Chapter 6

Software: Quantity, Quality, and the Marketplace

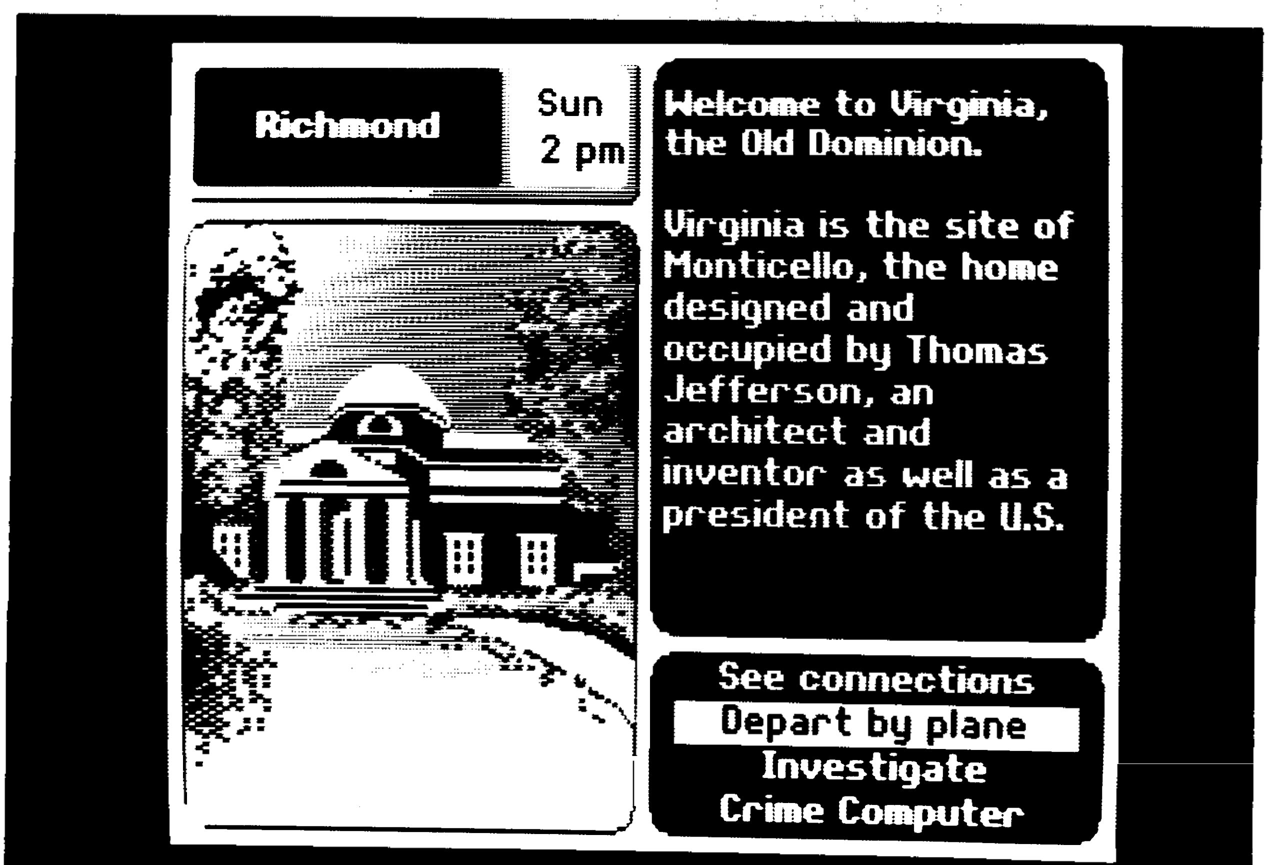


Photo credit: Broderbund Software

CONTENTS

Boxes

Figures

Tables

Chapter 6

Software: Quantity, Quality, and the Marketplace

INTRODUCTION

Since its first printed appearance in a technical computing journal in 1960, the word software has evolved into a familiar part of the English vernacular. It is now commonly used for technologies that predate computers, as a metaphor to distinguish machines from people or their attitudes,[2] as well as for codified instructions that make the computer's electronic circuitry responsive to decisionmaking, information gathering, and data processing tasks.

Because the computer is a technology for collecting, organizing, analyzing, and communicating information, it might be argued that all software is educational.[3] Business persons who calculate profits, losses, and market positions; military analysts concerned with logistics; physicians who view three dimensional images of the human anatomy; econometricians who forecast inflation and unemployment; writers who create and revise poetry and prose; children who use computers at home to play chess or Pac Man; cognitive psychologists who attempt to simulate brain behavior; and research scientists who model the movement of subatomic particles—all can be said to be *learning*.

The term educational software, then, which is fast entering the popular lexicon, can refer to a broad category of programs: generic computational, word processing, data management, industrial design, games, and communications tools originally designed for business, science, and industry; training programs that are cost-effective supplements or substitutes for classroom training in business and the military; as well as didactic or instructional programs designed expressly for school curricula.[4] The last category includes a range of materials, from simple drill and practice routines and other electronic equivalents of the conventional workbook, to sophisticated simulation, problem solving, and tutorial software that makes use of artificial intelligence and multimedia technologies, to full curricula that theoretically can substitute for teachers.[5]

While the question whether to install computers in schools is by now moot, neither the future development and acquisition of appropriate software nor the effective use of these learning tools is as certain as in other sectors of society. The economic and social environment of American public schools is fundamentally different from the worlds of business, the military, medicine, the arts, and science. Finding affordable software for schools and finding out how best to use it are challenges that must be met if technology is to achieve its desired effects.

[1]This chapter is based in part on two OTA contractor reports: W. Curtiss Priest, "Educational Technology: Information Networks, Markets and Innovation," September 1987; and Ellen Bialo and Jay Sivin, "An Analysis of the Scope and Quality of the Current Supply of Educational Software and of the Available Sources of Information on Educational Software," Sept. 30, 1987.

[2]A good example comes from the *Observer*, which noted that an arms agreement had been phrased "in terms of giving the United States 'software'—a more flexible attitude on the Middle East—in return for 'hardware' -arms and military equipment. " Cited in *Supplement to the Oxford English Language Dictionary*, vol. 4 (Oxford, England: Oxford University Press, 1966), p. 333.

[3]*Scientific American* devoted an entire issue to computer software and its role in business, science, and medicine, but did not address education per se. See *Scientific American*, *vol. 251,* No. 3, September 1984, and especially the article by Alan Kay, pp. 52-59.

[4]The administrative software that many schools acquire to automate scheduling, personnel, and student records clearly plays an Important role in creating an interactive educational atmosphere, but is beyond the scope of this report.

[5]OTA has found no evidence of teacher displacement by computers and related technologies. However, shortages of teachers in some fields and in some parts of the country has spurred interest in the development of comprehensive, interactive curricula. See Arthur Melmed and Robert Burnham (eds.), *New Information Technology Directions for American Education: improving Science and Mathematics Education* (Washington, DC: National Science Foundation, December 1987). A resurgence in education school enrollments, following two decades of sharp decline, may partially offset the predicted teacher shortages. But there are still grounds for concern that future requirements will not be met. See Joseph Berger, "Allure of Teaching Reviving; Education Schools Rolls Surge," *The New York Times,* May 6,1988, p. 1.

This chapter takes a close look at educational software's problems and promise, and suggests how the Federal Government might help to remedy the former and realize the latter. In addition, while educational computer software is an important subject in itself, this analysis has wider relevance: the challenges educaters face in using computer software in schools are similar to some they already face, or soon will, using many other forms of interactive technology.

FINDINGS

Quantity, Quality, and Scope

- There are now over 10,000 available stand-alone (floppy disc-based) instructional programs produced by about 900 firms. In addition, about a dozen major manufacturers specialize in producing expensive and elaborate "integrated learning systems" (ILSs) that span large segments of the elementary and secondary curriculum.
- The technical quality of most commercially produced software is quite good. However, there is a general consensus that most software does not yet sufficiently exploit the capacity of the computer to enhance teaching and learning.
- It will be difficult to justify the costs of acquiring and implementing new interactive learning tools unless their software genuinely improves upon conventional learning materials. However, innovative software that departs from familiar teaching methods, and that may be highly respected by computer scientists and educational technologists, is not necessarily selected by teachers. Pressured to raise test scores and meet other performance mandates, many teachers prefer software that is closely tied to the curriculum; and software publishers can usually strengthen their market position by developing products that are linked to textbooks and other familiar instructional materials.
- While commercial software publishers are reluctant to take risks with innovative software, many of the available titles are attractive and fun to use, even if they are geared toward familiar objectives. Even the most rudimentary drill and practice programs have been proven effective in raising some children's basic quantitative and language skills.
- Many teachers use database, spreadsheet, and word processing programs that are not necessarily new in concept or design. These programs have become powerful new classroom tools and are applied in exciting ways to traditional classroom activities.
- Mathematics programs continue to dominate the market. Although there have been some increases in the availability of software for social studies and language arts, at the same time there has been a slight decrease in the number of new science programs, especially chemistry and physics.
- In the category of didactic programs, the vast majority of titles aim at basic skills. Software to teach "higher order" skills, such as hypothesis testing and problem solving, is in much shorter supply. Drill and practice software continues to dominate all subject areas, to the chagrin of many educators and educational technologists.

Market Characteristics

- Most of the firms that manufacture stand-alone educational software are small—the average firm has two employees. Even the largest firms have an average of only 35 employees. Total annual sales in this market were approximately $170 million in 1987.
- Integrated software that covers entire curricula are very expensive to develop. Firms in the ILS market, as distinguished from the stand-alone market had annual sales of roughly $100 million in 1987. These firms have found that their ability to raise venture capital is governed by two main factors: evidence that their learning systems can achieve positive results on standardized tests, and evidence that their systems are cost-effective (that they can achieve defined objectives more efficiently than other methods).
- The demand side of the software market consists of thousands of independent school districts with varying administrative rules, serving a diverse pop-

ulation of school children with differing needs, talents, and learning styles.

- The number of children in a given grade, learning a particular subject, represents a small fraction of the total student population. An even smaller proportion have regular access to computers, a fact that poses a formidable problem to software developers and vendors. Teachers, computer coordinators, and instructional design experts are concerned that in trying to serve such a fragmented market software publishers will be inclined toward increasingly homogeneous and less innovative products.
- While the cost of developing software (especially the type marketed on floppy discs) has dropped considerably due to advances in programming environments and the know-how of programmers, marketing to the educational sector remains a costly, sometimes prohibitive factor.
- The existence of numerous information channels makes it difficult for software producers to receive clear market signals and to adjust their designs accordingly. State and local initiatives to define curriculum needs and invite targeted software development have met with mixed results.
- A limited survey of software publishers indicates that the larger concerns are typically both more rigid (bureaucratic) and less innovative than smaller firms. Evidence of the performance of firms of different sizes and market share is mixed and inconclusive.
- The problem of unauthorized copying (piracy) continues to undermine investments in new product development, especially among smaller publishers with little experience in the school market.
- The principal factors that will determine the structure and quality of the educational software industry are: high development costs for innovative state-of-the-art applications; marketing advantages that accrue to incumbents in the school market; risks associated with idiosyncratic acquisition policies and procedures; small demand for subject and grade specific products; and the difficulty of appropriating the returns to investments in software that is easily copied.

QUANTITY AND SCOPE OF THE EDUCATIONAL SOFTWARE SUPPLY

When computers were first used for instruction in the late-1950s, software consisted largely of drill and practice materials delivered from mainframe computers to students working at "dumb" terminals. Students could not modify the programs. Since then, educational software has come to include everything from computer programming languages to networked simulation programs that allow instantaneous international communication of data.

