at the same time, many, if not most, firms use ICT to control work and cut costs rather than to enhance team production.

Most analysts of business practices agree that despite apparent biases in the data collection in many of the surveys, «between one-quarter and one-third of U.S. firms have made significant changes in how workers are managed and about one-third of large firms have serious quality programs in place or have experienced significant gains from their quality programs» (Appelbaum and Batt, 1994, p. 68). Yet some argue that the implementation of these practices represents not a single coherent strategy to build flexibility but rather a historical process that results in two very different models of work organization. The first is an «American version of lean production»; the second, an «American version of team production» (Appelbaum and Batt, 1994, p. 7).

The two models evolved over the past thirty years. Firms introduced a series of employee-involvement practices, from socio-technical improvements in the 1960s and early 1970s to quality circles in the late 1970s and early 1980s, total quality management in the middle to late 1980s, and networking in the flexible specialization model from the mid-1980s on. The various practices continue to operate side by side, even though some, such as quality circles, have been discredited in most U.S. applications. As these fads were adopted, the goal of efforts to implement change at the workplace shifted, «from the humanization of work in the 1960s, to job satisfaction and productivity in the 1970s, to quality and competitiveness in the 1980s» (Appelbaum and Batt, 1994, p. 70).

Although many of the changes in the workplace are small, involve relatively few employees, do not change the work system in any fundamental way, and invest relatively little in training, a handful of firms, such as Xerox, Federal Express, Saturn, and Corning, show a «more serious commitment» to developing strategies for continuous improvement. Such firms are American versions of high-performance workplaces. Unlike the typical business trying employee-involvement practices, high-performance firms put a heavy emphasis on worker training, spending at least 5 percent and in some cases as much as 15 percent or more of payroll on self-directed team-based systems.

More prevalent are firms that focus not on increasing productivity but on cutting costs by freezing wage rates, introducing two-tiered systems, or replacing base pay with pay for skill. For business worldwide, flexibility is as important in its ability to reduce labor costs and to increase or decrease the labor force quickly and «painlessly» as in its capacity to raise labor productivity.[3] From the employer's point of view, bottom-line improvements under lean production and team production probably look alike. They differ, however, in «their mobilization of the work force and the relative weight they give to the strategic value of human resource and industrial relations practices,» making the outcomes for employees very different (Appelbaum and Batt, 1994, p. 7).[4] Lean production is a top-down strategy, using mainly managerial and technical expertise and centralized decision making. It focuses on lowering the wage bill without damaging productivity. Team production tends to decentralize discretionary decision making and develops structures of worker representation at different levels of the organization. It provides employees with greater autonomy, more employment security, and a greater guarantee of a share in any performance gains.

ICT has played a major role both in promoting higher productivity through team production and through lean production. For example, using ICT, workers in teams can communicate, share information, and provide feedback in real time without being in the same physical location. Teams can continuously assess their performance and compare it to the performance of other teams, also in real time. Simultaneously, managers can use ICT to exert greater hierarchical control over individual work performance through monitoring techniques. Managers can check continuously on worker productivity using ICT data collection at point of work or point of sales.

ICT and Training

Using ICT in training workers and managers would seem to be a natural and important application of information technology, par-

3. In another version of this analysis, Charles Derber argues that business is transforming itself in «two fundamentally contradictory directions.» One is toward «cooperative capitalism,» which uses the ideas of worker-centered cooperative work arrangements that emphasize security and training. The second moves toward «contingent capitalism,» which emphasizes measures that reduce labor cost, including downsizing, moving operations offshore, wage reductions, and generally eliminating job security and training. See Derber, 1994, p. 15.
4. Eileen Appelbaum and Rosemary Batt support these conclusions elsewhere with surveys of workers who are involved in innovations in three occupational groups (network craft workers, semiskilled office workers, and semiskilled machine operators) in two industries, telecommunications and apparel. They find that network craft workers benefit the most from innovations through greater autonomy and self-satisfaction, but they also have greater workloads (Batt and Appelbaum, 1995).

ticularly because computers are so ubiquitous in businesses, because of the real time feedback possibilities that computers offer, and because of computer simulation possibilities. Indeed, several attempts have been made to generalize management training via computer courseware. Phoenix University, in addition to its regular degree courses, has partnered with an online corporate training company, Interwise, to make Phoenix's business courseware available for management training. UNext,[www1] which offers degrees through Cardean University, is another such effort. The UNext model is based on putting specific business courseware on line, using name business schools such as Stanford and Chicago to develop and present the courseware, providing feedback from name professors, and contracting with corporations and individual managers, who are UNext's student body. Stanford University has developed off-campus training engineering courses for credit at the Masters degree level, also provided mainly to corporate users. Some corporations, such as IBM and General Electric also have their own universities that utilize computer-assisted instruction. All these examples of computer training are effective but expensive (UNext has had enormous up-front expenses because courseware development has cost much more than expected;[5] Stanford's engineering program is more costly per student than attending Stanford).

No information is available on the cost-effectiveness of such management training. Corporations invest considerable sums in management training, much of it in-house, but much of it subcontracted to specialized management training companies that run seminars on, for example, project management, financial management, risk assessment, etc. ICT enhances such existing management training. Whether management training actually raises productivity is difficult to assess, but «good» companies apparently consider that offering such training is, at the least, a benefit they should offer their employees.

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Most employee training using ICT involves training workers to use ICT itself. Even when secretaries and clerks come to firms trained to use many kinds of ubiquitous software, such as Excel and Word, firms usually put them through their own training program. Similarly, production workers are trained to use a variety of ICT applications specific to each firm. An agency of the Finnish government successfully trained individuals living in its eastern region, hard hit economically in the post-Soviet nineties, in the use of computers for new small business applications (Castells and Himanin, 2002).

