Economists generally use the term "technology" to refer to any way of combining inputs in a production process. In education, processes that make different uses of teachers, textbooks, radio, computers, or peer tutoring are all technologies. This entry focuses on the more capital-intensive hardware associated with the vernacular meaning of educational technology, examining the use of radio, television, the computer, and multimedia distance education systems.

1. Economists, Educators, and Technologies

Economic perspectives on educational technology are best understood as part of larger social, political, and academic debates. In the twentieth century, new technology has increasingly been viewed as the principal means for raising productivity and making economic progress. In education, this belief has translated into considerable enthusiasm for the transformative powers of each new technology: film in the 1920s, radio in the 1930s, television in the 1950s, and computers in the 1980s. Throughout this history, extravagant claims were often made, from Thomas Edison's assertion that, with film "books will soon be obsolete" (Cuban 1986 p.11), to more recent speculations on likely "computopias" (Masuda 1985). Less visionary but more common among educators has been an optimism that new technologies could be used to improve the quality of education, to extend access to educational opportunities, and to serve as catalysts to revitalize teaching and learning (Schramm 1977). Neoclassical economists complemented this optimism by pointing out how, as teacher salaries rise and the costs of alternative technologies fall, technology use becomes increasingly cost-effective.

The enthusiasm and optimism with which many educators and economists greeted new technologies has been dampened by experience and considerable criticism. Overall, Cuban (1986) argued that the same historical cycle has been repeated for each new educational technology: great enthusiasm, early research support, later research showing failure, and the eventual discarding of the technology. Technology failures, especially of high-profile educational television projects, seriously challenged early optimism (Emery 1985). Media advocates such as Schramm (1977)

rethought the attention being given to "big media" such as TV especially in developing countries, and argued for greater use of less expensive "little media," such as radio. Despite such reassessments, critical' analysts, often using a political economy perspective, have argued that
most new educational technologies have been applied in ways that increased inequalities, took power away from teachers, and had problematic economic and cultural consequences (Arnove 1976; Camoy and Levin 1975, 1985; Klees and Wells 1983).

A new dominant wisdom has been emerging, however. It still argues that alternative educational technologies may have a high payoff, but it adopts a more modest approach to their application than in previous eras. It should not be presumed that all problems have technological solutions; rather, the educational problem should be the starting point for finding solutions (Anzalone 1987, Lockheed and Middleton 1991). Applications of educational technology should be specific and targeted, and not seen as general catalysts for reform (Lockheed and Middleton 1991, Nettleton 1991). The question should no longer be whether educational technologies can work; research and experience has shown some situations where they do, and others must be examined on a case-by-case basis. Particular attention needs to be paid to conditions for sustainable use (Oliveira 1988, Lockheed and Middleton 1991, Nettleton 1991).

The remainder of this entry focuses on how contrasting economic perspectives on educational technology support or challenge this new dominant wisdom of “qualified optimism” (Oliveira 1988). It is organized around the media-television, radio, multimedia distance education, and the computer while recognizing that their impact is due not to the characteristics of the media themselves but to the specifics of the applications (Clark 1983). Each section is divided in two, beginning with an examination of the prevailing wisdom and how a neoclassical economics perspective and related research have supported it, followed by a discussion of how a political economy perspective and related research yield a much more critical view (recognizing, of course, that this dichotomy is a useful simplification).

2. Television

2.1 The Dominant View

Apart from the use of television as a component of open university systems, the new conventional wisdom is uniformly negative about the potential of television to contribute substantially to educational systems. In wealthier countries, such as the United States, educational television (ETV) never got off the ground. Few major applications were made, and those few were usually short-lived: For the most part, the televisions purchased for schools ended up in storerooms, largely neglected by teachers and students (Cuban 1986). For less industrialized countries (LICS), more substantial experimentation was undertaken, but in the main was not considered successful. Anzalone (1991 p. 55) summed up the dominant view: "The use of television in classrooms in developing countries has generally proved to be an expensive addition to educational budgets, but little evidence has been gathered to show that the expenditure brought results that were worthwhile."

The idea that master teachers, superior teaching, and an endless variety of audiovisual aids could be brought to every classroom overnight was a powerful argument for early ETV enthusiasts, especially in Third World countries. However, in practice, most large-scale uses of ETV did not involve very creative programming. In a project in Niger, one of the few where programming was acclaimed as creative, the project did not proceed far beyond the pilot stage, consequently
had very high costs, about US$1200 per student, and had mixed evaluation results (Carnoy 1976, Anzalone 1987).