The companies that manufacture different kinds of products face different problems and compete in specific markets. The three principal sources of software are suppliers of free-standing floppy disc-based programs, manufacturers of ILSs that sometimes come bundled with dedicated hardware, and developers of public domain and "shareware" products that are accessible through electronic bulletin boards, interest groups, and various cooperative organizations. The last group of products are typically produced by teachers, students, and computer buffs to fill specific curriculum niches that commercial developers have neglected. It is difficult to estimate the size of the informal shareware market for elementary and secondary school, although a growing number of teachers use shareware via electronic bulletin boards. In addition, there is considerable trickling down to the upper secondary grades of software created for postsecondary environments, much of which is distributed by nonprofit organizations or by joint commercial arrangements.[h]

Integrated Learning Systems: The High End of the Software Market

ILSs are packaged to span part or all of a curriculum (for example, fourth to sixth grade arithmetic

[h]One example in higher education is the Apple University Consortium, which promotes academic software exchange through Kinkos, a nationwide chain of photocopying centers.

or K-6 language arts), and typically run on networked systems of microcomputers linked to a file-serving micro or minicomputer. Many ILSs are designed to run on hardware that is already in the schools, such as Apple or MS-DOS compatible machines, and some ILS manufacturers have become licensed vendors for one or more computer companies. Some schools prefer to purchase hardware directly from manufacturers, because of price advantages; others prefer one-stop shopping and purchase bundled systems from the ILS software developers. These systems are usually packaged with curriculum guides and management tools, and are typically geared toward basic skills improvement. They all claim to ". . . offer the advantages of using computers to diagnose, reinforce, and enhance learning individually, to monitor student improvement, and to produce documented evidence of gains. Most companies correlate [software] to district goals, curriculum, and standardized tests."[7]

The appeal of these systems is their comprehensive coverage: in terms of lesson planning and integration of electronic media, they make fewer demands on teachers than do individual programs that treat small sections of the curriculum. ILS developers are aware that the centralized approach may be perceived as mechanistic and inflexible, so they go to great lengths to show that their materials can be tailored to individual students' needs and abilities.[8] An additional important selling point is the system's ability to accommodate other companies' software: school personnel who want the option of using programs developed by other companies, now or in the future, often choose integrated systems that run on standard microcomputers.

Some systems permit students to advance at their own pace through a fixed curriculum; others permit students to move horizontally within subjects, for example, to move from a study of the planet Earth to the larger solar system, depending on prior knowledge and rate of learning. Nevertheless, all these systems permit considerably less flexibility than generic tools such as word processors and individual instructional programs that teachers can apply to specific segments of the curriculum.

Another important factor is cost. A typical algebra course, providing 100 contact hours for the middle school grades, can cost upwards of $1 million to develop. The costs of installing an ILS, including hardware, software leasing, maintenance, and training, can run as high as $100,000 for a laboratory with 20 or 25 terminals. For a school district this translates to multimillion dollar contracts, and therefore necessitates a long-term commitment to both the network concept and the particular software.[9]

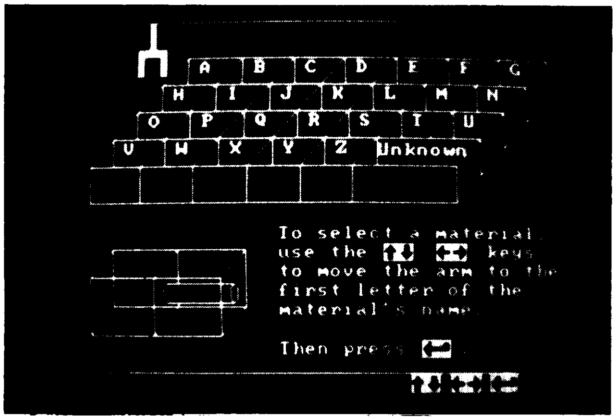
The companies that manufacture these systems include Education Systems Corp., Wasatch Education Systems, Prescription Learning Corp., Wicat, Degem Systems, Houghton Mifflin, and Unisys. Their products have been heavily influenced by the early experiences of the Computer Curriculum Corp. (CCC) and of Control Data Corp. (CDC). CCC, under the leadership of Patrick Suppes, a noted philosopher and decision scientist, was one of the first developers of computer-assisted instruction systems, and has retained a significant market share. CDC's PLATO system, once a pioneer in computer-based training, has strived to maintain its place in the education market with updated tutorials and drill materials.

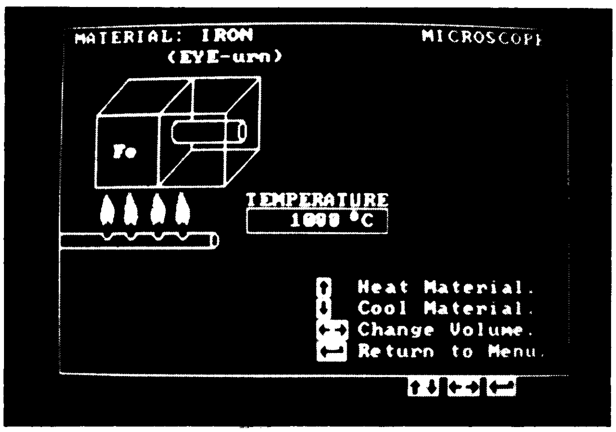
While some firms entered this market with substantial capital resources (CDC, for example, was already a manufacturer of mainframe computers), the majority have relied on venture capital. Their ability to raise venture capital has been governed primarily by two factors: evidence that their learning systems can achieve tangible results, usually improved performance on basic skills tests; and evidence that their learning systems are cost-effective (that schools will choose to purchase those systems rather than rely on other strategies to achieve the same objectives). Even the smallest firms in this industry have had to raise substantial sums (at least $5 million), and have devised creative public/private consortia. In one case, private venture capital of about $1.2 million was leveraged to gain commitments from a consortium of school districts

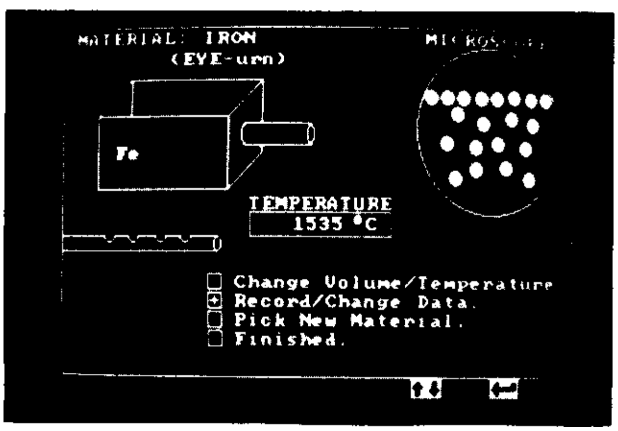
[7] Gwen Solomon, "In An ILS, LANS are Part of a Larger Teaching System," *Electronic Learning, vol. 7, No. 4,* January 1988, p. 27.

[8] Integrated learning systems programs are not necessarily limited to drill and practice: ". . . one is as likely to find problem solving, simulations, and tool software in integrated learning systems as one is to find such programs among the general mix of floppy disk programs. . . ." Ariela Lehrer, "A Network Primer: How They're Used . . . and How They Could be Used," *Classroom Computer Learning,* vol. 8, No. 7, April 1988, p. 42.

[9] See also ch. 4 for a detailed illustration of the costs of acquiring and implementing an integrated learning system.







whose joint participation brought the total funding base to about $5 million. A larger firm, which was able to raise over $20 million in the same amount of time, has moved more rapidly in the development and production of more comprehensive systems.

The grade span of the courseware, as well as its scope, reflects to some extent the size and capitalization of the company. Prescription Learning Corp., for example, with estimated annual sales of $40 million and with installed laboratories in most of the 50 States, offers a complete kindergarten-adult curriculum in basic skills, writing, English as a second language, adult education, GED preparation, and vocational education.[10] Smaller and newer entrants in this market have necessarily focused their efforts on smaller segments of the curriculum, such as fourth to sixth grade reading or junior high school mathematics.

The Low-Priced Market: Stand-Alone Software

The alternative to networked and integrated learning systems is the use of floppy disc-based programs that typically cost under $50 and address specific topics or concepts rather than an entire curriculum.[11] There are now over 10,000 such software titles available, covering the major school subjects and many of the minor subjects, produced by an estimated 900 firms. In the general software market, 85 percent of sales are accounted for by less that 20 percent of firms; in educational software, the top 25 firms account for about 65 percent of sales, with average sales of $4 million. The average firm in this segment of the educational software industry has less than 2 full-time employees, and even the top 25 firms are relatively small, averaging about 35 employees.

The amount of money spent by schools on educational software, about $170 million in 1987 according to the Software Publishers Association, represents a tiny fraction of total 1986-87 expenditures

[10] Solomon, op. cit., footnote i'.

[11] Most Integrated learning systems run on computers that can accommodate individual floppy disc-based programs as well; but the typical free-standing microcomputer found in American schools, e.g., the Apple II-c, does not have sufficient memory capacity to handle integrated software systems.

on elementary and secondary schools: it is approximately 0.1 percent, or about $1 in $800. Assuming roughly 40 million public school students, the average outlay for software in 1987 was about $4.25 per student, out of a total of about $35 per student on all instructional materials (including books).

Firm Size and Innovation

Firms in this market vary significantly by size and organizational structure, and employ different production and sales strategies. In addition, interviews conducted with 10 educational software companies revealed a range of attitudes about important issues facing this industry .[12] From discussions with the chief executive officers, marketing vice presidents, or product development managers at the firms chosen for this survey, OTA found that the largest firms are typically the most bureaucratic, as might be expected. These firms also appear to be less innovative than smaller ones, an impression which is consistent with findings on a wide range of industries in the United States and abroad.[13] The three largest firms in the sample, with annual sales in the range of $25 million to $3.6 billion, were found to be relatively noninnovative. In fact, small firms believed that scale advantages of their larger competitors did not result in better products or greater market power.

However, some of the most important new software ideas have been successfully commercialized by large firms, which means that size alone is a poor predictor of innovative capacity. Firms use different methods to generate new ideas and update their product lines. In some, current or former educators are on the full-time staff; in others, teachers are paid royalties from sales of software they have designed or written. Another approach is to rely on information from dealers, from the sales force, and from direct contact with teachers. In addition, professional journals, national computer exhibits and conferences, and regional conventions are cited as important sources of innovative ideas. Hardware suppliers were never mentioned as sources for software innovations. It is difficult to assess the research and development efforts of firms in this industry, especially because the smaller ones tend not to distinguish expenditures on these activities from other business expenses.

Small firms in this sample did not perceive a greater threat from unauthorized copying than the larger firms. Advances in copy protection and dedication to providing new learning tools for children were the reasons mentioned for not being overly concerned with unauthorized duplication. It should be noted, however, that copying continues to preoccupy industry associations as well as many publishers, who have issued strident calls for increased copyright protection. At least one small educational software publisher has called for a governmental ban on the sale of disc-copying technology;[14] and controversial copyright infringement lawsuits continue to occupy headlines in the computing and general press. [15]

The Analogy to Textbooks

Many of the largest firms that supply educational software are textbook publishers that have entered the software business hoping to capitalize on their expertise in marketing to schools. As a result, they are inclined toward strategies that work well in the book business but that may inhibit software innovation. By linking computer products to textbooks—both their own and competitors'—these companies are further solidifying the curricula that some educators are attempting to reform. Textbook companies argue that products with recognizable curricular goals will be attractive to teachers, who will therefore be more willing to promote expanded use and innovative applications of the technologies in the classroom. But textbook publishers have not always been successful in the software market. Sales representatives who usually work on a commission basis can make more money by concentrating on book orders, which are much larger than software orders. (This is what is meant by fragmented demand for software, and is a function of the relatively small amount of time most students spend with com-

[12] For methodological detail about these Interviews, see Priest, op. cit., footnote 1.

[13] Morton Kamien and Nancy Schwartz, *Market Structure and Innovation* (Cambridge, England: Cambridge University Press, 1982).

[14] Dwight Johnson, The Home School, San Diego, CA, in U.S. Congress, Office of Technology Assessment, "Transcript of Proceedings—OTA Workshop on the Educational Software Market," unpublished typescript, Aug. 6, 1987.