ICT in education

Most analyses of ICT in the educational sector focus on the impact it has had on pupil teaching/learning. However, as our analysis of the private business sector suggests, this focus, although obviously important, direct changes in the way teaching and learning are organized should be only part of the effect ICT has in the organization of the education sector. As above with the business sector, we analyze the role of ICT in education in three parts:

- Changes in the management of the educational sector associated with ICT.
- Changes in the work process in education associated with ICT.
- Changes in the training of educational personnel and of students associated with ICT.

ICT and Management of the Education Sector

As in business, ICT has contributed greatly to networking among schools and universities and among individuals in schools and universities. This has been especially true in the developed countries, and is now spreading to developing countries. For example, *Enlaces*—the Chilean government's educational ICT system—has made a priority of connecting rural schools to the Internet and thereby integrating them more tightly into the larger educational system, and hooking them up to the outside world. Many school districts and almost all universities now communicate internally and externally largely through e-mail.

However, this is where the similarity with business begins to fade. Schools and school districts hardly use ICT to manage the quality of output, or to raise teacher productivity, or to reduce costs through analyzing spending.

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Beginning in the 1970s US school districts regularly used computers to store student and personnel data. With the advent of high-speed personal computers in the 1990s, computers became a permanent fixture in school offices. In many school districts in

5. Carr, Sarah (2001), «Rich in Cash and Prestige, UNext Struggles in Its Search for Sales,» *Chronicle of Higher Education*, May 4 http://chronicle.com/free/v47/i34/34a03301.htm.
[www1]: http://www.unext.com

the U.S., school administrators have access to data from district computers; in many schools, individual teachers are hooked up to central data files either in the school or district office. Educational administrative offices in most developed countries have ICT, and data collection in the developed world is universally computerized.

Bilateral assistance agencies and international banks put increasing emphasis in the 1980s and 1990s on using ICT to collect educational data and to improve the administration of educational systems in developing countries, particularly through decentralizing educational offices to regions, states, municipalities, and states themselves (cite). As in developed countries, such ICT systems have been used mainly for collecting enrollment data, student attendance, basic information on teachers, and basic information on schools. In other words, ICT mainly helps administrators get a better idea of the size of the educational system, student dropout and repetition, and the number of students per teacher.

In some sense, this can be characterized as measuring the «efficiency» of the educational system and as a first step in improved resource allocation. We could liken this to inventory control in business. Educational administrators need to have basic information on student and teacher flows, probably also of school supplies, and how much the system is spending on various inputs, in order to make the most basic resource allocation decisions. Undoubtedly, ICT has played an important role in improving data collection in educational systems. It has also made these data more widely available to school personnel, parents, and the public at large through central administration Web sites, and in some countries through direct access to central or district databases by school personnel.

These rudimentary data collection functions are expanded in some countries and regions by more sophisticated quality control data, namely student evaluation data. France makes available the results of the *baccalaureat* examination, school by school, on the Ministry's Web site. These results are presented in «adjusted» form, corrected for the socioeconomic background of the students in each school. Chile also makes available the results of its national SIMCE assessments at the 4th, 8th, and 10th grade, school by school. Until 1996, these results were only available to schools; now they are also posted on the Web. States such as Texas and North Carolina are pioneers in using testing in grades 3-8 and a high school exit test to monitor individual school «success» or «failure» with students from different ethnic groups. Now many states use similar state standards and testing to monitor schools. ICT is crucial to these national and state accountability systems, both in collecting/processing the data and disseminating the results. In all these systems, however, the centralized administration uses ICT to «regulate» the system from above. It collects information from and distributes information to the different «departments» (schools), and uses the information to extract greater effort from the different parts of the system. In many countries, such top-down use of ICT to monitor performance could be extended to collecting and disseminating information on student and teacher absenteeism, student attainment (survival rates), and other variables, all on a school-by-school basis.

As mentioned above, top-down monitoring is a typical use of ICT in business applications. Many would consider this monitoring a form what Derber calls «contingent capitalism,» an effort to reduce wages and job security. The education industry is largely public, marked by permanent contracts and wage negotiations that have little to do with measures of productivity. Thus, any effort to measure educational productivity, even of firms (schools), could be considered as moving in the direction of labor «control,» of attempting to take «autonomy» away from teachers.

Such top-down administrative controls are not widely practiced even in developed countries, especially those with more decentralized systems. The single most prevalent form of centralized control is a standardized curriculum and a system of inspection. This system is «supply» based. It assumes that if the «technology» (curriculum) is fixed, and teachers are applying the technology (this is controlled by the once per year inspection), student will learn at an «expected» rate. In practice, «supply» based management leaves an enormous amount of control of the educational process in the hands of individual, unsupervised, un-evaluated teachers.

In all the cases mentioned of attempts to augment centralized control with student evaluations, the central administration uses ICT to regulate schools but leaves to schools (decentralized administrative units) the choice of method to improve performance. How much of a role does ICT play in helping schools do better, either in improving school attendance, student test scores, or student promotion? In France and Chile, for example, the curriculum is centrally controlled, and student evaluations in 3rd and 6th grade in France and in 4th, 8th, and 10th grade in Chile are all tied directly to the standard curriculum. Similarly, in many U.S. states where students are regularly tested and schools «judged» on the basis of test scores, individual student test scores are made available to schools (in France, the tests are graded by school personnel at each school). With computer capacity available to schools, it would not be difficult to assess student results against components of the curriculum. In states or countries where students are tested in every grade, it would be possible to assess student progress grade-by-grade (gain scores) in each school—provided that students stayed in a school. Patterns of incorrect answers by students could even be matched to individual teachers, thus helping teachers improve their productivity, at least in terms of test items.

There is evidence of teacher resistance to external accountability using student testing as a measure of school productivity (Benveniste, 2000; DeBray, Parson and Avila, 2002). However, teacher resistance has not impeded the application of external accountability, and there are some studies that indicate its positive effects on student outcomes, particularly in mathematics (Grissmer and Flanagan, 2000; Carnoy and Loeb, 2002).