Mixed evaluation results, in terms of the relative gains in cognitive achievement for ETV versus non-ETV students, also characterized most of the large scale ETV projects studied in the 1960s and 1970s. Early evaluations were often positive. In American Samoa, the location of one of the first big ETV projects, early evaluations reported achievement gains, while later ones showed that ETV student achievement declined over time (Emery 1985, Cuban 1986, Anzalone 1987). In El Salvador, early evaluations reported mixed results but considered ETV a success, while later reanalyses suggested that the gains were novelty effects and that no clear advantage could be substantiated for ETV (Klees and Wells 1983, Cuban 1986, Anzalone 1987, Mayo 1990). Similar conclusions have been drawn for projects in Colombia and the Ivory Coast (Anzalone 1987).

There were also no cost advantages to ETV. In these large-scale projects, television was an add-on to the educational system, often one part of a larger reform package. The add-on cost of the ETV component varied considerably: US$4 per student in Colombia, US$13 in the Ivory Coast, US$26 in El Salvador, and US$166 in Samoa (Carnoy 1976; Anzalone 1987, 1991).

The only large project that actually reduced costs by substituting ETV for teacher quality (i.e., capital for labor) was Telesecundaria in Mexico. In order to reach an unserved population it used primary school teachers in secondary school classrooms, in which they were adjuncts to an intensive use of televised instruction. Achievement was evaluated as equal between the regular secondary school students and ETV system students. Initially there was a substantial cost advantage to the ETV system, leading to assessments of the system as cost-effective. However, this was eroded early on by a teachers’ strike and subsequent contract agreements that put ETV teachers’ salaries on a par with those of qualified secondary school teachers (Carnoy and Levin 1975, Anzalone 1987, Mayo 1990, Nettleton 1991).

Almost all of these projects were started with large amounts of foreign aid, with the exception of Mexico’s, which may account for its cost-saving structure. Mexico also seems to be the only project that has continued, actually expanding considerably during the 1970s and 1980s (Nettleton 1991). The reasons for the limited effectiveness of ETV are often seen as due to logistical, mechanical, and training problems, teacher resistance, a focus on hardware instead of software, and overall poor planning and implementation. While the assessment is not uniformly negative (Jamison and Orivel 1982), the new prevailing wisdom does not envisage television as a major educational tool for the future.

2.2 The Critical View

For ETV the dominant and critical perspectives have similar conclusions, although for largely different reasons. Issues of cost and achievement gain play a part in a critical assessment of ETV, with critics sometimes claiming monetary costs to be even higher, and the achievement picture worse, than other research had indicated (Carnoy 1976, Klees and Wells 1983).
However, most of the negative conclusions reached by the critics stem from other dimensions of costs, effects, and benefits.

In educational and social terms, ETV systems continued to transmit what many regarded as inappropriate curricula. The structure of an ETV system is seen as leading almost inevitably to a lockstep curriculum imbued with a one-way, hierarchical view of the teaching-learning process (Arnowe 1976, Emery 1985). Critics have emphasized how strongly teachers resisted many of these ETV experiments, with anything from strikes to refusal to turn on the television set. This point has also been made by mainstream researchers who generally attribute it to lack of teacher involvement in planning and to poor implementation strategies (Anzalone 1991). Critics from a political economy perspective usually interpret the resistance as more fundamental. In part, it is seen as arising from the very nature of ETV projects, which are premised on a lack of teacher competence and the belief that ETV can circumvent this. More broadly, critics have viewed teacher resistance as part of the general struggle between labor and capital: ETV systems are resisted because they disadvantage and deskill teachers (Arnowe 1976, Carnoy 1976, Klees and Wells 1983).

The foreign aid-supported nature of many ETV projects is also seen as problematic. Aid came with conditions that turned foreign manufacturers and experts into the major beneficiaries; donor political agendas determined the nature of projects; once begun, donors had too much control over project decision-making (Klees and Wells 1983). Related challenges to national sovereignty came from the cultural effects of ETV systems: the influence of foreign cultures on the curriculum and structure of these projects, the devaluing of non-modern cultures, and the tendency to increase the market penetration of commercial television (Arnowe 1976). In broad development terms, ETV projects have been seen as not helping to remedy educational or social inequalities and as running counter to necessary improvements in the capabilities and status of teachers in their roles in education and local development (Arnowe 1976, Carnoy 1976).