[15] See Richard M. Lucash, "Look and Feel Lawsuits, " *High Technology Business*, October 1987, p. 17; and Katherine M. Hafner and Richard Brandt, "Does This Lawsuit Compute for Apple?" *Business Week*, Apr. 4, 1988, p. 32.

puters.) As a result, some companies have tried to separate their book and software divisions, but in so doing have sacrificed economies of scope (see box 6-A).

Some of the most successful software publishers are not in the book business, but are subject to the same types of political and market forces that have shaped the textbook industry (see boxes 6-B and 6-C). Growing concern with the quality and diversity of that industry's products, coupled with wide agreement that innovation is crucial for interactive technologies to achieve their desired effects in education, has spurred interest in the analogy between the textbook and computer software markets.

The principal criticism of American textbooks is leveled not against book publishers, but rather against the system and environment in which they operate: "The source of the writing problem is not in the publishing house, but in the public agency. Legislators, educational policy makers, and administrative regulators have unintentionally drained the life out of children's textbooks.'" This criticism is consistent with other analyses conducted over the past decade. In 1978, the textbook market was described thus:

> A planner setting out to design a system guaranteed to discourage the purchase of innovative instructional materials would be hard-pressed to improve on the system for materials selection that is followed throughout the country today. Although margins for efficacy and diversity do exist, the overwhelming preference is for the lowest, least unsettling common denominator in instructional materials content. This pattern of preference stems from a concert of forces. Instructional materials selection is an open textured process, inviting and accommodating the opinions and decisions of State lawmakers, State and local school administrators, teachers, parents and students, and the variety of organizations into which they group themselves. The fact that current patterns of consumer prefer-

"Harriet Tyson-Bernstein, *A Conspiracy of Good Intentions: America's Textbook Fiasco* (Washington, DC: Council for Basic Education, 1988).

Box 6-A.—"Early Burned, Inc."

A prominent firm in school textbooks, Early Burned made two critical errors: it separated its software division entirely from the book division, and it produced a line of products that were intended for a computer that would subsequently be withdrawn from the market. Just 3 years after starting, the software division was completely shut down. Since then the firm has cut back its software line from over 100 titles to about 25. Lack of backing from the book division, coupled with software designed for use with a computer that was one of the first casualties in the hardware shakeout of the early 1980s, led to the failure of the software division. The remaining 25 software titles produced by this firm account for less than 0.5 percent of total sales. The firm has become extremely cautious with its innovations and product line. Company executives and market strategists have adopted a policy to keep software closely tied to textbooks, both organizationally and with respect to content.

Early Burned views the education market for software as "., , . one where the buyers keep demanding higher quality but are willing to pay less and less." The market is becoming more and more competitive and will probably never be as profitable as textbooks: barriers to entry and high margins make it a "hot" industry.

The central strategy of this firm is to link software to books. In the words of the Vice President for Marketing,". . . schools had better be using our texts. , . "to match with the software. This linkage gives the company an obvious market advantage, especially because teachers know and respect the books and are, therefore, willing to experiment with the computer applications. The implication of this strategy is that high-risk projects are simply not undertaken. The typical investment is about 1 person-year, and extravagant projects that have been launched by some competitors would not be approved. In fact, the firm is a bit frightened by new technologies, such as compact disc-read only memory (CD-ROM), and is not planning to invest in the necessary programming talent.

SOURCES: OTA interviews with software publishers; and W. Curtiss Priest, "Educational Technology: Information Networks, Markets and Innovation," OTA contractor report, September 1987. The name of the company has been changed to preserve confidentiality.

Box 6-B.—"Major Force, Inc."

Major Force is one of the larger companies that develops software but does not sell textbooks. It is an innovative company, with considerable brand recognition in the industry, employing over 200 people and producing over 100 software products. The company was founded about 15 years ago, is privately held, and began by developing filmstrips for health and guidance. Many former teachers work at Major Force, in a computer division established 5 years ago.

The company works in three main product areas: elementary print materials, filmstrips, and computer software. There is little or no integration between software development and the other activities. Marketing is through direct mail catalogs, in addition to 1 sales person who concentrates on the top 20 school districts. Major Force no longer works with the independent dealer network, preferring to focus their efforts on direct telephone support for customers. According to the Vice President for Marketing, the company judges the market by "intuition," "facts," and conversations with people. They do not believe in surveys because there is too much uncertainty in the minds of respondents.

The leadership style at Major Force is "participatory." As the software business grew, there was a concern for preventing the bureaucracy from encroaching on the software developers' creativity. Five development offices around the country are kept small, with 1 key person, 3 programmers, and up to 10 part-time staff.

This firm considers the education market "good, but difficult." Brand recognition brings stability, and the market as a whole is considered more secure than the home software market. Software is not directly oriented to curricula, except when curriculum changes are amenable to software solutions. For example, the trend to view "writing as a process" brings opportunities for good software development.

Curiously, Major Force is not terribly concerned about piracy at the school level. Their products are copy protected, mainly to prevent dealers from making illegal copies. School boards are viewed as doing a good job of preventing piracy.

Finally, Major Force does not believe there are significant economies of scale in this business. But they are quick to point out that small and innovative firms succeed only if they are quick and if they know their market. Thus, the transaction costs of an uncertain and complex market are important barriers to entry, while ". . . knowing the ins and outs of the business creates opportunities and lowers competition."

SOURCES: OTA interviews with software publishers; and W. Curtiss Priest, "Educational Technology: Information Networks, Markets and Innovation," OTA contractor report, September 1987. The name of the company has been changed to preserve confidentiality.

ence are formed from so many forces helps to explain their persistence and the futility of efforts to alter the pattern by altering one or even a handful of the elements that form it.[17]

Developers and publishers of instructional software face-similar problems in their attempt to satisfy the demands of educational consumers. At present, however, there appears to be far less political intervention in software acquisition than in textbook adoption. Teachers, parents, children, and administrators all have some say, but the selection process is typically much less formal and less bureaucratic than for books. There is some concern that as interactive media become more prominent in classrooms, software decisions may become entangled in the political forces that have influenced book content and quality.

The analogy between books and software *is* not limited to bureaucratic features. Market forces, even in the absence of divergent political interests, play a role. First, good ideas for textbook revisions quickly become "public goods," and their authors cannot be sure to recoup development costs.[18] In

[17]Paul Goldstein, *Changing the American Schoolbook: Law, Politics and Technology* (Lexington, MA: Lexington Books, 1978), p. 53. For a rejoinder see Alexander J. Burke, "Textbook Publishing in America," *The Textbook in American Society, J.* Cole and T. Sticht (eds.) (Washington, DC: Library of Congress, 1981), p. 47. See also Harriet Tyson-Bernstein, "The New Politics of Textbook Adoption," *Phi Delta Kappan*, March 1985; and Frances Fitzgerald, *America Revised* (Boston: Little Brown, 1979).

[18]The relationship between intellectual property protection and returns to innovators, in general but not with specific reference to educational technologies, is the subject in David Teece, "Profiting From Technological Innovation: Implications for Integration, Collaboration, Licensing, and Public Policy," *Research Policy, vol. 15, 1986,* pp. *285-305. See* also Goldstein, op. cit., footnote 17, for a discussion of copyright and other property rights protections as they impinge on instructional materials development.

Box 6-C.--"Street Vendor Co., kc."

For a firm with only one and one-half employees, the annual sales volume of $250,000 and the number of software packages produced-80-is surprisingly high. The President of the firm has considerable prior experience with large companies, but wanted a greater "sense of service," and, therefore, created this company in 1980.

Many of the programs marketed by Street Vendor are written by teachers. They cover a wide variety of topics, from alphabet skills to geographical statistics to college-level tutorials. Outside authors are attracted to Street Vendor by the possibility of earning royalties (15 percent of sales, net of discounts and freight charges), and respond quickly without the imposition of rigid deadlines.

Products are not matched to school curricula, but teachers and students seem receptive nonetheless. To avoid the catastrophic consequences of a "big mistake," projects are kept small and manageable; the ones that do not seem to work are dropped quickly. Piracy is a problem that this firm cannot solve; besides copy protecting some preview discs, they essentially ignore the unauthorized copying problem. A central concern is that teachers who see many similar programs will increasingly % prefer familiar brand names. Finally, Street Vendor resents having to compete with companies that started out under State auspices and who, therefore, enjoy significant (and unfair) competitive advantages.

Street Vendor perceives the market as reasonably strong, but weaker than some years ago. If the President were interested in more profit, rather than in the entrepreneurship of owning and managing his own firm, he says he would go into the business market.

SOURCES: OTA interviews with software publishers; and W. Curtiss Mat, "Educational Technology: Information Networks, Markets and Innovation," OTA contractor report, September 1987. The name of the company has been changed to preserve confidentiality.

addition, there is a strong economic rationale for producing books and software that are familiar to consumers, rather than attempting to gain market share by introducing a truly differentiated product. Together these factors create a disincentive to innovate.

As instructive as these comparisons may be, there are important differences between books and software that should also be taken into account. First, as suggested above, the reason so many people are involved in decisions about books is because of their *content.* Most instructional software, on the other hand, even the didactic kind, focuses on learning *processes,* about which there may be less ideological controversy. Even programs that are closely linked to existing textbooks do not simply translate the material found in those books into electronic screen images but rather provide supplementary drill and exercises. Second, some of the most popular software programs in the schools are generic word processors, database management systems, and spreadsheets. These programs are completely neutral in content, and are not likely to arouse conflict between parents, school boards, teachers, and legislators. The strength of the analogy between textbooks and software, therefore, depends in part on the balance between generic and content-specific (and value-laden) materials adopted by teachers and schools, and in part on the perceived impact of the technology upon local curriculum planning.[19]

Scope of Instructional Software

OTA analyzed several comprehensive educational software databases to characterize the quantity and coverage of educational software products.[20] As shown in table 6-1, mathematics, science, English, reading, and social studies account for the greatest share of these products. Publishers of educational software are influenced by their perception of the subject areas that comprise most of the instructional

[19] Local curriculum planning and school management, and the degree of teacher autonomy in the classroom, are critical issues in American education policy, with implications for educational software. Some reformers advocate greater teacher (and parent) participation in school decisionmaking, along with other initiatives to enhance the professional status of teaching. Generic software that provides teachers with increased opportunities is compatible with this general strategy of reform. However, others question whether a sufficient proportion of teachers currently are able and willing to work effectively with open-ended materials. It is clear that the relationship between expanded individual choice and quality control should be a central criterion in the design of appropriate software.

[20] Bialo and Sivin, op. cit., footnote 1.

Table 6-1.-Distribution of Educational Software Programs by Subject (N=7,325)

	Percent of programs[a]	Number of programs[a]
Comprehensive	6	427
Computers	5	331
English/language arts	12	894
Foreign language	5	356
Mathematics	27	1,971
Reading	12	869
Science	16	1,148
Social science	8	565
Other[b]	18	1,329

[a] The sum of the programs is greater than N because some programs We assigned to more than one subject category. Accordingly, the total of the percentages is greater than 100 percent. All percentages were rounded tothe nearest unit.
[b] The Other category combines 13 subjects (agriculture, aviation, business, driver education, early learning/preschool, fine arts, guidance, health, home economics, industrial arts, library skills, logic/problem solving, and physical education, each of which accounts for less than 4 percent of the total number of programs.

SOURCE: Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987.

day, as well as by their perception of teachers' preferences.

For example, within the general category of reading, there are more programs in vocabulary and comprehension than in decoding skills (see table 6-2); and in mathematics the majority of software titles aim at basic skills (see table 6-3). A strong indicator of suppliers' attempts to satisfy school demand is the variation by grade range. As shown in table 6-4, most of the kindergarten software is intended for reading, mathematics, and preschool skills taught at this level. In the higher grades, the distribution shifts, with less emphasis on reading and graduall y increasing emphasis on science programs. In general, the higher grades are served by a greater variety of subjects, including foreign language and business.