How much is ICT used at the *school and local district level* to improve productivity? Certainly, good school administrators do use data to improve student performance, but there is very little evidence that ICT is widely used even in countries where schools have ample computer hardware and software to use available information in this way. Even more than at the central administration level, educational administrators at the «department» level are unlikely to use ICT for managing educational output or quality. Nevertheless, under pressure from state-based external accountability demands, some schools are using specially prepared software packages that allow teachers and the school to measure student gains on tests and compare test items missed by individuals and the sum of individuals in a classroom against the required curriculum.[www2] Thus, *for the first time,* some schools in states such as California are helping teachers by using ICT to track systematically how much students are learning.

The OECD has recently completed 107 case studies of schools using ICT in 22 OECD countries plus Singapore.[6] The objective of the study is to study the organizational changes wrought by ICT in «cutting edge» schools in various countries. Although the studies were focused on the organization of teaching and learning, not administrative changes, it is remarkable that little mention is made in any of the cases of using ICT to monitor teacher application of curriculum through analyzing test results. Indeed, one of the claims made in some of the studies is that the use of ICT helped shift performance monitoring to students themselves. As students used interactive modes of instruction, the software provided performance evaluation (see School 2, Singapore, for example).

Why is ICT used so much less in educational management decision-making than in private business? One argument could be that it is not being used this way because it would not be useful for increasing productivity, and that teachers, the «production managers» in education, realize this and resist applying ICT to assessing student learning gains at the classroom and school level.

A major use of ICT in business decision-making is gathering data on various aspects of business performance (sales by department or sub-department, for example) and, on the basis of those data, assessing how performance can be improved. In education, data on student performance (test data) is readily available in many schools and school districts, and these data can be related to curricular content to assess whether required or tested curriculum is being applied.

However, many educators have claimed that measuring learning through achievement tests essentially pushes schools to teach the tests, and is detrimental to a broader, more valid conception of learning (see, for example, McNeil, 2000). «Constructivist» approaches to education argue that «understanding arises as learners through prolonged engagement relate new ideas and explanations to their own prior beliefs» (OECD, 2001, p. 26). Standardized testing, many argue, fails to measure this understanding; hence, analysis of test data would lead to incorrect educational decisions, often pushing teachers who might be providing «understanding» of the material to focus on teaching test items.

The other side of this coin is that ICT used for student-centered teaching, in which student engagement, hence greater understanding of the material, may require new kinds of assessment tools. In its recent publication, *Learning to Change: ICT in Schools*, the OECD discusses recent work by Voogt and Odenthal (1999), who «have proposed a series of *emergent practices* associated with the integration of ICT in education, which imply and invite radical change. They see an emphasis on skill development and on cross-disciplinary activity more in keeping with real life, developed and accredited through formative and summative student assessment by a variety of means, including portfolios. Students will themselves accept more responsibility for their own learning and its assessment, developing expertise in the process» (OECD, 2001, pp. 28-29). The OECD study further concludes that the potential of ICT will not be realized as long as assessment is «primarily in terms of student achievement in single subjects, by means of conventional written tests» (OECD, 2001, p. 31).

Yet, this does not explain why ICT has not been more extensively used in translating traditional assessment procedures into more systematic educational improvement. It would seem logical to harness the information processing power of today's desktops to monitor student progress on curriculum-based assessments. With more workers (teachers) per supervisor (school directors and academic supervisors) than in almost any other industry, we should see ICT more extensively utilized to assess student performance gains classroom by classroom. Even if we assume that teachers would resist such external supervision, in the current accountability environment, we should observe ICT being increasingly used by teachers for assessing and improving their own performance in meeting state and national standards. The fact that little of this occurs anywhere suggests that there are major barriers to employing ICT as an administrative tool in schools.

One obvious barrier could be teacher resistance, as discussed above. But there are many ways that ICT could be used in helping teachers assess their individual work, or their collective work with other teachers in their school. Benveniste (2000) shows how external assessment was applied in Uruguay, with teacher union participation, and greater teacher involvement and acceptance at the school level than in Argentina or Chile. If teacher resistance were the main obstacle to ICT as an administrative tool, we should observe much more teacher shaped assessment using ICT. This would be analogous to business applications where labor unions are involved in defining productivity measures and worker evaluation. We rarely observe any use of ICT by teachers even for self-assessment.[7]

6. For a summary, see Venezky and Davis, 2002; for all the studies, see http://www.oecd.org.
7. There has been considerable discussion in the educational literature of teachers as practitioner-researchers. Part of the professional definition of a teacher has always included student assessment. The current literature on ICT discusses shifts in assessment to students themselves (see above) and to easing teachers' assessment of students. But there is little or no discussion of using ICT to help teachers assess their own performance; in other words, to use ICT to research how students are performing in terms of what they are supposed to be learning.

[www2]: http://www.edusoft.com/wested.html

> «If teacher resistance were the main obstacle to ICT as an administrative tool, we should observe much more teacher shaped assessment using ICT. This would be analogous to business applications where labor unions are involved in defining productivity measures and worker evaluation. We rarely observe any use of ICT by teachers even for self-assessment.»

Rather, the most important barriers appear to be the lack of data analysis skills among administrators and teachers and, until recently, the lack of user-friendly software for analyzing test results at the school level. Few school directors, their staffs, or teachers are trained in using basic ICT tools such as Excel or Edusoft and in applying them to assessing student performance in schools and classrooms even in states that have provided major incentives to schools to do so by pressuring them to approve through both moral and financial rewards and sanctions.

As mentioned above, data analyses are highly centralized, usually at the state level, and sometimes at the district level. Even these centralized analyses are relatively limited. In those countries and states that implement accountability systems, schools and districts are usually responsible for finding the means to improve student performance, yet have little or no capacity to do so. In some OECD countries, were there is a tradition of educational research, or collecting extensive data on education, and making these data available to researchers, there is considerable analysis of educational productivity. In the past decade, Chilean researchers, assisted by the Ministry of Education, have also begun doing extensive analysis of Chilean educational data on a regular basis using the power of ICT. Yet, even in these countries, ICT as a management tool has not reached into local school districts and schools.