3. Radio

3.1 The Dominant View

While radio has been used in a variety of educational ways since the 1920s, it has been around one particular application to primary schools in the mid1970s that the new dominant wisdom has coalesced. The interactive radio instruction (IRI) approach used in the Nicaragua Radio Mathematics Project has come to be seen as a "major breakthrough" in educational technology use, with very low costs and large achievement gains (Anzalone 1987 p. 20). The success of IRI is attributed to its careful attention to instructional design and its "interactive," conversational style that elicits responses (often 100 in a half-hour lesson) from the classes listening (Anzalone 1987). Similar projects have been started in at least 14 countries, aimed chiefly at primary school mathematics and language. In the early 1990s these projects were reaching as many as 600,000 children in 10 countries (Anzalone 1991). Presented as three times more cost-effective than textbooks (Lockheed and Middleton 1991), it is no surprise that IRI strategies have become the epitome of the new wisdom: they have been seen as targeted interventions for specific contexts with a proven track record of high cost-effectiveness.
Evaluations of these projects have often shown substantially larger achievement gains than those found for other educational interventions. Reported effect sizes (gains in standard deviation units) range from 0.24 for reading in Kenya to 0.91 for mathematics in Bolivia, with most results toward the higher end (Anzalone 1991). Costs have generally been seen as modest, with estimates ranging from US$0.34 per student per year in Kenya to US$3.05 per student per year in Nicaragua (Anzalone 1987, 1991). For all but one of these IRI projects, radio has been an add-on cost to the existing educational system. The exception is Radio-assisted Community Basic Education (RADECO) in the Dominican Republic, which uses IRI in combination with monitors who have minimal education, to offer the equivalent of the first four grades of primary school to about 1,500 children in an unserved rural area. An evaluation reported that achievement levels were equal with conventional schools, but RADFCO students learned the material in half the time at half the cost (Anzalone 1987).

There have been other significant uses of radio in education, but many were never evaluated and those evaluated did not yield results as positive as those of IRI, often having unclear effects and/or high costs. Nonetheless, there have been many applications that could well have been cost-effective. Thailand has used radio since the 1950s to enrich formal schooling, at times reaching close to a million students (Anzalone 1987). In Colombia, radio has also been used for as long as an integral part of the non-formal education efforts of the ACPO (Popular Cultural Action) community development organization. Overall, the dominant consensus has been generally favorable to radio applications, but has principally championed IRI.

3.2 The Critical View

Few critical analyses of educational radio applications have been conducted (Byrram 1981, Arias-Godinez and Ginsburg 1984), partly because the small scale and low funding of educational radio has limited evaluation of any kind. IRI has been heavily evaluated only because evaluation has been integral to its testing and marketing campaign, and the evaluations therefore have primarily been undertaken in-house. Nonetheless, the picture that emerges of IRI from the few critical accounts and from the discussion of problems by system advocates bears little resemblance to the dominant view: costs may have been considerably underestimated, achievement gains overestimated, the whole IRI approach has not proven sustainable, and, more broadly, it has carried much of the same development strategy baggage for which ETV was criticized.

Several analysts have pointed out how IRI costs have been underestimated. Some estimates have omitted the costs of important components: start-up and development, program revision, delivery of printed materials, radio repair, transmission, or even initial radio purchase. Furthermore, most of the lower estimates of IRI costs have been based on hypothetical project expansion to an entire nation (Wagner and Kemmerer 1986, Mayo 1990). While some argue that IRI can actually substitute for printed materials, needing neither workbooks nor texts, many IRI projects have used printed materials along with radio lessons, reportedly doubling the Cost of IRI (Nettleton
The wide 1:8 variation observed in IRI project cost estimates reported earlier underscores how different assumptions may yield very different cost pictures of an IRI project. There is also the possibility that the phenomenal achievement gains reported for IRI have been overstated. First, a portion of the gain may well have been caused by novelty effects: almost all the data are from the first few years of pilot project operations (Anzalone 1991). Second, since all the data are from pilot projects, it is unclear what will happen to the achievement gains in an expanded system, which is a less accessible and controllable environment (Wagner and Kemmerer 1986). Third, in most cases, achievement tests were constructed by IRI project implementors. While there is no reason to suspect overt bias, the formulation and selection of questions could implicitly favor IRI. The implementors themselves recognized some related problems (Friend et al. 1988) and if the tests had been constructed by the respective ministries of education, the achievement advantage of IRI may have been considerably smaller.