Table 6-2.—Distribution of Reading Software by Area (N =869)

	Percent of programs[a]	Number of programs[a]
Comprehension skills	24	210
Decoding skills	10	87
Reading in content areas	6	54
Reading readiness	20	174
Vocabulary	38	333

[a] The sum of the programs is less than N because some programs would not fit any of the area categories. Accordingly, the total of the percentages is less than 100%. All percentages were rounded to the nearest unit.

SOURCE: Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987

Table 6-3.—Distribut[on of Mathematics Software by Area (N =1971)

	Percent of programs[a]	Number of programs[a]
Basic skills	72	1,425
Algebra	10	201
Geometry	6	123
Other[b]	11	225

[a] The sum of the programs is greater than N because some programs were assigned to more than one area category. The total of the percentages Is still equal to 100 percent, since all percentages were rounded to the nearest unit.
[b] The Other category combines 10 areas (analysis, calculus, consumer mathematics, differential equations, finite mathematics, general mathematics, number theory, probability statistics, and trigonometry), each of which accounts for less than 4 percent of the total number of programs.

SOURCE: Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987.

Table 6-5 gives an estimate of the "fit" between software availability and amount of time in the school day allocated to the corresponding subjects. For the junior and senior high school grades, the fit is strongest for mathematics and communications (which includes English/language arts and reading), with some apparent discrepancies for social and natural sciences and the fine arts.

The discrepancies (which seem to be more pronounced at the junior high level) point to another factor influencing the quantity and scope of software. Developers are influenced not only by their understanding of curriculum scope and sequencing, but also by their ability to apply state-of-the-art programming and design techniques to different instructional areas. It is clear, for example, that the earliest applications of computers—in all fields—were in *computing:* performing arithmetic operations that would otherwise have taken countless human hours to complete. With this head start, it is not surprising that much of the early educational software enabled teachers and students to work on basic computational skills (such as adding and subtracting) through a variety of electronic versions of workbooks, flash cards, and other routinized functions. Mathematics programs continue to dominate the market, although there have been some slight increases in the availability of software titles for social studies and language arts. In fact, one of the most popular programs (Where *in the World is Carmen Sandiego?* published by Broderbund), is used to teach geography, a subject which has also attracted the attention of developers working in interactive video.

Table 6-4.—Distribution of Educational Software by Subject Area and Grade Range (N =7,325) [a]

Subject	K	1-3	4-6	7-8	9-12
	Grade range				
Business	00/0	1 %	2 %	3 %	4 %
	1	16	61	106	205
Comprehensive skills	7%	4%	5 %	6 %	70/0
	41	86	167	224	363
Computers	4%	3 %	4 %	5 %	6%
	27	61	131	209	294
Early learning/preschool	240/o	7 %	0 %	O%	00/0
	146	139	11	2	o
English/language arts	7%	19%	18%	14%	9 %
	45	373	646	532	462
Fine arts	5%	4 %	40/0	4 %	30/0
	32	81	143	144	145
Foreign language	1%	1 %	4%	7 %	70/0
	4	29	134	264	343
Home economics	00/0	O%	2%	3 %	4%
	o	5	57	125	176
Logic/problem solving	1 %	3%	30/0	3 %	20/0
	8	58	122	115	97
Mathematics	19%	21%	22%	21%	160/0
	115	402	775	807	767
Reading	31%	26%	160/0	90/o	60/o
	192	511	545	334	279
Science	10/0	40/0	8%	120/0	21%
	4	70	275	451	1,031
Social science	1%	40/0	90/0	10%	8%
	5	75	313	398	404
Other	1%	20/0	30/0	5%	7'%
	1	40	116	208	357
Total programs	621	1,946	3,496	3,919	4,923

[a] Percentages (rounded to the nearest whole number) refer to column totals. Forexample, of a total of 621 programs intended for use *in* kindergarten, 31 percent were in reading. Below each percentage is the number of programs in a given subject intended for that grade range Total programs are greater than 7,325, because programs can be classified in more than one grade range

[b] "Other" combines agriculture, aviation, driver education, guidance, health, industrial arts, library skills, and physical education, each of which accounts for less than 4 percent of the total programs in each grade range.

SOURCE Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987

Table 6-5.—Curriculum Requirements and Available Software: Middle and High Schools

	Middle schools		High schools	
	Time spent[a]	Availability of software[b]	Time spent	Availability of software
Communication skills	High	High	High	High
Social science	High	Moderate	High	Moderate
Mathematics	High	High	High	High
Science	High	Moderate	Moderate	Moderate
Fine arts	Moderate	Low	c	c

[a] The proportion of time spent on an given subject ranges from less than 1 percent to 18 percent in grades 7 and 8, and from 1 Percent to 23 Percent in grades 9-12 Subjects accounting for 13-18 percent are rated "High," subjects accounting for 7-12 percent are rated "Moderate. "

[b] Th, proportion of available software for any given subject ranges from less than 1 percent to 23 percent fOr the middle grades, and frOm leSS than 1 PerCent to 24 percent for the high school grades "High," "Moderate," and Low," respectively, refer to subjects that account for 17 to 24 percent, 9 to 16 percent, and less than 9 percent of available titles for the middle grades; and to subjects that account for 16 to 23 percent, 8 to 15 percent, and below 15 percent, for the high school grades

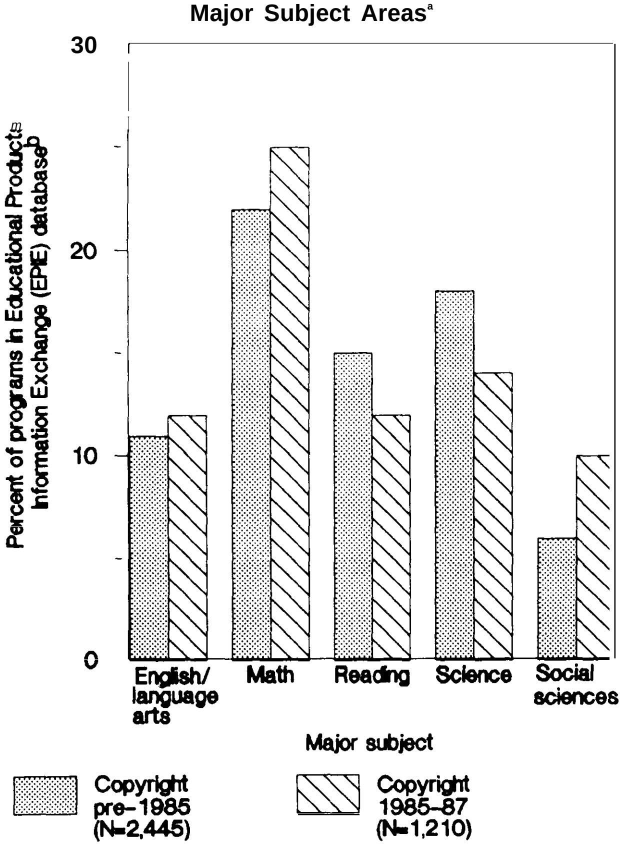
[c] f+. Jot included in grades 9-12

SOURCES For time spent, data from Departments of Education in eight States; for availability of software, Educational Products Information Exchange, July 1987 For methodology of class! fication used in this table see Ellen Bialo and Jayu Sivin, "An Analysis of the Scope and Quality of the Current Supply of Educational SOftWare and of the Available Sources of Information on Educational software," OTA contractor report, Sept 30, 1987.

At the same time, the number of new science programs, especially in chemistry and physics, has decreased (see figure 6-1), to the disappointment of many educational technologists who are concerned about the state of science teaching in the United States. The reason for this decline is difficult to establish. However, one explanation may be that many of the early science programs were quickly found to be wanting, especially in comparison with the new "microcomputer-based laboratories, " and were discontinued. At the same time, high development costs have prevented all but a few players from entering this field. The net result is fewer, but generally more sophisticated, programs.

The importance of perceived teacher demand and technical-ability in shaping the scope and quantity of software is demonstrated by statistics on the type of software available on the market. As shown in table 6-6, the vast majority of titles provide drill, skills practice, and tutorials. Software to develop so-called "higher order thinking skills," such as hypothesis testing and concept development, is in thin supply. In addition, as shown in table 6-7, drill, practice, and tutorial software continues to dominate all subject areas, to the chagrin of many educators and educational technologists. The fact that teachers have often preferred this type of software, which is typically closely linked to curriculum sequences and/or to texts or other instructional materials, suggests that the market responds well to demand signals, but also points to a fundamental predicament: products that are highly rated by "experts" because they represent the most innovative uses are not necessarily the ones preferred by most teachers.[21]

Figure 6-1.—Trends in Availability of Software for Major Subject Areas[a]



[a]Does not include programs in subjects such as problem solving, fine arts, foreign language, or business.
[b]Includes only those programs in the database, that specify a copyright date (3,655 programs). No copyright information is available for approximately half of the programs in the database.

SOURCE: Office of Technology Assessment, based on contractor's analysis of data in the Educational Products Information Exchange, July 1987.

School Uses of Noninstructional Software

Many software products purchased for school use were originally developed for other applications. The home market, for example, has influenced the types of software acquired by schools.[22] Some educators

[21]This issue was discussed at length by participants at the "OTA Workshop on the Educational Software Market," op. cit., footnote 14.
[22]Use of "home" products in schools, and vice versa, makes it difficult to calculate educational software sales and other market statistics with precision.

Table 6-6.—Distribution of Educational Software by Type (N =7,325)

	Percent of programs[a]	Number of programs[a]
Rote drill	15	1,107
Skills practice	51	3,708
Tutorial	33	2,447
Concept demonstration	3	216
Concept development	4	270
Hypothesis testing	1	91
Educational games	19	1,425
Simulations	9	669
Tool programs	11	807

[a]The sum of the programs is greater than N because some programs were assigned to more than one category. Accordingly, the total of the percentages is greater than 100 percent. All percentages were rounded to the nearest unit.

SOURCE: Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987.

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Table 6-7.—Distribution of Major Subject Software by Type

	Program type									
Subject	Rote drill	Skills practice	Tutor	Concept demonstration	Concept development	Hypothesis testing	Educational games	Simulations	Tools	Subject total
English/language arts	26°/0	72%	360/o	0 %	1 %	0 %	240/o	0 %	60/0	
	229	640	318	1	13	1	216	2	58	894
Mathematics.	90/o	550/0	280/.	2 %	3 %	O%	13%	3 %	50/0	
	186	1,089	550	49	61	0	264	52	94	1,971
Reading	250/0	740/0	240/0	0%	1%	0%	290/0	0%	20/0	
	215	645	207	0	12	0	253	4	16	869
Science	9 %	370/o	450/o	80/0	60/0	1 %	12 "/0	32%	8 %	
	107	424	514	88	70	12	140	365	89	1,148
Social science	180/0	320/0	37 "/0	4%	7%	2%	320/0	21 %	4 %	
	100	182	209	25	37	13	183	119	24	565

NOTE: Each row gives percentages (rounded) of all programs in a subject area that are of a given type. For example, 55 percent of all mathematics programs were in the "skills practice" category. Below each percentage is the number of programs in a subject and category. Rows sum to more than 100 percent of the total for each subject because programs can be classified in more than one type.

SOURCE: Office of Technology Assessment, based on analysis of data in the Educational Products Information Exchange, July 1987.

are skeptical about games, while others recognize their potential educational value. Similarly, software originally developed for the business environment has also become enormously popular among teachers, children, and parents alike. Word processing programs, for example, have become a staple of writing classes; some have been customized to allow for illustrated story composition and other activities appropriate to primary and secondary grades. A best-selling software product on the educational market today is an integrated word processing, database management, and spreadsheet utility. The success of this program suggests that many teachers prefer generic materials that improve the way children approach many different subjects over didactic programs that provide specific lessons. This type of software also appeals to parents who want their children to be prepared for a world of work that depends on similar interactive technologies.

Photo credit: Scholastic Software

Teachers use word processing software such as the *Bank Street Writer* to help students improve their writing skills, teaching them to analyze and revise drafts until they have expressed themselves as clearly as possible.