From this analysis, the most obvious policies inside education that could stimulate more use of ICT in educational management would be widespread training of secondary school and university students in using ICT-based management tools and preparing high school students and education majors in college in rudimentary statistical analysis. By making such training part and parcel of a general educational preparation, the younger generation of teachers and educational administrators would be highly trainable in using data to assess their students' and their own work.

ICT and Changes in the Work Process in Education

The OECD school case studies discuss potential and actual changes in the work process in education with the introduction of ICT. The study concludes that «ICT rarely acts as a catalyst by itself for schooling change yet can be a powerful lever for realizing planned educational innovations» (Venezky and Davis, 2002, p. 13). It suggests that the drive to reform teaching and the organization of the teaching learning process in schools is aided by ICT, which often stimulates additional reform and innovations.

What are some of the changes in the work process in schools most facilitated by ICT? In business, one of the major changes in work associated with ICT is the shift from more traditional networking within organizations to networking between organizations. Likewise, in schools, one of the most important ways that ICT changes student and teacher work is by creating new networking possibilities directly with other schools or, indirectly, to informational data bases on the World Wide Web.

In business, ICT has transformed radically work that requires communication with others, processing information, or creating information. Similarly, ICT can change student and teacher work around teaching and learning. When computers are readily available to students and teachers are also trained to use computers, students can do a major part of their schoolwork using Web resources, preparing written work on their computers, and consulting special databases and learning software to help with their math. Teachers can also consult databases for lesson plans, can interact with other teachers to share teaching ideas, and can help students become more self-sufficient and creative in their schoolwork. The OECD study (2002) documents many cases of substantial change in teaching practices in schools with the help of ICT, even though the changes in practices were the object of conscious reforms rather than the result of introducing ICT per se.

A good example of changes in work practices is in schools in the United States that have introduced laptops for all students and have trained teachers to organize teaching around students' doing all their written assignments on their laptops. This system, introduced by NetSchools,[www3] specifically changes teacher and student work, with the purpose of improving the academic performance of at risk students. In schools we visited in El Paso, Texas, relatively low-income Latino middle school students had improved their writing skills significantly, were much more likely to complete their homework assignments (a major step in raising their overall academic performance), and spent significant amounts of time using Web resources, including special databases developed by NetSchools to help students in their coursework. Teachers in those schools were able to communicate with parents more effectively through the students' laptops, used NetSchools' databases to improve teaching, and used the teacher-student connection through the laptops to improve teacher-student communication.

Our observations in El Paso are similar to that reported in many schools in the OECD study: improved writing, greater enthusiasm about doing schoolwork, increased use of the Web, and increased use of e-mail. In some cases, teaching also changed because of the intense use of computers in the school.

But the OECD studies make a clear distinction between increased student use of ICT because it is available in the school

[www3]: http://www.netschools.com

and major changes in work practices. The OECD study concludes that «Both infrastructure and teacher competencies are required for successful implementation of ICT in a school» (Venezky and Davis, 2002, p. 40). For work practices to change significantly in association with ICT, teachers have to be much more comfortable with using ICT than most are. Even if teachers are familiar with ICT, additional technical support is needed to make ICT a tool for curricular change and changes in the teaching-learning process. The case studies suggest further that the less that ICT is part and parcel of a concerted effort in the school to drastically change teaching practices, ICT has relatively little impact on such practices.

Larry Cuban's (1996) historical research on technology adoption in schools argues that teachers have resisted technology «when the innovations under consideration contribute to, rather than alleviate, the multiple conflicting goals they are asked to carry out daily for masses of diverse children: 'maintain order for many students while creating personal relationships with each one...cover academic content and teach skills while cultivating depth of understanding in each student...socialize students to abide by community values while nurturing independent thought...' Cuban reminds us that while the purchase of technology is an administrative decision, using the technology has always been a teacher decision, based upon ease of mastery of the technology, reliability, flexibility of uses, and classroom order preservation» (Maldonado, 2000, pp. 15-16).

However, Henry Becker's (1994) analysis of the responses of more than a thousand teachers to the 1989 International Association for the Evaluation of Educational Achievement survey, found that low levels of computer use by teachers were the result mainly of low levels of computer literacy, that in turn results from a lack of resources supporting teacher use of technology. Further, Becker's study suggests that «Teachers using computers more effectively were more likely to work in schools offering high levels of teacher development on computers and having technology coordinators available to assist teachers with ongoing problems» (Maldonado, 2000, p. 16).

These are some of the key elements for understanding why we observe rapid increases in the number of computers per pupil in schools throughout the world and especially in OECD countries without observing significant changes in educational work practices. Many years ago, Henry Levin and his associates at Stanford University analyzed the cost-effectiveness of computer-assisted instruction (CAI) in a number of U.S. schools comparing it to other interventions, such as peer tutoring. Levin et al found significant test score gains associated with CAI but also high costs of implementing it. They estimated that only 10 percent of the total cost of CAI was in the hardware and the rest mostly in the wages of highly-skilled ICT trained teachers and ICT technical support staff (Levin et al, 1985). In an informal study we did of four schools in California's Silicon Valley in 1999, we found that despite high computer per pupil ratios, schools had invested little either in training classroom teachers to incorporate ICT into their daily work or even in additional computer trained teaching staff to support ICT use as an add-on to regular classroom activities.