Even if IRI has the cost-effectiveness that its proponents claim, it has not been sufficient to overcome IRI’s biggest practical problem: getting a country to agree to expansion beyond the pilot. Since around 1975 the United States Agency for International Development (USAID) has invested more than US$50 million to test and market IRI globally. Yet of the 14 IRI projects initiated, only two have expanded nationwide, in Honduras and Lesotho, and the latter on the basis of voluntary use by teachers.

This problem with "sustainability" is openly acknowledged by IRI proponents and critics alike, and an array of explanations have been proffered. One problem, common to many innovations, has been the lack of specific attention paid to institutionalization — during the pilot phase. The independent management and budgets that are such an advantage to pilot project operations often make it difficult later to find a permanent organizational home, as well as to function within government budgetary limits (Wagner and Kemmerer 1986, Mayo 1990).

There have also been several explanations for expansion and sustainability problems specific to an IRI system, mostly centered on how IRI may be much more difficult to operate in less accessible and controllable contexts. Technical problems will be magnified when operating on a large scale: radio repair, battery replacement, radio signal strength, delivery of printed materials, and so forth (Wagner and Kemmerer 1986). The centralized nature of an IRI system yields other problems for educational operations on a large scale. A fixed national broadcast schedule does not function easily with local variations in schedules and school calendar. Teacher and student absenteeism, more prevalent in remoter regions, can make large-scale IRI systems less effective or even unusable (Wagner and Kemmerer 1986; Anzalone 1987, 1991).

It is difficult to assess the financing of those costs on a large scale may be difficult or impossible. Recognizing this, some IRI pilot projects experimented with alternative financing mechanisms: e.g., getting teachers to buy the radios by offering them a price substantially below retail, or getting communities to buy batteries. However, these strategies met with mixed success in pilot projects and could be even more problematic nationwide (Wagner and Kemmerer 1986; Anzalone 1987, 1991).

There has not been the overt teacher resistance to IRI that characterized some ETV efforts, but it has been suggested that resistance comes from other stakeholders, such as "textbook writers and publishers, local curriculum specialists, teacher trainers, or expatriate educational advisors" (Anzalone 1987 p. 30).
From a more explicitly political economy perspective there are some additional problems with IRI: the use of radio programming from other countries; IRI's centralized structure, which takes responsibility and control away from the classroom teacher and often makes it harder to meet the needs of disadvantaged groups (Anzalone 1987); and its regressive financing strategy when teachers and communities have to pay a substantial portion of the add-on costs.

4. Distance Education

4.1 The Dominant View

At least some, and perhaps all, of the projects discussed above could be classified as distance education systems. The essential meaning of distance education is that a substantial amount of teaching is done by someone at a distance from the learner. Usually the term is applied to out-of-school systems that are alternatives to conventional schooling (Nettleton 1991). Distance education systems originated in the 1800s and most today still rely almost exclusively on print media. When broadcast technologies are included, they are usually not used as significant teachers, but in a more minor role for "variety, enrichment and motivation," curriculum "pacing," and, increasingly, for advertising (Nettleton 1991 p. 111).

The new dominant wisdom believes that distance education is potentially a very cost-effective alternative to conventional schooling, especially to extend access to hard-to-reach populations. The rapid proliferation of open universities, enrolling almost four million students worldwide, is seen as efficient and equity-promoting because of the costs and problems associated with opening conventional universities to a diffuse population that, for the most part, must work full-time (Oliveira 1988, Lockheed and Middleton 1991). The Open University in the United Kingdom has been generally evaluated as having lower costs per student, per graduate, and per pass rate on standardized exams than traditional universities. Evaluations of open universities in Lics have provided less information. Costs per student have been generally one-third to two-thirds of the cost of conventional universities. However, dropout rates are usually high, sometimes amounting to 40-50 percent a year. This could make costs per graduate relatively high, but comparisons with conventional schooling are unavailable (Nettleton 1991).