EVALUATION AND ACQUISITION OF EDUCATIONAL SOFTWARE

Effects of Local Public Decision making

Forty million children are now enrolled in over 81,000 U.S. public elementary and secondary schools located in close to *16,000* public school districts. On a typical school day, over 2 million teachers work with many types of instructional materials to teach a wide variety of behavioral, intellectual, and social skills. The different needs and abilities of school children and their teachers, coupled with deeply held beliefs in universal access and local financing and decisionmaking, have gained for the American school system a reputation for participation and diversity that is unmatched anywhere in the world. This feature of our public school system is sometimes overlooked, especially by advocates of reform who focus on the ubiquitous classroom in which stu-

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dents passively digest facts and figures as they emanate from the mouth of the teacher.[23]

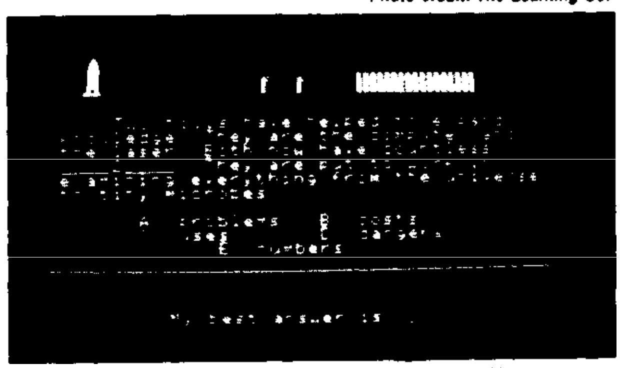
One of the consequences of this long-standing history of pluralism and local decisionmaking is that the way school systems acquire instructional materials is highly idiosyncratic. In some States, such as New York, there is no central textbook selection process. Publishers are guided by Regents examinations, which define statewide standards, and local districts choose books they believe are best suited to meeting those standards. In California and Texas, on the other hand, the State role in textbook selection and acquisition is more dominant. The combined effects of State policy, local jurisdiction, teacher preferences, and parental voice vary widely with respect to software as well. The major textbook publishers and suppliers of other instructional materials have an understanding of this market that can come only from experience, which gives them a potential edge over newcomers.

In addition to the diversity of acquisition procedures, there is also considerable variation in how school districts gather information about software products. To gain further insight into this aspect of the complex market in educational software, OTA conducted a series of open-ended interviews with computer coordinators and other personnel in school districts throughout the country.[24] These interviews convey the general impression that those in charge of acquiring software seek information about competing products, that such information is available from many different sources, and that the information is fragmented and largely subjective. Indeed, the need for information upon which teachers and others can base their selections raises important policy considerations. (See box 6-D.)

Evaluation of Software Quality

Educational software, like other educational resources, can be criticized or praised on many criteria. A first cut at this problem involves the distinction between technical quality—does it work? how often does the program crash? are the screen displays clear?—and its educational quality—do children learn? are they motivated to continue learning? Rapid advances in programming experience have substantially raised the proportion of technically sound products on the market. Yet teachers continue to lament those intermittent bugs and crashes that disrupt children's learning. Although

Photo credit: The Learning Co.



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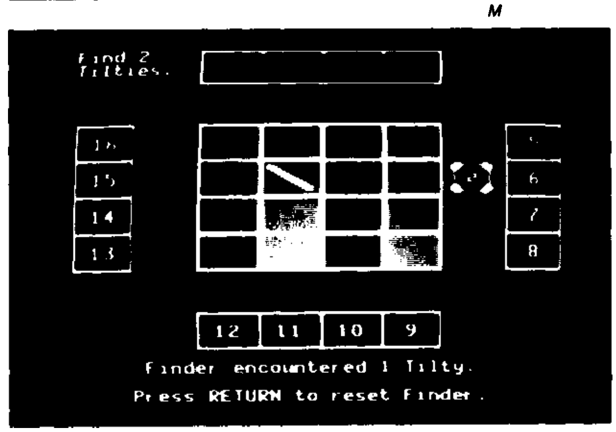

Photo credit: Sunburst Communications

Graphics, animation, and topics children find appealing are used in software to make learning feel like a game.

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[23] For all their superficial similarities, American classrooms are remarkably diverse. There is considerable variation in children's achievement, and subtle differences in teacher backgrounds and styles have been proven to make a difference. Indeed, one of the most frustrating conclusions from years of education policy research is that positive results attained in one school are not easily replicated elsewhere by adopting the same apparent teaching style or curriculum. While many teachers believe they have found a successful method, most teachers recognize that there is no "one best way." See Richard Murnane and Richard Nelson, "Production and Innovation When Techniques are Tacit: The Case of Education," Journal *of Economic Behavior and Organization,* vol. 5, 1984, pp. 353-373.

[24] For methodological detail, see Priest, op. cit., footnote 1.

Box 6-D.—Information for Software Decisions: A Sampling

- The Orange Windsor School district in South Royalton, Vermont, has been designated as the Education Resource Center for the entire State. Approximately 15 new software titles come in each week, all of which are previewed and evaluated by the same person. A grade of A, B, C, or D is assigned to each product, where the main criteria are "user friendliness," whether the product lives up to its stated goals, and whether it is a "good" educational tool. Teachers may visit the center and preview new products, for which they are charged $1 per day.
- The principal source of information about software used by the Bedford City School District in Bedford, Ohio, is the Educational Computer Consortium of Ohio. Established in 1981, the Consortium helps teachers, administrators, and parents become familiar with a wide range of educational technologies and materials. It is a nonprofit consortium, made up of 80 school districts, 7 universities, and 8 other nonprofit organizations. The resource center contains more than 100 different software packages and houses a lending library with 2-week borrowing privileges.
- The Billerica School District in Billerica, Massachusetts, is part of the 22-member Merrimack Educational Consortium. This group specializes in review of software for low achievers. Several thousand software titles are available for preview, as well as information provided by various software review organizations (such as the Educational Products Information Exchange and Digest of Software Reviews). The Consortium also publishes a review of resources targeted for adult education.
- At the Leander Independent School District in Leander, Texas, the only source of information is descriptions and reviews that appear in magazines: the district does not make use of formal evaluations. In addition, the computer instruction supervisor from the neighboring district, which is larger, offers advice. Recommendations are often made by the high school principal, assisted by a teacher, and sent up to the central district office for approval by the assistant superintendent.

SOURCES: OTA interviews with school district technology personnel; and W. Curtiss Priest, "Educational Technology: Information Networks, Markets and Innovation," OTA contractor report, September 1987.

most educators are more concerned with program content and educational effects, the costs of technical failures should not be underestimated. As the *Wall Street Journal* reported recently: ". . . corporate computer programmers now spend 80 percent of their time just repairing the software and updating it to keep it running. "[25] As educational software becomes more and more sophisticated, product reliability will become an increasingly important factor in schools' purchase decisions.

Evaluating educational effects is far more complicated than measuring technical quality of software. At one extreme, evaluation is done by academic researchers who design and conduct various sorts of experiments. Unfortunately, few of the studies to date have adhered to rigorous norms of scientific inquiry (see chapter 3). In addition, these studies typically focus on generic software types, rather than particular products. At the other extreme are the many magazines aimed at the diverse audience of computer-using teachers, most of which devote considerable space to software reviews. These reviews are invaluable, because they are usually written by computer-using teachers or by specialists in particular subject areas. But magazines are reluctant to publish negative reviews, in part for fear of alienating potential advertisers; and in selecting which of the nearly 2,000 new titles per year they will review, they are influenced by publishers' prior track records, which introduces a bias against new entrants.

In addition to magazine reviews and formal academic research, the booming educational software industry has led to the creation of a number of independent product review organizations. Many of these are private, nonprofit agencies, supported by States, universities, or school districts, individually or in consortia. (See boxes 6-E and 6-F for descriptions of two of the largest public school district and State evaluation efforts.) They use a wide range of evaluation criteria and methodologies, and serve a diverse clientele. Some, such as Educational Products Information Exchange (EPIE), attempt to include in their databases all types of software titles (although no evaluation agency catalogs every sin-

[25] *Wall Street Journal*, "Patching Up Software Occupies Programmers and Disables Systems," Jan. 22, 1988, p. 1.

Box 6-E.—Software Evaluation in New York City

In crowded offices on the fourth floor of 131 Livingston Street, across the street from the headquarters of the New York City Board of Education, a small group in the Division of Computer Information Services receive, catalog, and attempt to review almost 300 new educational software products each month. Their principal objective is to provide some systematic information about these products to a complex and diverse population of computer users. With almost 1 million enrolled children, 1,000 schools, including 32 separate school districts and 5 high school districts, the New York City school system is larger than many State systems. Last year alone, New York City spent over $4 million on software, nearly 3 percent of educational software sales nationwide.

According to Jeffrey Branzburg, a former junior high school mathematics teacher with 15 years experience and currently Special Assistant to the Director in the Office of Technology Assistance and Support for the City, over 7,000 different titles have been approved for the schools since the review process began in 1982. Who are the reviewers? They are mostly teachers, assistant principals, and principals, who are "on-call" for after school and weekend work, and who have some experience and training in software review. All reviewers have worked for major review organizations (like the Education Products Information Exchange), or have taken college-level courses in software evaluation (Teachers' College at Columbia University, Bank Street College of Education, and other institutions have begun offering credit-bearing courses in software review).

As Branzburg recognizes: ". . . software is very subjective, almost like movies, and it's difficult to be scientific. But we still feel that it's important to communicate to teachers what their peers' reactions to different products are."

Indeed, New York's highly decentralized system, the result of a bitter struggle that took place in the late-1960s, is reflected in their approach to software evaluation. Irwin Kaufman, who heads the division, points out that while the central board sets standards, districts are encouraged to do their own purchasing depending on specific needs: "LOGO might work fine in one school setting, but CAI may be best for another. It would be a big mistake to force all the different classes and kids in this system to use the same software."

Kaufman sees three main tasks for his operation: weed out the software that is racist, sexist, or otherwise unacceptable; offer teachers a variety of opportunities to try out a wide range of software products before using them in class; and negotiate hard with publishers and distributors for the best prices.

In addition to circulating a printed list of approved titles, the division maintains an on-line database, accessible via telephone and modem, with current approved titles and brief descriptions; a lending library with a large sample of software that teachers can take home; and technical assistance centers located throughout the five boroughs where teachers learn about software and sign up for training.

SOURCE: OTA site visit and interview, 1987.

gle one). while others have special interests (such as software for the learning disabled or the handicapped). The States have also become heavily involved in their own evaluations (see below).

OTA finds that among 36 software review organizations, including those funded by State or local governments and private for-profit and nonprofit entities, there is considerable overlap in the definition of quality criteria. A complete list of the criteria includes more than 200 items, the majority of which pertain to technical characteristics rather than learning effects. (See appendix B.)[26]

[26]The checklist approach to software evaluation has been challenged because products that meet certain technical criteria do not necessarily accomplish their educational objectives. See Joanne Capper, "Computers and Learning: Do They Work? A Review of Research," OTA contractor report, January 1988. For a scientific attempt to specify criteria for software see T. Malone, "Toward a Theory of Intrinsically Motivating Instruction," *Cognitive Science,* vol. 4, 1981, which makes a more formal effort to identify ingredients of effective software.

Box 6-F.—Software Evaluation in California

The State of California early on recognized the need to provide systematic information about educational software to a vast and complex school system. With over 1,000 public school districts, more than 7,500 schools, and close to 4.2 million enrolled students, the stakes are high; allocation of educational resources has always been viewed as a high-priority governmental activity.

Funding from the comprehensive State educational reform bill S.B. 813 supported a variety of initiatives, including the establishment of the Teacher Education and Computer (TEC) Center Software Library and Clearinghouse in 1982. The following year, under the leadership of Ann Lathrop and her staff at the San Mateo County Office of Education, representatives from a number of agencies across the Nation met at the first California TEC Center Software Evaluation Forum. The Consortium that emerged from this meeting has met each year since, with the principal objective of selecting software titles to be included in the *Educational Software Preview Guide*. While California holds the copyright on the *Guide*, participating agencies are encouraged to make its information available to their own local and State audiences. The *Guide* is intended to assist educators in locating software for preview. It is not intended to endorse products for purchase without examination. Thus, the underlying principle is to inform educators of their choices and to help them learn about products before adopting them for classroom use.

