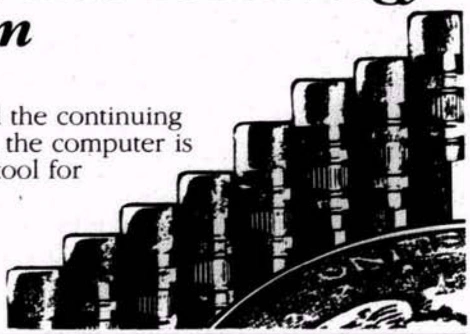
Productivity and Technology in Education

With budget cutbacks and the continuing loss of qualified teachers, the computer is potentially our strongest tool for improving productivity.



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Productivity may be the central problem for education and educational research for the remainder of this decade. Failure to deal successfully with this issue must inevitably lead to continued reduction in the real income of teachers and the loss of competent teachers to higher-salaried jobs. The result will be declines in student achievement, followed by lagging economic growth for the nation. Some early signs of these conditions are already visible.

Unfortunately, we presently lack the empirical tools needed to improve productivity. In the short term, educational policy makers must be guided by experience, judgment, and opportunity. Options include larger classes, reduction in administrative staff, reduction in nonessential instructional and extracurricular activities, delayed and smaller increases in teacher salaries, and the substitution of lower-cost capital inputs, say TV, for higher-cost labor inputs. Providing information to education policy makers on the productivity implications of these options is a task for educational research.

The key to productivity improvement in every other economic sector has been technological innovation. Effective application of modern information technology in schools is therefore a critical subject for research.

Lagging Educational Productivity

A picture of lagging educational productivity and its implications for schools and the nation can be quickly sketched. There are those who believe that the nature of the present educational system makes productivity improvement impossible. In a widely cited article, William Baumol (1967) stated the case in the following way:

> If productivity growth per man hour rises cumulatively in one sector relative to its rate of growth elsewhere in the economy, while wages rise commensurately in all areas, then relative costs in the nonprogressive sectors must inevitably rise, *and these costs will rise cumulatively and without limit* [emphasis in original]. For, while in the progressive sector productivity increases will serve as an offset to rising wages, this offset must be smaller in the non-progressive sectors. . . . Thus, the very progress of the technologically progressive sectors inevitably adds to the costs of the technologically unchanging sectors of the economy, unless somehow the labor markets in these areas can be sealed off and wages held absolutely constant, a most unlikely possibility.

Baumol then explicitly applies his theory to education:

> . . . [the model] suggests that, as productivity in the remainder of the economy continues to increase, costs of running educational organizations will mount correspondingly, so that whatever the magnitude of the funds they need today, we can be reasonably certain that they will require more tomorrow, and even more on the day after that.

Strong empirical support for Baumol's theory is lacking so far because the assessment of educational productivity is hedged by serious conceptual and practical difficulties. The first is a lack of identification and agreement on the goals of education, primarily because these goals tend to vary over time and for different populations. Second, we do not have adequate ways to measure the attainment of complex academic skills and affective outcomes. Most productivity studies are impaired by their reliance on inadequately defined and measured outputs. Third, research has thus far failed to establish many valid connections between (factor) inputs and the outcomes of education. We know little, for instance, about the effects on educational achievement, of adding graduate courses and degrees to teacher training, or consolidating school districts.

Despite the difficulties of measuring productivity, there is evidence that the increased cost of schooling can be attributed only slightly to improved quality, and that educational productivity has lagged behind productivity growth in the economy as a whole and in most segments of the economy. Woodhall and Blaug (1965) found that the productivity of the British university system declined between 1938 and 1952, and declined somewhat more rapidly between 1952 and 1962. They also found a decline in the productivity of British secondary school education in the period 1952–1962 (Woodhall and Blaug, 1967). In a more recent study, O'Neill (1971) found a productivity decrease of 0.1 percent to 0.3 percent per year (depending on output measure employed) for U.S. universities and colleges in the period 1930–1967, with some variation over time, and between public and private institutions.