Distance education at the primary and secondary level has not grown as much as have open universities. However, many substantial applications exist, such as the Telesecundaria and RADECO systems mentioned earlier. Evaluations at these levels have shown mixed results: costs per student have been usually lower than those for conventional schooling, but sometimes learning and graduation rates have also been lower (Jamison and Orivel 1982, Nettleton 1991). Teacher training has been a major specialized application of distance education and has been considered very successful. Studies have often been cited of projects in Tanzania and Brazil, where costs were one sixth and one-fourth of conventional teacher training costs respectively, and which were evaluated as being at least as effective. Yet the evidence is also somewhat mixed here, with studies showing other distance education teacher-training systems, in Kenya and South Africa, not to be cost-effective (Nettleton 1991).
Some of the mixed results can be attributed to economies of scale. Jamison and Orivel (1982) judge that for secondary, and perhaps postsecondary schooling, distance education systems require enrollments of at least 10,000 before their costs drop below the costs of conventional schooling. For more specialized applications, such as teacher training, some analysts have argued that distance education can be cost-effective with enrollments as low as 1,000 to 2,000 (Jamison and Orivel 1982).

Even with large enrollments, costs may vary substantially because of a wide array of contextual factors and policy choices. In particular, the relative costs of distance education diminish the more reliance there is on independent study instead of on local teachers, and the higher the opportunity costs students face in attending a conventional institution (Jamison and Orivel 1982). While for these and other reasons, the costs of distance education can vary greatly, the new conventional wisdom generally regards distance education as both cost-effective and a factor in reducing inequity in a variety of proven applications.

4.2 The Critical View

Many analysts have been skeptical of the claims made for distance education. For the most part, the cost-effectiveness claims have been based on costs alone. Little outcome data have been available on achievement or even graduation rates; what exists is problematic because non-comparable groups are usually compared. Distance education students generally must be more highly motivated than the average student in conventional schooling—this may be the explanation for any superior results. Tsang (1988 pp. 217-18) concludes that, given the "fragmentary" Information available on outcomes, "firm conclusions are unwarranted" about the cost-effectiveness of distance education.

The other major claim made for distance education systems is their "clear, positive impact on educational equity—in terms of making quality education more widely available, and in terms of making access to any education at all possible for previously excluded groups" (Jamison and Orivel 1982 p. 267). It appears equitable to extend access to education, but what are these latecomers getting? In an early critique from a political economy perspective, Carnoy and Levin (1975 p. 390) pointed out that assessment by "a narrow measure of educational attainment" misses

the important ways in which the socialization and teaching-learning processes in a traditional education setting offer many advantages to students over distance education substitutes such as the United Kingdom's Open University or Mexico's Telesecundaria (also see Mayo 1990). Even advocates have recognized that distance education is often perceived "as second choice, indeed second rate" (Oliveira 1988 p. 15).

The issue is not one of narrow cost-effectiveness. From a political economy perspective, the massive expansion of education since the 1950s in part reflects gains that have been made by the poor and the working classes, but expansion has also served to maintain the inequities of a global capitalist system. Over time, ever higher educational credentials are needed to get the same economic rewards. Disadvantaged populations are the last to be incorporated into the education
system and generally get a lower economic return to schooling than did their predecessors. Moreover, as schooling has expanded over time, its nature has often changed so that the expectations of these latecomers are "cooled out," moving away from the desire for more schooling that brought success to their predecessors and toward more vocational goals (Carnoy and Levin 1985).

Distance education systems, from a political economy perspective, have thus usually been seen as giving a second-class, inferior education to those allowed into education last, namely, those who are hardest to reach and frequently the most disadvantaged. To add insult to injury, cost-recovery efforts have usually been higher in distance education systems, so disadvantaged students have ended up paying more for their education than those in conventional schools (Oliveira 1988, Nettleton 1991). Moreover, the independent study nature of distance education lets fewer students through the education pipeline. Those who do not get through are often "cooled out" from higher expectations, and society is absolved of blame for not having given them a fair chance. Indeed, more broadly, distance education systems have been seen to help maintain the stability of unfair societies by legitimating what is only a pretense of equal opportunity. More directly, especially for authoritarian regimes, stability can be enhanced because, with distance education, students do not conglomerate and are therefore less likely to be a political force.