On another front, the State developed *Guidelines for Educational Software in California Schools* in 1985, designed with two main goals: to suggest criteria for software evaluation and to provide direction to educational software developers about State expectations for instructional technologies.

As a natural outgrowth of these *Guidelines*, the Technology in the Curriculum (TIC) Projects were commissioned in 1985, with the following objectives: to establish quality standards and content specifications for the production of software materials that would meet specific curricular needs; to broaden the scope in order to include video programs as well as conventional computer software; and to provide a resource to California educators in the selection of appropriate technological materials for classroom use. This effort—staffed primarily by teams of school teachers—focused at first on six major areas of the curriculum—English/language arts, foreign languages, history/social science, mathematics, science, and visual/performing arts. Resource guides, which are updated periodically, include annotated listings of available software programs that are compatible with curriculum objectives.

According to Wendy Harris, who has been instrumental in developing and supporting many of these activities during her tenure as Director of Technology in the Superintendent's office: ". . . the high cost of providing the service that the TIC guides represent, as well as the inevitable lag in timely review and distribution of information about new programs via conventional print media, are issues whose resolution remain a challenge."

SOURCE: OTA site visit and interviews, 1987.

One of the obvious problems of quality evaluation is that there are many instances of tool software not designed for instructional use that have yielded surprisingly good learning and motivational results in classrooms. Word processing packages, for example, originally designed for home and office use, were quickly found to create new and exciting ways for children and teachers to write, edit, and publish school newspapers. Database programs have been applied to science subjects as well as to classroom management; spreadsheets have made strong tools for teaching basic business subjects; and even games have been found to be effective. But many educators question the value of some of the more popular packages: speaking at a national conference of software publishers, one senior marketing executive said that ". . . what we don't need are more programs that print invitations and make banners. . . ."[27] In a similar vein, the assistant coordinator for technology at a large suburban school district has argued that we send children to school

[27]Phil Miller, Scholastic, Inc., speaking at the Tandy/Radio Shack Software Publishers Workshop, Fort Worth, TX, April 1987.

". . . to read, write, learn how to communicate, learn how to develop an argument, and how to get along with people," goals that will not be advanced with many of the easy and fun programs on the market today.[28]

OTA tried to compare the different formal review mechanisms that are designed to help prospective teachers and other users. As shown in table 6-9, reviews vary as to their emphasis on the following criteria:

- basic program data, i.e., whether a review gives intended age and grade range, a clear statement of the product's educational goals, type of software (drill, tutorial, simulation);
- reliability, meaning the independence of the reviewing agency and the extent to which its ratings are free from promotional considerations;
- evaluative information, meaning primarily the extent to which measurement biases are eliminated;
- number of programs reviewed;
- timeliness, measured as the number of months that typically pass between a product's release and the publication of an evaluation; and
- accessibility considerations, including the organization's familiarity, its costs for reviewing products, its circulation, and its availability.

In order to develop a composite statement about the quality of educational software, OTA also aggregated the findings of eight evaluation agencies whose criteria and review procedures seemed to provide a reasonable estimate of the state of the software supply.[29]

According to data from these agencies, nearly 60 percent of the reviewed software products are "high quality." However, it is important to point out that of the roughly **7,300** titles in the EPIE database, only 21 percent, or about 1,550 titles, were reviewed by one or more of the eight agencies. Thus, it is difficult to assess what fraction of all available software would pass muster under the evaluative criteria employed by these agencies. Even these selected agencies can be faulted for not adequately incorporating evaluators' field test results, and most reviews provide only partial information about implementation strategies adopted by teachers.

More important than these gross aggregates are subject area breakdowns. (See table 6-8.) In particu-

[28]Charles Philipp, Montgomery County Schools, MD, in Office of Technology Assessment, op. cit., footnote 14.

[29]See Bialo and Sivin, op. cit., footnote 1.

Table 6-8.—Educational Software Titles Reviewed and Recommended[a]

Subject	Number reviewed	Number recommended	Percent recommended
Business	35	23	66
Comprehensive skills	69	53	77
Computers	58	40	69
Early learning/preschool	61	25	41
English/language arts	169	103	61
Fine arts	54	41	76
Foreign language	56	36	64
Logic/problem solving	58	44	76
Mathematics	457	223	49
Reading	194	100	52
Science	267	176	66
Social science	102	73	72
Other[b]	90	56	62
All subjects	1,550[c]	915[c]	59

[a]Based on evaluations of educational software published through July 1987 from eight selected agencies: Alberta (Canada) Department of Education, Curriculum Branch Computer Courseware Clearinghouse; Connecticut Special Network for Software Evaluation; Educational Products Information Exchange Institute; Florida Center for Instructional Computing, High Scope Educational Research Foundations; Microsift, Northwest Regional Laboratory; North Carolina Department of Public Instruction, Media Evaluation Services; York University (Canada) YESSUS Project.

[b]The Other category combines nine subjects (agriculture, aviation, driver education, guidance, health, home economics, industrial arts, library skills, and physical education), each having less than 35 programs reviewed.

[c]The sum of the programs in the "Number Recommended" column and in the "Number Reviewed" column is greater than N because some programs were assigned to more than one subject category. All percentages were rounded to the nearest unit.

SOURCE: Office of Technology Assessment, 1987.

Table 6-9.-Educational Software Information Sources: Typology

Source type	Basic program data	Evaluation information	Number of programs	Timeliness	Familiarity with source	Circulation	Cost per year	Availability
Independent evaluation agencies	Moderately complete Reliability: high	Always provided Level of detail: high Field testing: sometimes Bias: low	50-500+	6-12 month lag	Low-moderate	5,000 or less	Ranges from no charge to $275	Low
Independent directories	Moderately complete Reliability: moderate-high	Always provided Level of detail: low Field testing: sometimes Bias: low-moderate	200-7,500 +	3-12 month lag	Low	3,000-10,000	$20-$75	Low
Professional journals	Moderately complete Reliability: high	Rarely-sometimes provided Level of detail: moderate-high Field testing: sometimes Bias: low-moderate	10-125+	8-16 month lag	Moderate	5,000-160,000	$15-$50	Low-moderate
Popular educational computing magazines	Moderately complete Reliability: moderate-high	Always provided Level of detail: moderate-high Field testing: sometimes Bias: low-moderate	250-400	2-12 month lag	High	45,000-82,000	$16-$24	High
Advertisements	Ranges from incomplete to moderately complete	Sometimes provided Level of detail: low Field testing: rarely Bias: high	200 and up; varies widely	No lag	High	Varies widely	Not applicable	High
Catalogs	Moderately complete Reliability: low-moderate	Sometimes provided Level of detail: low Field testing: rarely Bias: high	10-500+	Ranges from no lag to 12-month lag	High	Varies widely	No charge	High
Word of mouth	Ranges from incomplete to complete Reliability: low-high	Always provided Level of detail: low-high Field testing: sometimes Bias: low-high	Varies widely	Lag varies widely	High	5-500+	Ranges from no charge to $300+	High

SOURCE: Ellen Bialo and Jay Sivin, "An Analysis of the Scope and Quality of the Current Supply of Educational Software, and of the Available Sources of Information on Educational Software," OTA contractor report, Sept. 30, 1987 lar, the percentage of recommended programs varies significantly, from 41 percent in the early learning category to 77 percent in the comprehensive category (for example, tools and multipurpose programs). Furthermore, among the major subject areas, there appears to be an inverse relation between quantity and quality: although mathematics programs are the most abundant, less than one-half are "high quality." Social sciences, which constitute the lowest proportion of titles for major subjects (see table 6-2), are very well represented in quality terms. Similarly, new science programs, which have dropped in number since 1985, receive relatively good ratings. Indeed, the overall quality picture seems to be improving, especially if one considers changes in the percentage of recommended programs since 1985, as shown in figure 6-2.[30]

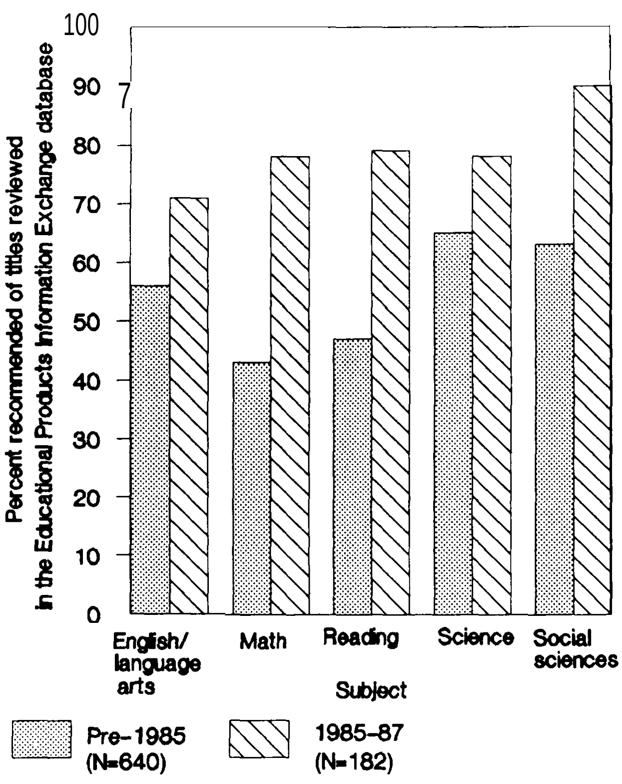
The software of most ILSs is not typically evaluated by independent review organizations or in the professional press because it is too costly to set up an entire system and test it in classroom settings. EPIE has recently begun to evaluate segments of some integrated systems, but their findings are preliminary. School districts acquiring such systems rely primarily on information contained in competitive proposals. Proposals contain information on a number of factors including correlation of software materials with district instructional objectives, cost per pupil for various configurations, and examples of how the systems have been used in other districts. Those charged with evaluating competitive bids may also conduct site visits to other school districts that are already using these systems.

The opinions of computer-using teachers can be useful indicators of software quality. As the penultimate consumers, their views are often the most credible, even if their assessments do not conform to rigorous methodology. Computer-using teachers are usually months ahead of formal reviewing agencies, who undoubtedly base their choice of which products to review at least partly on the suggestion of active teachers.

[30] Note that the sample of titles that include a copyright date is a small fraction of the total, raising questions of inference and generalizability.

In loosely structured interviews with 12 "leading edge" teachers, OTA found that they listed some 115 "best" programs. Most were characterized as "open-ended," allowing students substantial range of choices and decisions, and/or allowing the teacher considerable latitude to adapt program content to the needs of their particular student population. The highest percentage of named programs were in the "comprehensive" category (multipurpose tools rather than structured curriculum-specific software). About half the programs named by these select teachers were also rated highly by the eight formal evaluation groups; those not included by these organizations were primarily in the tool category (including graphics and other utilities), suggesting an important difference between the opinions of "experts" and the opinions of "expert teachers."

Figure 6-2.— Recommended Software Titles Before and After 1985[a]



SOURCE: Office of Technology Assessment, based on contractor's analysis of data in the Educational Products Information Exchange, July 1987.

THE STATES AND SOFTWARE

According to a 1987 survey by *Electronic Learning* magazine, 37 States operate software preview centers and 32 support software evaluation.[31] OTA expanded on this survey and obtained responses to a detailed questionnaire from all of the 50 States and the District of Columbia.[32] State efforts vary, Some States collect and evaluate software independently, others are members of consortia, and some make available evaluations conducted by nongovernmental agencies. In Arizona, for example, staff from the State Department of Education evaluate software under guidelines developed with faculty at Arizona State University. Connecticut provides partial funding for six regional education centers, which receive additional support from local districts. These centers provide a range of educational services, including software preview. Washington State does not evaluate software, but provides curriculum guidelines for educators and runs a network of technical assistance, training, and preview centers. California has been a leader in software review efforts, as well as in evaluation and technical assistance (see box 6-F).