Thus, in contrast to large and sustained productivity increases in most of the economy during the same period—averaging 2.8 percent per year between 1919 and 1948, and 4.0 percent per year between 1948 and 1966 (Nadiri, 1970)—the education sector registered not just lagging productivity gains, but actual productivity declines. Although these productivity studies have a variety

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of shortcomings and fail to cover elementary school education, and although economists continue to debate the "true" rate of increase in total factor productivity in the private sector of the economy during this period (as opposed to growth in capital and labor inputs), it seems fair to conclude that educational productivity failed to rise at all in the period studied, and *substantially lagged behind productivity growth in the private sector*.

As teachers try to maintain their relative economic position in the community, lagging educational productivity translates directly into rising cost and educational expenditures. In the U.S. the federal government's growing contributions to education expenditures have cushioned the effect of rising educational costs on the taxpayer's reaction, but not altogether. W. L. Hansen (1981) reports a decrease in real terms of academic salaries, averaging just under 3 percent per year from 1973 to 1981, in U.S. institutions of higher learning. Recent teacher layoffs and strikes at the start of each school year testify to the tension created by lagging educational productivity when offsetting factors such as increasing student enrollments and growing federal support of education are not present.

In light of increased economic competition among nations and the accelerated restructuring of the American economy, our nation's education system must improve its capacity for producing students equipped with writing skills, critical and quantitative thinking skills, and the specific skills and knowledge of mathematics and science required by our increasingly technological business, service, and information industries (Ginzberg and Vojta, 1981). Getting more for less increase may well sum up the problem of productivity improvement that now faces American education.

Framework for Research on Productivity Improvement

Productivity improvement may be realized either by reduction in input without degradation in system output, or by enhancing system output without appreciable increase in input. In the language of economics, at any point on the production curve describing a process, it is generally possible to realize efficiencies by improving the mix of labor and capital input that will produce the same output. Or, technological innovation can create an improved production process by which increased output can be realized from the same level of input. How to achieve improvement in education productivity, whether by changed labor and capital input or by technological innovation, should be a matter of concern to educators. Educational research can help. There have already been described here a set of important and difficult issues concerned with a better understanding of schooling outcomes and their measurements; and of the educational process, or the causal relationships between educational input and outcomes.

One set of issues that will not be discussed much here concerns alternative forms of educational management and organization for structuring new incentives for practitioners and learners. In this category belongs the variety of earlier attempts to introduce into the educational system the efficiencies associated with a competitive market; that is, performance contracting and education vouchers. Community control, alternative schools, and new arrangements for postsecondary education represent other possibilities for making the educational process more responsive and productive.

Another set of issues concerns the reallocation of school input. This includes such options as variations in the degree of physical centralization, amount of student time in school, procedures for awarding grades and credits, and the mix of such instructional variables as size of class, use of capital input, differential staffing, and so on.

Considering lagging educational revenues and the microelectronics revolution, the rest of this article discusses the two strategies of reducing input and technological innovation to improve educational productivity.

Reducing Input

The history of educational resource use since World War II shows a steady increase in the number of middle managers and the amount of teacher specialization, and a steady lowering of student-teacher ratios. This trend is particularly striking in the absence of data that link these increased inputs to improved student achievement and in light of considerable research that shows mean student achievement measures to be indifferent to a very substantial range of variation in teaching techniques and teacher-student ratios. This result is often summarized in reports of empirical studies with the phrase "no significant difference." Research should assist educators in their search for ways to produce, at lower costs, substantially the same mean student achievement that we now realize with reduced input.

The possibility of using mature technologies to partially substitute lower-cost for higher cost input is addressed by Jamison and others (1974):

> The key to productivity improvement in every economic sector has been through the augmentation of human efforts by technology, and we see no reason to expect a different pattern in education. We use the term *augmentation* deliberately here to set aside the notion of technology's replacing teachers; the purpose of the technology must be to make teachers more productive, not to replace them completely. The problem is not that of replacing teachers but of *successfully* using the technology to improve productivity. The overwhelming majority of the efforts devoted to developing educational technology have been directed toward improving quality with little regard for cost. We have learned much from these efforts, primarily in ITV (instructional television) and CAI (computer-assisted instruction), and now have a background of experience, program material, and evaluation that is quite substantial. Yet there has been widespread disillusionment with where educational technology is today that results, by and large, from the pattern of no significant difference findings that we have reported in this paper. Furthermore, because technology has been primarily an add-on to enrich the individual student's experience, there are few, if any, examples one can point to where it has improved system productivity. . . . Technology has not yet proved that it can play an important role in American schools.