Therefore, beyond putting computers into classrooms or into computer labs and employing them for (a) training pupils in computer use; (b) some add-on Web-based activities; or (c) having pupils use student-centered, individualized learning games, changing teaching practices around ICT requires a major investment in developing new teacher ICT skills and in training teachers to teach differently using ICT. The downside of this proposition is that in many countries teachers lack adequate content knowledge to teach even basic academic skills to primary school pupils; thus, providing this kind of training to teachers is a tall order. The upside is that as a new generation of teachers, raised as children on ICT use, enter the schools, ICT training costs will fall substantially. Indeed, eventually, as training and hardware costs fall, we can assume that teachers will use ICT as easily as they use books today. Nevertheless, unless teacher content knowledge also increases substantially, we may see little, if any, increase in student achievement beyond the improvements facilitated by computer-assisted drill and practice.

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The Academic Benefits of Using ICT in Education

Research on cognitive impacts addresses the effect of ICT both on what students think (intellectual content) and on how students think (intellectual competence). Studies of the effect on intellectual content focus on the relative advantage of ICT in the delivery of instruction in traditional subject areas, and measure the effect in terms of standard subject area achievement examinations. Studies of how students think, researchers are primarily concerned with postulated side-effects of ICT on students' reasoning skills.

In the mid-1980s, a number of meta analyses (Kulik, Kulik and Cohen, 1980; Kulik, 1983; Kulik, Bangert and Williams, 1983) found consistently positive and moderately high achievement gains at all educational levels from computer mediation in traditional subjects, especially math. These studies also suggested that CAI was more effective in lower educational levels and with lower-achieving students (for an extensive review of these studies, see Carnoy, Daley and Loop, 1986). CAI drill and practice applications that *reinforced* traditional instruction were much more effective than tutorial applications that *substituted* for human instruction.

More recent research include Wenglinsky's (1998) study using national Assessment of Educational Progress (NAEP) data on student mathematics achievement, computer use and teacher computer preparation for national samples of 6,227 fourth-graders and

7,146 eighth-graders. Wenglinsky found significant gains for students in cases where ICT was used for «applications that stimulate higher order thinking»—defined as learning games for fourth-graders and simulations for eighth-graders—in teaching the math curriculum for teachers who had received professional development in computer use (Maldonado, 2000, p. 17). Wenglinsky's results also showed that students that used computers for drill and practice, controlling for other variables, did worse than the control group, and that the more time students spent doing «lower order» drills, the worse they did on the NAEP. This contradicted earlier findings (Kulik, 1994). But Wenglinsky's study does not correct for selection bias—those students doing more drill and practice may have also been the students weaker in math—and he was only estimating math achievement at one point in time, not gain scores, as estimated by many of the studies Kulik reviewed.

A study of West Virginia Basic Skills/Computer Education Program, one of the most comprehensive and long-lived statewide educational technology programs within the US, Mann, Shakeshaft, Becker and Kottkamp (1999) used multiple regression analysis to show that the sum of effects of the program (largely drill and practice) «accounts for 11 percent of the total variance in the basic skills achievement gain scores of fifth-graders, the first class to have had consistent exposure to the program across their entire school experience. Lower achievement students, and those without home computers, experience the sharpest raise in scores. The best predictors for achievement gains were prior positive attitudes towards the technology by both teachers and students, consistent student access to the technology, and teacher training in the technology» (Maldonado, 2000, p. 21).

Studies assessing the effects of ICT on *how students think* have not been nearly as positive in their findings. A major two-year study of LOGO, for example, found no significant effects on cognitive skills (Pea, Kurland and Howkins, 1985). More recently, with the introduction of the Internet, student use of ICT in schools is increasingly Web-based, so how student think, if it is altered at all, is mainly influenced by Internet use. The OECD study of ICT use in schools notes that «According to a recent study of 500 [Internet] sites, only 28.2 percent included inquiry-based activities and only 5 percent included problem solving or decision making … In contrast, 42 percent of the sites featured rote learning and over 52 percent mainly involved information retrieval» (Venzky and Davis, 2002, p. 33). Based on responses from the various school reports, the OECD study suggests that, «in general, the quality of instruction was *not reduced* through ICT applications such as searching for information on the Web» (ibid, p. 33).

Thus, contrary to idealistic notions of changes in student thinking—particularly the enhancement of problem-solving skills—through ICT in schools, there is little or no evidence that this occurs, Wenglinsky's results notwithstanding. On the other hand, ICT may be rather effective in increasing student performance on standardized tests by employing CAI, especially in conjunction with teacher-student interaction around imaginative drill and practice software (improving what students learn). SCORE!,[www4] a private storefront chain of after-school CAI-based learning centers located mainly in California has apparently been very successful in raising student achievement on traditional math tests by using an individual learning, self-paced, drill and practice learning software.

If this is the case, ICT may not be widely incorporated into more sophisticated use in schools and universities because it does not produce observable changes in how students think. Although this conclusion is complicated by the possible negative interaction between relatively low levels of computer ability in the teacher corps in most countries, this is a fact of life. Without better trained teachers, ICT is probably ineffective in teaching higher level skills.

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Using ICT as a supplement to improve test score results, may, however, be seen to be more effective than traditional teaching alone, hence is much more applied. Similarly, using computers to teach middle and high school students to become familiar with standard ICT business applications is also fairly ubiquitous for the obvious reason that it contributes directly to students' ability of earn a livelihood.

However, an important caveat in all these conclusions is that there is relatively little research on the academic effects of student Internet use, and this is becoming the dominant form of ICT in schools. There is little doubt that the Internet allows for more student independence in learning, but does this benefit all students in similar fashion? Are the effects on learning significant? These are important questions for future research.

Work process changes at the university level

We can assume that the absence of computer skills we observe in primary and secondary schools is much less of a problem at the university level. Thus, we should observe much greater ICT-associated changes in the work process in higher education.