Some States have joined together in collaborative evaluation and dissemination efforts. Project Software Evaluation Exchange Dissemination (SEED) is coordinated by the Southeastern Education Improvement Laboratory. SEED facilitates and coordinates the evaluation of software for six Southeastern States (Alabama, Florida, Georgia, Mississippi, North Carolina, and South Carolina). Participating States distribute evaluations independently to local school districts. Another consortia effort was launched in 1983 by the Council of Chief State School Officers (CCSSO). With funding from the National Institute of Education, CCSSO provided States on-line information about educational technology products (including software), gathered data about State curriculum requirements, and established links between the Federal Government, the States, and other organizations involved in educational technology. While this project, called the National Technology Leadership Project, was terminated in 1986 due to lack of funds, CCSSO has remained interested in educational technology and has been exploring new funding possibilities.

In addition to these review and evaluation efforts, 18 States fund or offer technical assistance to instructional software development projects.[33] Project IMPAC in Arkansas is a notable example, in which a comprehensive effort to match software and basic skills has been supported by business and industry and coordinated by the State. Project Vision in Kentucky, a pilot program supported by IBM and tested in eight sites, uses videodisc to teach basic mathematics skills to children in grades K-2. The software is based on the Kentucky Essential Skills, and was designed by a former teacher working as a technology consultant to the State. Because the software is developed in-house, the original cost of $10,000 per site has been cut to about $6,000.

One of the more ambitious efforts by a State to stimulate quality software development is currently underway in California. As already mentioned, one of the results of the Technology in the Curriculum Projects, started in 1984, was the identification of areas in the California curriculum for which there was little or no quality software (including video programming). Papers were subsequently commissioned to provide recommendations for software development in mathematics, science, history/social science, and English/language arts. The State then developed a request for proposals, and last year awarded development grants for six projects in mathematics, science, and history/social science. (No English/language arts projects were supported, because reviewers felt that the proposals were inadequate.) Under the terms of the program, publishers of the software retain the copyright, while the State receives a royalty

[31] *Electronic Learning,* "Educational Technology 1987, a Report on EL's Seventh Annual Survey of the States," vol. 7, No. 2, October 1987.

[32] OTA State Educational Technology Survey, 1987. Many States provided additional information and supporting documentation. For further derail, see app. A.

[33] The States are Arkansas, California, Connecticut, Delaware, Florida, Kentucky, Massachusetts, Minnesota, Nebraska, New York, North Carolina, North Dakota, Ohio, Oregon, Pennsylvania, Texas, Utah, and West Virginia.

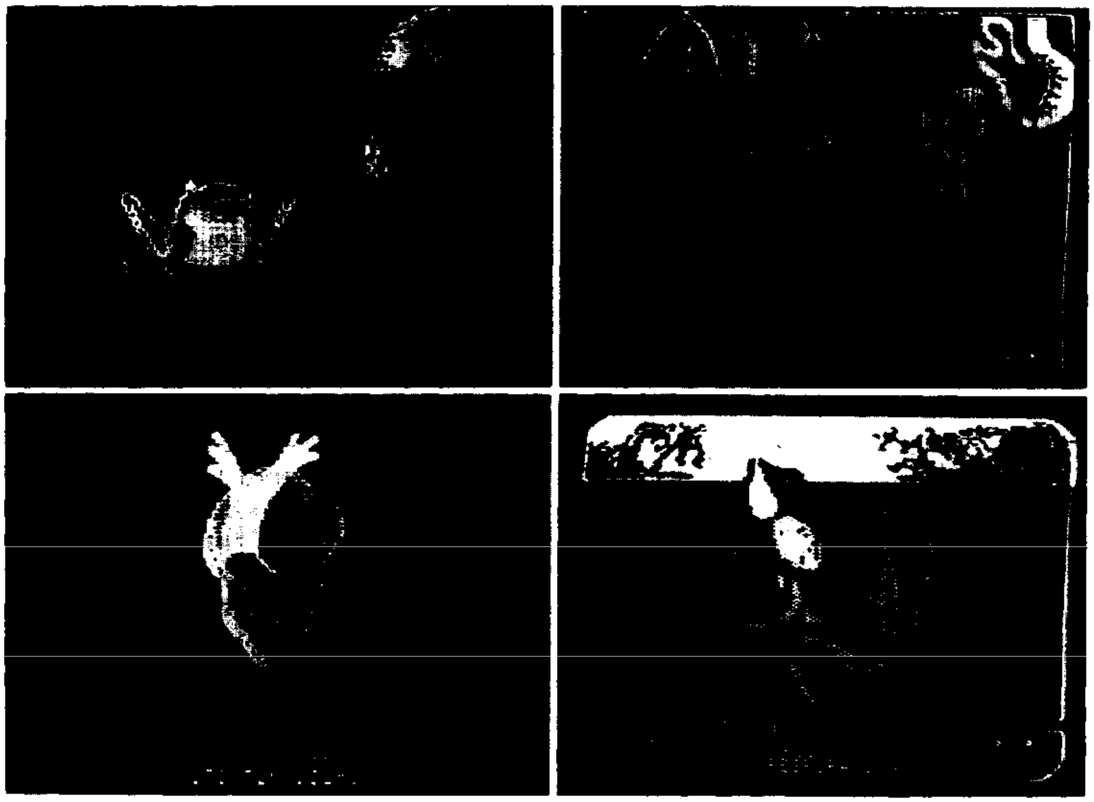


Photo credit: Scholastic Software

With an interactive computer simulation of a frog dissection, students use the computer to probe, snip, remove, and examine organs; then they attempt to replace them in the right order.

as well as the right to purchase the product at reduced cost. The royalty funds are intended to provide seed money for continued State activity. The State committed over $1 million to this effort. State officials found that despite the State's willingness to subsidize upfront development costs, few small developers submitted bids. One explanation is that the request for proposals stipulated that developers —not the State—would be responsible for marketing, the high costs of which posed a barrier to developers who were not already well established in the market. In addition, State officials believe that States will find it impossible to sustain this type of development effort unless they group themselves in consortia or receive additional outside funding. The cost of developing comprehensive software packages, for example, would exceed most States' resources.

PUBLIC POLICY; ISSUES AND DIRECTIONS

Assuming there is general agreement that computers and related technologies can play an important role in enlarging and enriching the school experiences of children, an overarching public policy question becomes how to best stimulate continued **production and use of high quality software. Indeed, since** most of the **hardware** used by schools is generic—computers are multipurpose machines—the "educational" part of "educational technology" really means software.

OTA **finds a general consensus among de. velopers, publishers, educators, and other users that the quality of available educational software**

is not as high as it might be. Moreover, despite the appearance of an active commercial market, the ability of the private sector to continue to produce and market innovative programs over the long-run, and to achieve the promise of new interactive learning tools, is uncertain.

Capital Limitations

The current national average of 1 computer per 30 children represents a small fraction of most school budgets. For a medium-sized district with 1,800 enrolled children, for example, the cost of providing 60 desktop computers is roughly $90,000, or less than 1.5 percent of the average district budget.[34] Indeed, some school districts that began installing interactive technologies in the late 1970s and early 1980s hardly noticed the expense.[35]

The problem, however, is that this level of expenditure translates to very limited instructional use of the technologies. Most computer-using students still spend only about 1 hour per week with the computer, which means that the demand for software is too low to allow most publishers to recoup their development and marketing costs. Consider the proportion of enrolled students in a given grade who study a given subject, and among them, the proportion with regular access to computers. It is clear that software publishers face a severely fragmented demand that can seldom justify the level of investment necessary to create products for those subjects and grade levels.

Property Rights

In addition to the capital limitations, software innovation is constrained by problems of *appropriability*.[36] It is difficult (or impossible) for innovators to recoup investments in products that become public goods. This is a familiar problem in education where, for example, one determinant of the quality and diversity of textbooks is the ease with which new ideas can be copied.[37] It is also a familiar problem in the general software market, where both theft of innovation (the idea for a software design or interface) and unauthorized duplication of discs have plagued the industry.

Information Barriers and Transaction Costs

This chapter earlier described various sources of information about software, and suggested that despite a great many available reviews and evaluations, purchasers of instructional software often act on imperfect knowledge. (Some would claim that it is the *overabundance* of information that complicates decisionmaking.) But software consumers are not alone in making choices with incomplete information. On the supply side, too, design and marketing decisions would be considerably more efficient if producers had better market information. One study identified four characteristics of the U.S. school system that erect barriers to information: informal acquisition decisions by teachers, principals, and parent associations which are not necessarily aligned with formal mechanisms and funding; adoption processes that vary from district to district and State to State; the inadequacy of the installed base of hardware coupled with the presence of many different computers that run different operating systems; and a fragmented market with a diverse student population taking many different subjects at different grade levels.[38]

The high costs of marketing are perceived as a critical problem in the industry. As shown in figure 6-3, over half of all software firms responding to a recent survey cited sales and marketing costs as the factor most affecting profitability. Moreover, it is important to note that this problem does not affect all firms equally. Textbook publishers and multiproduct firms are least victimized by the complexities of educational marketing. The former group, especially those with substantial market share who

[34] This estimate is based on the assumption of $1,500 per computer, which may be high, given the possibility of volume discounts. The district budget figure is based on the national average of $3,449 per enrolled child. U.S. Department of Education, Center for Education Statistics, *Digest of Education Statistics* (Washington, DC: 1987). See also ch. 6 for a more detailed discussion of costs.

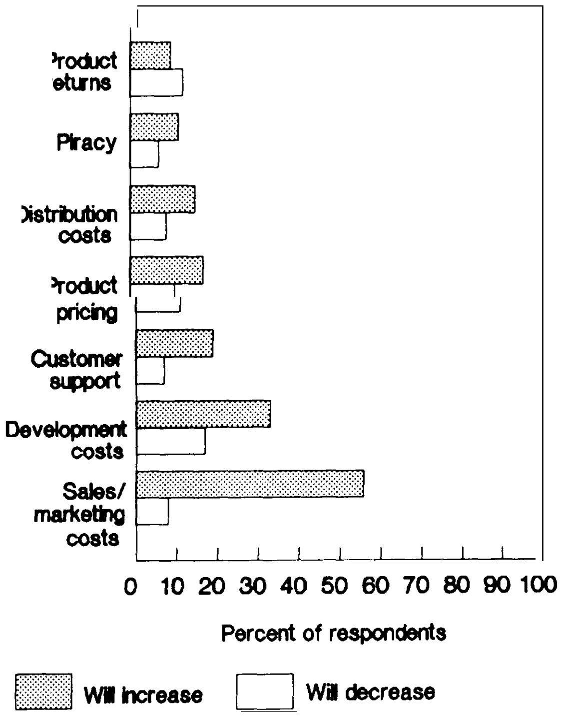
[35] George Ridler, associate superintendent for administration, Prince Georges County Public Schools, MD, Interview, Feb. 18, 1988.

[36] Appropriability is the term used by economists generally for an investor's ability to recoup returns, and specifically in the context of inventors recouping the development costs of their Inventions.

[37] See Goldstein, op. cit., footnote 17.

[38] See Henry Levin and Gail Meister, Stanford University, Center for Educational Research at Stanford, "Educational Technology and Computers: Promises, Promises, Always Promises," Project Report No. 85-A13, November 1985.

Figure 6.3.—Software Publishers' Expectations of Factors Affecting Future Profitability



SOURCE: Office of Technology Assessment, based on data from TALMIS, 1987.

have been selling books and other materials to schools for a long time, enjoy a significant advantage because of their sales networks and intimate knowledge of local acquisition policies; and even these firms must devote a considerable fraction of their budgets to marketing. By comparison, new entrants need substantial time to catch up and familiarize themselves with the best distribution and sales channels. The balance sheet of a small software developer, shown in table 6-10, illustrates the relatively high proportion of total expenses allocated to marketing.