5. Computers

5.1 The Dominant View

Given the relative newness of computers there is less of a consensus about computer uses in education than for other technologies, but overall expectations are positive. For wealthier countries, it has been argued that high technology in the workplace will increasingly be a source of productivity and international competitive advantage and that this requires that schools teach computer literacy and skills as basic competencies (Levin and Rumberger 1989). In addition, it is believed that computers can be effective, and increasingly cost-effective, in augmenting cognitive achievement, perhaps in developing creativity and higher-order thinking skills, and, certainly, in teaching some vocational and technical skills. For LICS, the conventional wisdom has argued that the relatively high costs of computers has severely restricted applications. Nonetheless, LICS too must move toward high technology in the workplace for reasons of economic competitiveness, and therefore they too must have enough computer applications in schools to move toward this future (Carnoy et al. 1987, Papagiannis et al. 1987, Anzalone 1991).

Evidence for the positive effect of microcomputer use on cognitive achievement comes principally from one application - computer-assisted instruction (CAI) drill and practice. There is no evidence that computer use in education has any advantage in teaching higher-order thinking skills (Carnoy et al. 1987, Papagiannis et al. 1987). Very little research is available on the cost-effectiveness of microcomputer applications, although Niemec et al. (1986) claimed that, compared to a number of educational interventions (a longer school day, reduced class size, and peer or adult tutoring) CAI was by far the most cost-effective.

In the United States research on CAI has also been used to argue that computers can contribute to a more equitable educational system: they can be effective in compensatory education strategies; are generally more effective for minorities; and may be perceived by disadvantaged populations
as fairer than teachers. Moreover, United States survey data have been interpreted as showing an equitable distribution of in-school access to and use of computers not particularly biased according to gender, race, or social class (Clark 1983, Carnoy et al. 1987, Papagiannis et al. 1987).

Many analysts have pointed out that computer technologies will not be like film, radio, and television, which have not played major roles in education. To an ever greater degree, computers are a pervasive part of cultures and workplaces around the world, they are a leading symbol of modernity, they often have the support of teachers and parents, and they thus have a sizable political constituency (Cuban 1986, Papagiannis et al. 1987, Anzalone 1991). The new conventional wisdom has argued that while some of this optimism is exaggerated, computers will become more and more integrated into education in cost-effective and equitable ways. What is needed is more R&D, experimentation, and analysis to discover how computer technologies may best enhance education.

5.2 The Critical View

Critics have argued that the evidence does not support most of the past or current efforts to use computer technologies in education. Even for CAI, the research shows mixed and inconsistent results. At best, only modest effects have been observed, and these may result from biases in studies using inappropriate control groups, tests that are tailored to the intervention, and evaluator involvement in the intervention (Levin et al. 1986, Papagiannis et al. 1987). Clark (1983) argued that novelty effects and content differences may also account for such gains; any leftover is due to-method, -not medium. If the effort put into designing computer instruction was put into designing conventional instruction the gains might even be greater.

Even if CAI were effective, it has not been seen as cost-effective. Niemec et al.'s (1986) claim that CAI is cost-effective compared to other interventions is a critique of work by Levin, Glass, and Meister which argued the contrary; in particular that peer tutoring is about twice as cost-effective as CAI. Niemec et al. (1986) drew on meta-analysis results showing lower peer-tutoring effects and higher CAI effects, thus yielding the reverse finding: that CAI is twice as cost-effective as peer tutoring. In a pointed response entitled "The Political Arithmetic of Cost-Effectiveness Analysis," Levin et al. (1986) argued that the meta-analysis averages their critics use "exaggerate the effects Of CAI" (p. 71). Such political arithmetic, they continue, is "invoked to bolster a political position in lieu of carefully subjecting that position to scientific scrutiny" (p. 72).

The critics argue that the application of computer technologies in education has contributed to greater inequalities along gender, race, and class lines. In the United States studies may show some improvements over time, but they have also indicated that disadvantaged groups still face substantial disadvantages in access to computers, in their uses of the computer, and in the competencies they acquire through computer use (Sutton 1991). These disadvantages come about through many mechanisms: poorer schools can afford fewer computers and teachers
competent in their use, while richer individuals can afford computers in their homes; the bias toward computer applications in mathematics and science combines with the biases that keep women and minorities away from precisely these subjects, so disadvantaging them further; the content of computer magazines, textbooks, and software reinforces these same racial and gender biases; and schools segregated by race and wealth, tracking, and teacher prejudices combine to give lower status computer applications to disadvantaged groups (Apple 1986, Carnoy et al. 1987, Grubb 1987, Papagiannis et al. 1987). Sutton's (1991 p. 94) review of these issues, in the United States concluded: "children who were minority, poor, female or low achieving were likely to be further behind after the introduction of computers into schools."