If these statements evoke pessimism that some forms of educational technology can little improve educational outcomes, it should not deter careful empirical studies of the use of capital input to improve productivity by reducing costs.

Improving Educational Productivity by Technological Innovation

Among the information technologies that may be used to improve educational productivity, perhaps the most unique is the small personal computer, which schools are acquiring in substantial numbers. With suitable educational software that can individualize instruction, the computer holds powerful promise for improving student learning. With declining costs for hardware (if not necessarily for software), it can be a productivity-enhancing tool for teachers.

A survey by the National Center for Education Statistics (1982) reveals that the number of small personal computers available for student use in schools is 96,000. This compares with 31,000 in fall 1980 (NCES, 1981), 18 months earlier, and represents about a doubling every 12 months. The number of computer terminals increased from about 21,000 to 24,000 in the same period. Of the 82,000 U.S. public schools, some 29,000 have at least one small personal computer or computer terminal for instructional use by students. Impressive and potentially important as these figures may be, the data from which they are drawn, together with other school and industry data, suggest some equally important failings for our purpose.

1. The current inventory of educational computer software available for student learning, both public and privately held, is inadequate in quantity and quality. Some schools at least, and perhaps many, are investing in hardware without a realistic plan for acquiring software, which is left as an exercise for the teacher.

2. Software available from educational publishers is largely for basic skills instruction, and is expensive, often approaching the price of hardware. If schools continue to spend only a small amount of their budgets on printed materials of various kinds, books, hardware and software, the amount of software they acquire is unlikely to increase much annually; the unit price of software is unlikely to decrease much; and publisher investment in the development of new software is unlikely to increase from its present small size (Melmed, 1982).

3. Software for student learning available from new developers is substantially less expensive than that of established educational publishers, but does not often conform to schools' instructional objectives. These developers also lack marketing and distribution systems targeted toward schools. They aim instead at the consumer market.

4. Some educators imagine that occasional development efforts of individual teachers will produce necessary software. This is unlikely. The time and effort required is too great; the mix of needed knowledge and skills is specialized and beyond the reach of individual developers; and the equipment generally available for student use in the schools is too "underpowered" to support development activity (Melmed, 1982).

5. Most important, educators tend to treat this new educational technology as an add-on cost with the potential to increase educational output—say, by improved student learning in the basic skills, or by new learning in computer literacy—but without any implication for overall productivity improvement. At present, with limited software supply that is of limited quality and of very limited sophistication, this practice may represent either a realistic assessment by educators of the present opportunity or a preference for increasing input. The promise of this technological innovation lies in its potential for improving teacher productivity by individualizing instruction. The optimum mix of teacher input (that presently makes an overwhelming contribution to the cost of instruction) and student learning by computer will need to be determined empirically for students at various age levels and for various curriculum areas. But first, an investment must be made to develop the potential.

Realizing the Promise

Some necessary developments will occur without any special demand of the education market. They include the following:

1. The cost of hardware will continue to decline. New, more sophisticated educational software with greater productivity-improving implications will become available at the same price schools now pay. The cost for this software will undoubtedly rise; its price is presently uncertain.

2. The dramatic graphics capability of video games will become available at a price that education can afford.

3. The quality of synthetic speech will continue to improve, driven by competition in noneducation markets, as in the case for graphics.

4. Limited speech recognition capability will be available by the end of this decade, bypassing the use of the clumsy keyboard that intrudes on the learning experience for certain educational applications.

Critically needed to realize the promise of these developments for productivity improvement in education is an intensive program of basic and applied research that:

- Builds on our present knowledge of factors affecting student learning, and that takes advantage of new hardware functions and new knowledge from cognitive science and artificial intelligence to create a broad range of more powerful "teaching" effects
- Improves our knowledge of factors affecting schools' use of capital inputs, with special emphasis on the new educational technology.

The consequences of our failure to improve educational productivity and to undertake the research needed to do so are almost certain: lagging teacher salaries, which must inevitably discourage able individuals from entering this important profession, followed by declining student achievement. The cost to the nation will be high.□

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