Indeed, we do observe such changes at the university level. To a much greater extent than in lower levels of education, university teachers use e-mail as a major form of communicating with colleagues, and increasingly, with students. Many courses are posted on the Web, and, increasingly, teacher assignments and student work is Web-based. Research and teaching networks have been greatly extended—for professors at many universities, these networks are worldwide. These represent important changes in work processes in universities and they are widespread. The fact that teachers (and students) in higher education have greater ICT

[www4]: http://www.score.kaplan.com

skills, hence higher education is characterized by greater use of ICT and work processes are more likely to be affected by ICT, seems to confirm that the main barrier to changing work processes in lower levels of schooling through ICT is lack of ICT skills.

Because university faculty use ICT extensively to handle their correspondence and to do their writing, universities have used ICT to reduce the numbers of secretarial staff, shifting considerable clerical work to professors and some to students.

We can also observe that universities are much more likely to use ICT-based data analysis to evaluate themselves both financially and in terms of cost-effectiveness. Administrative analysts at universities are much more likely than at lower levels of schooling to assess university performance, the effectiveness of faculty in terms of numbers of students taught, years to degree, and student satisfaction.

Yet, it is also important to note that despite characteristically greater ICT skills of university personnel and the greater degree of data analysis for administrative purposes, the core of higher education and particularly elite higher education remains solidly rooted in standard work arrangements (traditional teacher-student relationships, teaching methods, and professorial control of curriculum). Most professors still teach in classrooms, present their material in lecture form, and ask for written assignments, even though these assignments may be sent to the professor in electronic form. The highest form of academic work, the Ph.D. dissertation, is still a written book, supervised by a thesis advisor in a series of personal meetings. Indeed, one major reason why U.S. universities are considered the best in the world is because of the much more frequent and regularized professor-student contact in the U.S. than in the closest competitors, European and Japanese universities. American liberal-arts colleges, whose graduates almost universally attend graduate and professional schools, epitomize this traditional approach to higher education of personal spoken contact between professor and student.

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This apparent contradiction—the spread of ICT-driven work changes, such as e-mail and Web-facilitated teaching and learning and the continued persistence (and glorification) of very traditional teaching and learning—raises an important point about barriers to ICT use in education that go beyond teacher ICT skills. Is there something inherently different about the production of academic skills (cognitive learning) that puts limits on ICT use—even as a catalyst—in improving educational delivery? If we consider high quality higher education as a model for lower levels of education (if we could afford to spend as much per student on lower levels as we do on university), then we probably still believe that the «best» learning takes place where a professor (teacher) is able to have direct personal interaction with students over a period of time to analyze and discuss subject matter that the professor (teacher) judges to be important. The «best» professors are usually those that have greatest intellectual command over the subject matter, often introducing students to an unusual and original way to view the subject matter.

One question is: to what extent can ICT reproduce this «best» learning? Stanford University's electrical engineering program has long made available an off-campus version of its courses to students employed at local high-tech firms such as Hewlett-Packard. Off-campus students can get a masters degree equivalent to an on-campus degree. Originally, the «distance» course was based on students gathered in a group viewing videotapes of on-campus lectures with a Stanford graduate student facilitator, stopping the tape to ask questions and discuss certain points. Today, students view the tapes at their computer workstations (located at many different sites), and they ask questions and discuss issues via videoconference. The course costs more per student off-campus than Stanford tuition, but students taking it have traditionally gained better grades on the course tests than on-campus graduate students, suggesting that highly-motivated graduate students can do even better using this method than attending lectures and living on campus.

Phoenix University[8] in the U.S. and the Open University of Catalonia, (UOC) take «distance» education much farther. In both cases, students take Web-based courses developed by the university specifically for students who cannot come regularly to classes at a fixed site. Students do the course work according to their schedules. They send their completed assignments electronically to the university where they are graded by professors and their assistants. At UOC, each student is assigned a tutor professor to guide them through their coursework toward the degree and a consulting professor (often hired from other universities) for each course. UOC also has a few interactive virtual seminars available to advanced students. Both Phoenix and UOC grant degrees—UOC offers undergraduate and graduate degrees in many subjects, including engineering, computer science, law, psychology, and even a Ph.D. in the Information and Knowledge Society. Web-based training for business managers is also available, as well as extension and summer courses and a pre-university preparation course for adults over 25 years old.

8. The University of Phoenix was founded in 1976 and is the nation's largest private institution of higher learning. At May 31, 2004, over 100,000 students attend classes in any one of hundreds of campuses and learning centers located in more than 20 states, Puerto Rico, and Canada. Additionally, over 109,000 students attend via the Internet through the University's Online campus. This is by far the fastest growing part of Phoenix's business.
See http://www.university-of-phoenix-adult-education.com.

However, there are several important differences between distance universities such as UOC and Phoenix. Situated in a European context, UOC is non-profit and subsidized by the Catalan government. Although private, in the European context it is subject to regulation by the Catalan government, namely in terms of course content and the degrees and courses offered. Phoenix, on the contrary, is a for-profit university. Its degrees are accredited by an association of universities in the Midwest United States, but it does not have to offer a broad range of courses and degrees; rather Phoenix's offerings are based purely on profit considerations. Hence, its main offerings are in business, nursing, computer technology, and education (masters degree and non-degree teacher in-service courses).

The models represented by Phoenix Online and UOC are completely new versions of other distance education institutions, such as the UK's Open University. UOC, which is entirely Web-based (most of Phoenix's students are not «on-line» students), is the most recent and the most purely ICT. It represents the greatest change in the definition of a university. The work process in on-line institutions is clearly different from the traditional university. Professors do not teach traditional classes at fixed sites and at fixed times. The fact that many of the professors working at distance universities are doing so as a second job is part of the trend to more flexible work, and is only made possible through the virtual nature of the courses. Students study at their own pace and whenever they have time to do the work. They have access to the university mainly through the Web, and e-mail. All contact between professors and students is virtual, not face-to-face. In many ways, particularly when compared with traditional European universities, the professor-student contact at UOC is probably more intensive and more direct, despite its virtual nature. Student success depends even more than in traditional universities on self-discipline and self-direction. The major, if not only, form of student-to-student interaction is through e-mail.