Although little information is available about computer use in education in LICs, it is clearly much more prevalent in private schools and learning centers and in higher grade levels, with the concomitant biases that favor boys, the wealthy, dominant racial and ethnic groups, and the urban (UNESCO 1986, Anzalone 1987, Carnoy et al. 1987, Papagiannis et al. 1987). Papagiannis et al. (1987) pointed out the inequality double bind that LICs face: using computers in education will necessarily increase inequalities within a country, while restricting their use will necessarily increase inequalities between nations, as the technological gap between LICs and the industrialized world grows (also see Anzalone 1987).

Finally, the critics have pointed out that there is no reason to believe that computers in education can further the development of a hi-tech economy and there are reasons to worry that their use will have harmful educational and social consequences. The deskilling of jobs and the simplification of computers leave little need to develop computer skills at school (Levin and Rumberger 1989). The fact-oriented and programmed reasoning nature of computer uses in education exacerbates the neglect of the ambiguity, morality, creativity, critical understanding, and human interrelationships necessary to improving individual, social, and economic life. Moreover, in the aggregate, the money spent on computers has been generated by reductions in the numbers of teachers, their training and salaries, and from increased cutbacks in programs targeted to the disadvantaged (Apple 1986). Therefore, from a political economy perspective, for most microcomputer applications in education the broad costs have outweighed any arrow benefits.

6. Conclusion

The perspectives taken on the economics of educational technology depend on interpretations of theory, research, and experience. The dominant neoclassical economics perspective sees alternative educational technologies as means to improving efficiency, inside and outside the educational system, and, sometimes, to improving equity. The excessive optimism about past technologies has been rejected in favor of a new wisdom that argues that certain technologies have proven themselves, under certain conditions, to be efficient and equitable, particularly IRI and distance education, and perhaps some computer applications. Whether these interventions will remain advantageous, or whether others will become more attractive, will have to be determined by evaluation and monitoring activities, as with any educational or other governmental intervention.

From a political economy view of educational technology, the above framework is untenable. In a world of conflicting interests, technologies have been applied in schools (and workplaces) in ways that chiefly advance the interests of the more privileged. The disadvantaged receive fewer
computers and less valued applications, second-class distance education systems, and problematic band-aids, such as IRI, to overcome the major obstacles that keep them from educational

and social success. Between countries, education and social inequalities have been increasing; educational technology differences are a part of the gap.

A major problem with educational technology from a political economy perspective is that it has been governed by the same anti-labor logic as technology choice in the workplace. Educational technology applications usually run counter to teacher interests: for example, hi-tech schools are planned with a lower teacher-to-student ratio in order to pay for the technology; distance education gives disadvantaged groups minimal teacher contact; and IRI gives minimal teacher training. Most educational technology systems have assumed that teachers are not competent to deliver the curriculum and therefore delivery needs to be "teacher-proofed" (Apple 1986). Nicaragua's IRI was designed, explicitly to get around the poor training of the rural teacher (Wagner and Kemmerer 1986). In the United States in the 1950s and 1960s, the "needs" of the Cold War led to packaged curricula to get around the inadequacies of United States teachers. Microcomputer applications in the schools, although increasing the skills of some teachers, widened the gap among teachers and limited teacher control over an increasingly centralized curriculum (Apple 1986, Carnoy et al. 1987). Overall, educational technology use has been an alternative to investing in teachers, to training them, to paying them a good salary, and to giving them more professional control of their classrooms. Political economists, and others, would suggest that investment in teachers, not teacher substitution and deskilling, is essential to education and development success (Carnoy 1976, Carnoy et al. 1987, Papagiannis et al. 1987).

Political economists should not be seen as anti-technology. Technologies that are used as part of more participative education strategies, that enhance teacher skills and control, and that empower disadvantaged groups may be very worthwhile. To design and choose better technologies, political economists argue that better mechanisms for analysis and choice are needed. While there are no simple solutions, employing broader criteria and more participatory processes of investigation and choice can help progress toward more constructive and fairer analyses and uses of educational technology (Klees and Wells 1983, Arias-Godinez and Ginsburg 1984, Carnoy and Levin 1985, Apple 1986, Carnoy et al. 1987, Papagiannis et al. 1987).

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