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One of the hoped for features of virtual universities would be lower costs per students while simultaneously achieving equal or better academic results than traditional higher education. From the institutional side, however, costs per student at Phoenix Online seem to be about the same as or higher than in large state universities, and costs at the UOC are also no lower than and may be higher than in traditional Catalan and Spanish universities. The main saving is in private costs, since students attending UOC or Phoenix are bound to be working full time while taking on-line courses for credit. The savings in income foregone can be used to pay the relatively high tuition rates at Phoenix, or can be simply passed on directly to students by charging low tuition, such as in UOC. From a private standpoint, completing a UOC degree therefore yields a very high pecuniary rate of return even if the additional income earned from acquiring the degree is lower than to a traditional degree. But from a social point of view, the payoff may be lower, depending on how great is the additional cost of a UOC degree.

Virtual universities require much more analysis by researchers, not only in terms of what students learn (the limited studies done to date at UOC suggest that they learn the material just as well as students in traditional universities), but how employers regard the degrees from such universities, and the relative pay of students graduating with virtual university degrees. Surprisingly, little is known about the economic value of distance university degrees, even though institutions such as the UK's Open University and its spin-offs around the world have been in existence for many years. The main benefit to individuals and to society is probably that people can work while «attending» university, thereby reducing the cost of attaining a degree.

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Is this the future of universities in world where university degrees are needed to get good jobs, and many people already in full-time jobs would benefit from a university degree? Some, such as Teachers' College Columbia's president, Arthur Levine, believed it is. He and many other elite university presidents moved to develop on-line extensions of their universities for adult lifelong learning, in some cases degree granting, and for additional revenue. As it turned out, these efforts generally failed (Kirp, 2003). For example, Columbia University lost more than 20 million dollars in its attempt to develop an online extension university. The main «successful» example in traditional universities and the Web is that of the Massachusetts Institute of Technology, which has put its entire curriculum on-line with free access to anyone wants to use it, much as the LINUX operating system was made available to all, free of charge. MIT made this move «profitable» by raising tens of millions of dollars from foundations to finance its open curriculum, in hindsight a much cleverer approach than the profit-seeking efforts of other institutions.

Further, some higher educationists believe that the «twinning» of developed country universities with developing country institutions through on-line courses and degrees could revolutionize higher education worldwide, raising its quality markedly in countries with a shortage of high-level staff in many of the crucial fields of university education. Some developed country trade representatives are pushing hard in the WTO for freeing up trade in educational services are part of such distance education projects of developed country universities (OECD, 2002). Indeed, the UOC itself, as well as established centers of higher learning such as Mexico's Monterrey Institute of Technology, are creating satellite centers in South American countries. They may be even better positioned than developed country institutions to enter Spanish-speaking markets.

However, the UOC experience with costs suggests that good quality virtual higher education may be more expensive than traditional university education. Obviously the quality of the courseware, the number of students interacting with a course professor, the quality of the professors guiding the students through their degrees, and the quality of the course professor would all enter into raising or lowering the cost per student in virtual universities, just as they affect costs in traditional universities.

What might be the barriers to changing the work process in higher education toward virtual universities? We have established that ICT skills are much less an issue in higher education than in primary and secondary education. But if there is no clear *advantage* to taking a virtual university degree or from learning on-line, then many students—particularly younger students—would continue to prefer to attend traditional universities to interact with other students, have face-to-face contact with professors, and to learn in a class context. Much of the university experience for younger students is social contact with other students. It is difficult to assess the value of that experience, but we do know that important personal bonds result from the student experience, and that these contacts and bonds form work and social networks throughout adult life. Similarly, personal contact with students is important for many professors—indeed, this is why many teachers like being teachers. Thus, the value of ICT for students and professors who want this type of social experience is to facilitate and broaden their teaching and learning, but within the context of traditional university professor-student relations. Ultimately, then, taste for a particular teaching learning context may be the greatest barrier to the expansion of virtual universities. And this choice may also be rational in terms of the total learning experience and the economic payoff to that experience.

Thus, it seems likely that in the future, we will observe a *spectrum* of ICT use in universities, from little use in traditional classrooms and universities, to a hybrid of traditional university teaching mixed with partial virtuality for full time, residence students to much greater virtuality for universities with a mixture of working and residential students, to totally virtual universities for individuals already in the labor market who want university degrees but need to continue working.

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ICT and Teacher and Administrator Training in Education

Teacher in-service training is a huge industry in most OECD countries. California alone spends about $400 million per year on in-service training for teachers. In the U.S., school districts contract with a myriad of independent small contractors who operate teacher-training businesses delivering varying quality of product. In other OECD countries, such as Italy, much less is spent on in-service, but it is required for teachers who want to move up in pay. In the OECD mission to Italy in 1998, participants heard testimony that because the training is viewed by teachers as required to earn the points needed for pay increases, relatively little learning takes place in these in-service courses.

Private firms such as Sylvan quickly saw the potential of ICT as an in-service training medium for teachers, and this now forms an important part of Sylvan's extensive ICT learning systems. Another example of ICT teacher training is Teachscape, another private company that produces Web-based pedagogical training via streaming video in the form of documentaries of model teachers. The market for this Web-based training is U.S. school districts that pay for individual teacher access to Teachscape's interactive program. Teachers watch the documentaries and attempt to model their own teaching on the key elements shown. They can interact with other teachers, and trade experiences and critiques. The premise of the training is that better pedagogy leads to more learning and better student outcomes.

An entirely different approach to teacher improvement is Web access to course content, lesson plans, and networks to other teachers. This «data base,» or content, approach, is used by NetSchools and the IBM Foundation. Both of these organizations focus on using ICT as teacher training for improving course content rather than improving pedagogy. This is analogous to training sales people mainly by teaching them to be more knowledgeable about the product rather than by training them to give a more polished delivery. In countries where teachers' knowledge of subject matter is not especially great relative to what is required to produce world class, say, math education (most developing countries would fall into this category, as well as the lower tail of the quality distribution of teachers in, for example, the United States),[9] access to a database full of information about how to make subject matter understandable to students could be an effective way to improve teaching. It is also appealing to teachers, who are more likely to use ICT if it save them time and simultaneously helps them perform their jobs more effectively (Cuban, 1996; Cuban, 2001).

Remarkably, there is hardly any ICT based management training for school administrators. In private business, most in-firm training outside of neo-corporate societies such as Germany, Holland, Austria, or the Scandinavian countries is for managers rather than workers. In education, managers are the least trained personnel in the industry. In private business, private training firms—now heavily invested in ICT-based training—focus on management. But in education, private firms focus on teacher training, in part because education systems allocate almost all their training money to in-service teacher training and none to management training.

Conclusions

Education everywhere in the world, including in the OECD countries, is largely publicly financed and publicly provided. ICT is rapidly becoming ubiquitous in developed country public schools and is spreading in developing countries education systems. As is evidenced by the OECD's recent case studies of schools in 23 countries, ICT is being used in many imaginative ways to teach higher order reasoning skills. However, the case studies also reveal that the most common use of ICT in schools—even in these «cutting edge» ICT schools—is student networking and data collection through the Internet and student use of text editing programs to produce and edit their written work. Whereas these uses may increase student motivation to learn science and social studies and to write, there is little evidence that student higher order learning improves significantly as a result of ICT. On the other hand, there is much more evidence that computer assisted instruction improves achievement on traditional math tests, and—no surprise—that increased student use of ICT increases ICT-related vocational skills.

There are still many unanswered questions regarding the role of ICT in education. In this paper, I asked why, with the much greater availability of ICT in schools, ICT seems to play such a minor role in the teaching/learning process in most schools. OECD case studies notwithstanding, relatively few schools in the countries studied have made ICT central to their educational process.

Larry Cuban's historical research suggests that classroom teachers resist any technology that does not facilitate their achieving the diverse goals the educational system sets for them. Teacher resistance to ICT may be an important reason for ICT's «failure» to permeate teaching. But teachers may «resist» ICT because they do not feel comfortable using it except for the most rudimentary operations, and resources are not available to train them in teaching methods that incorporate ICT into everyday teaching. Furthermore, for ICT to permeate teaching, students may have to have access to computers on a scale only available in a limited number of schools (every student with a computer) and to databases that are now largely proprietary. I therefore conclude that the general lack of teacher computer skills is the single largest barrier to the spread of ICT-based learning in schools. Yet, it is important to note two additional facts: First, that the training required to make large numbers of teachers computer-savvy is not cheap. It requires substantial resources, as the NetSchools experience suggests. Second, even if the teachers were highly trained in computers and each student provided a computer, teacher content knowledge might still be insufficient to produce significant gains in student achievement, and student interpretive skills might be inadequate to sift and judge the vast amount of new information they might find on the Internet.

I have also argued that the most common use of ICT in business—to increase productivity by analyzing employee performance and working with employees to improve it—is a highly underdeveloped form of management in education. Again, I claim that the main obstacle to educational managers (or teachers) analyzing the vast amount of data on student performance is lack of skills in using ICT for data based management. Management training in education is almost entirely devoid of data analysis or the use of ICT for data based management.

In universities, many, if not most, teachers and administrators do have these skills, and, as a result we do find that teaching, research, and administration have been much more generally affected by the information revolution than primary and secondary schools. However, despite some innovative alternative forms of higher education that are Web-based, from Phoenix University, to the UOC, to Cardean University, to the attempts by many American universities to provide access through Web-based education (e-learning), there has not been a mad scramble to dismantle the traditional university. Indeed, again despite the much greater flexibility of e-learning, traditional universities are still favored by most students, in large part because of the social role they serve. Thus, an important barrier to more intensive and pervasive computer learning in schools and universities may be a private and social preference for traditional classroom education.

Perhaps the greatest potential for ICT in education is in educational management and the improvement of «traditional» teaching. Teacher access to lesson plans, networks of teachers, pedagogical techniques, and other forms teaching assistance in specially designed data bases creates many possibilities for teacher self-improvement. Combined with easily estimated student achievement gains available to teachers and school administrators on a regular basis, would allow for constant assessment of student educational progress and teacher and school performance against established norms.

Most educators are coming to an old conclusion: it is difficult to improve learning in schools by whatever means without improving the teachers' knowledge of subject matter (including ICT

9. There has been considerable research on the variation of teacher «quality» in the United States. For a recent study, see Lankford, Loeb, and Wykoff, 2002.

skills). Teachers cannot develop higher order thinking skills in students without having acquired such skills themselves and to a much greater depth than the material they are supposed to teach. ICT use, just like anything else in schools, depends on teacher skills. And this holds in universities as well as primary and secondary schools.

«The policy implications of my analysis point toward much more emphasis on bringing teachers and educational administrators into the information age with computer training and with more teacher-oriented, easily accessible data bases that help teachers in their teaching.»

The policy implications of my analysis point toward much more emphasis on bringing teachers and educational administrators into the information age with computer training and with more teacher-oriented, easily accessible data bases that help teachers in their teaching. Part of the «problem» of teacher and administrator discomfort with ICT may go away as the average age of teachers and administrators falls. Younger teachers, raised in the information age, will require much less training. The issue with ICT and educational management training is more complex, since the skills required are not those acquired just by spending more time with computers as a child. Our observations in schools suggest that the type of management training now available to private corporate management should be an integral part of educational administration training. Since little public money is available for administrative training in education, as contrasted with teacher in-service training, it is less likely that such management training will be supplied without a major shift in thinking about educational administration in government policy circles.

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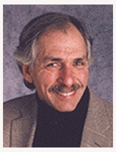

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