Policy Responses

Federal policy with respect to educational software must be sensitive to the broader context of educational achievement: indeed, the great appeal of new instructional technologies lies in their potential role in raising academic performance. But academic performance depends on many factors, and not just on the level of expenditures on specific instructional materials. More computers and more software alone are not likely to bring about significant improvements in children's learning and achievement. Decisions about educational technology generally, and software in particular, need to be sensitive to how the new tools will affect-and how their use will be affected by—the management and organization of schools.[39] In this context, OTA finds that the Fed-

Table 6-10.–"Self-Starter Software Co." Income Statement, 1986

Income:		
Cost of sales	$ (3,049.88)	
Cost of sales (computer equipment)	(3,060.00)	
Total cost of sales	(6,109.88)	
Total net sales	5,445.89	
Services (Joan)	8,459.49	
Services (David)	1,420.64	
Commissions earned	228,88	
Miscellaneous	1,032.52	
Other income and services	11,141.53	
Gross income		$ 16,587.42
Operating expenses:		
Advertising	**$5,171.34**	
Accounting and legal	**162.00**	
Automotive expenses	**1,216.12**	
Bank charges	151.88	
Electronic communications	95.38	
Depreciation	5,669.10	
Dues and publications	339.67	
Donations	39.50	
Entertainment and promotion	**396.77**	
Insurance	**782.92**	
Interest expense	*832.88*	
Miscellaneous expense	17.27	
Office expense	239,22	
Postage	**322.01**	
Repairs and maintenance	**215.97**	
Computer maintenance	20.00	
Supplies: general	63.71	
Office supplies	354.87	
Tax and license	214.40	
Telephone	1,292.60	
Travel	770.16	
Gas and electric	143.14	
Water	37.38	
Total expenses		$ (18,548.29)
Marketing expenses as percent of total:		49 percent
Net profit		$ (1,960.87)

NOTE: Items in bold considered marketing expenses.

SOURCE: These are actual data from a small software publisher in California. The name has been changed to preserve confidentiality.

[39] An example of an important school organizational issue is "autonomy": the degree to which schools are free from external political influence, and the degree to which teachers are encouraged to pursue lesson plans without stringent accountability to governmental authorities. See, for example, John Chubb, "Why the Current Wave of School Reform Will Fail," *The Public Interest, No. 90,* winter 1988, p. 36; and Carnegie Forum on Education and the Economy, *A Nation Prepared: Teachers for the 21st Century,* Report of the Task Force on Teaching as a Profession (New York, NY: 1986).

eral Government can respond to problems in the educational software market through a set of complementary strategies, as outlined below.

Technology Push

As described earlier, the combination of insufficient demand, unauthorized duplication, and theft of innovation make investments in new software very risky and may ultimately exclude all but the largest (or luckiest) players from the market. By subsidizing development costs, the government could improve the calculus of investment and returns, and provide partial relief. This "technology-push" strategy would be expected to result in a greater number of developers competing, and in a higher propensity to experiment with innovative software concepts.[40]

While the concept of providing Federal monies is separate from the question of how to distribute those monies, institutional features should not be overlooked. The ultimate success of this type of policy depends in part on the ability of the funding agency to judge the quality of project proposals, estimate their likelihood of commercial success, and allocate resources accordingly. The Federal Government has in the past supported several excellent development efforts through the Departments of Defense and Education and the National Science Foundation (see chapter 7). Although the distinction between basic and applied research in educational software is fuzzy, federally funded projects have tended toward the former. Most advocates of Federal support caution against involvement with product design and development, while they urge a steady support of basic research.

The trade-off implicit in this discussion is between the level of funding and the ability to *target* the funds effectively. The Federal Government clearly has resources and could afford to support the most qualified and sophisticated researchers. But it is poorly situated to judge the effects of various instructional tools on classroom teaching and learning.

A variation on the Federal technology-push strategy would involve joint Federal/State funding. Many States have already proven their interest and ability to stimulate software development, as discussed earlier. The principal obstacle standing in their way has been fluctuations in funding, which is often subject to changing political climates and regional economic shifts.[41] To overcome these obstacles the Federal Government could partially subsidize State and local development efforts. Local agencies would retain responsibility for curriculum definition, identification of software needs, and screening of project proposals, and their efforts would be backed by the assurance of continued Federal support.

Note, however, that even State-level software decisions may be insensitive to local needs, and may undermine efforts to grant teachers greater autonomy in classroom decisionmaking. Ideally, therefore, Federal and State resources could support local or school-level software development. This strategy necessarily implies a heightened willingness to recognize school and classroom idiosyncrasies, and to approach software development through classroom trial and error. The underlying idea is to help schools and teachers build greater instructional capacity, and not to reduce that capacity by mandating software standards from high in the educational bureaucracy. (The problem with this approach, though, is that it does not necessarily overcome fragmented demand.)

Market Pull

The complement to technology push is "market pull." As explained earlier, a principal cause of fragmented demand for software is the quantity of computer hardware in the schools and the degree of utilization. If more students had more access, it is reasonable to expect that more software developers would compete in the market. But the history of hardware acquisition by schools and school districts offers ample evidence of the power of local funding constraints and annual budget processes. Even the impressive growth in the number of schools with computers, and the dramatic reduction in the ratio of students to computers, pale in comparison to the rate at which business firms and other organizations have adopted the new technologies.

To remedy this aspect of the problem, the Federal Government could support the purchase of

[40] See also Levin and Meister, op. cit., footnote 38.

[41] The recent experiences of Texas and California are illustrative. See, for example, LeRoy Finkel, "Obituary: Teacher Education and Computer Centers (TECCS): July 1, 1982-July 7, 1987," *CUE Newsletter*, vol. 10, No. 1, September 1987. See also app. A.

hardware in sufficient quantity to improve software developers' chances of recouping their investments.[42] Again, the analogy with industry is illustrative: with office automation both widespread and intensive, incentives to software developers have led to a viable commercial market.[43] Here, too, caution should be exercised so that Federal support for hardware purchase not be perceived as Federal domination over hardware choices.

It is important to emphasize that technology push and market pull are complementary strategies. A radical increase in hardware, without assurance of appropriate software, would be risky.[44] On the other hand, Federal support for software research and development (R&D) coupled with stimulation of demand for the outputs of that R&D could be mutually reinforcing.

Portability

As mentioned previously, an additional complication software developers face stems from the incompatibility of various computer operating systems. A program written for the Apple line of computers, for example, does not work in IBM and MS-DOS machines. Thus, if all schools adopted a standard computer, software development costs would decrease significantly. However, the choice of a standard might interrupt research and experimentation on the hardware side, and might lock schools into systems that meet short-term goals at the expense of longer-term progress.

An alternative is to continue funding research on software "portability": standardized codes to make programs written in any programming language compatible with more than one operating system. This issue has been high on the research agenda of the Department of Defense, because of incompatibilities between computer-based training systems in the various uniformed services.[45] There is a clear Federal role in the development of portability: most computer manufacturers and software companies do not have the resources necessary to support this research, and none of them have the incentive to invest individually in a product that will benefit the industry as a whole.

Copyright Enforcement[46]

According to conventional economic analysis, unauthorized duplication of computer software (and other products that are easily copied, such as television broadcasts) causes producers to suffer economic loss, creates entry barriers to new developers, and threatens the long-run supply of new products. Stringent copyright enforcement, on the other hand, causes underutilization, because would-be copiers who cannot pay the market price for originals forego use of the product altogether. Recent extensions to the theory of copyright, however, suggest a more complex picture,[47] with implications for Federal policy toward educational software copyright infringements.

The relationship between property rights enforcement and underutilization is ambiguous. Under some conditions increased enforcement does not necessarily lead to greater underutilization. For example, if the costs of copying are already close to the market price for originals, then strengthening enforcement could induce copiers to purchase originals rather than forego usage. There is a similar type of ambiguity with respect to producers' losses: if individuals value originals largely because they can be copied–as in the case of taping television broadcasts for later viewing—then the prevention of copying could lead to reduced demand for originals.

Enforcement costs are another issue. In addition to the expenses of litigation, there is evidence that

[42] This policy is a variation on government procurement as a vehicle to stimulate demand.

[43] The French experience with Minitel, a highly successful videotex system, is a good example of how government purchase of hardware leads to a strong private sector supply of software. See, for example, U.S. Congress, Office of Technology Assessment, *International Competition in Services*, OTA-ITE-328 (Washington, DC: U.S. Government Printing Office, July 1987), pp. 172-173; and Steven J. Marcus, "The French Videotex Connection," *Issues in Science and Technology*, vol. 4, No. 1, fall 1987, pp. 108-112.

[44] Experience with other instructional technologies, such as film and television, suggest how important it is to concentrate on software. See for example, Larry Cuban, *Teachers and Machines* (New York: Columbia University Teachers College, 1986).

[45] See, for example, Dexter Fletcher, Institute for Defense Analyses, "An Approach to Achieving Courseware Portability," internal memorandum, February 1988.

[46] For a comprehensive treatment of copyright see U.S. Congress, Office of Technology Assessment, *Intellectual Property Rights in an Age of Electronics and information*, OTA-CIT-302 (Washington, DC: U.S. Government Printing Office, April 1986).

[47] See especially Ian Novos and Michael Waldman, "The Emergence of Copying Technologies: What Have We Learned?" *Contemporary Policy Issues*, vol. 5, July 1987, pp. 34-43; and Ian Novos and Michael Waldman, "The Effects of Increased Copyright Protection: An Analytic Approach," *Journal of Political Economy*, April 1984, pp. 236-246.

educational software publishers are reluctant to bring lawsuits against schools for fear of losing their principal customers (teachers can easily switch to other less expensive materials).

These issues point to the need for greater empirical investigation as a basis for government policy. OTA finds that the Federal Government could support research on these subjects, and could facilitate joint efforts by States, publishers, and school personnel to arrive at new agreements on software duplication and distribution.[48]

Firm Size and Market Structure

It is unlikely that any single policy will solve the problem of appropriability and guarantee innovators sufficient returns to their investments. To some extent, this problem is related to questions of firm size and market share: larger firms may have greater capacity for risk-bearing, but smaller firms may foster a greater enthusiasm for creativity.[49] In the absence of any magical firm size and market concentration ratio, a range of organizational and market structures should be allowed to coexist. The government could monitor shifts in these variables, for example, by examining the effects of mergers among instructional software publishers; and there should bean openness to experimenting with new organizational forms, such as joint development ventures and research consortia.

Information

A combination of actions undertaken by the Federal Government can play an important role in alleviating information barriers that impede the software market. To help on the demand side, the government could consider new efforts to collect and review software evaluation data, while supporting or incorporating existing State-level efforts and disseminating that information to school districts and user groups. For the supply side, information about State curriculum requirements would be particularly beneficial to new entrants in the software market.

Summary of Policy Directions

A challenge of educational technology is to devise incentives for the development of innovative software while encouraging continued and widespread use in the schools of new and existing products. OTA believes the Federal Government could:

- continue to fund a wide range of basic research on learning and interactive software, including both advanced laboratory-based research and field studies of the effects of various software designs in real school situations;
- provide incentives to the States to subsidize software developers' front-end costs and to identify superior software designs for instructional use;
- provide money to States, school districts, and schools, independently or in consortia, to study curriculum needs, define goals for interactive media, and stimulate demand;
- discourage the formation of politicized software adoption mechanisms that may inhibit innovation and lead to homogeneity in the software supply;
- provide money to States and school districts for the purchase of additional hardware, as a means to stimulate new software production;
- support national and/or regional evaluations of software that provide commensurable data on program content, process, and measured learning effects;
- support collection and dissemination of data on school district acquisition policies and curriculum requirements;
- encourage publishers and school officials to craft mutually beneficial policies on software duplication; and
- explore innovative alternatives to strict copyright enforcement, including (but not limited to) site-licensing and State purchase of copyrights.

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[48] A model currently under consideration by Educom, a consortium of colleges and universities participating in academic software development, may be a basis on which to develop effective pricing and distribution mechanisms for the K-12 market.

[49] The trade-off is at the core of industrial organization research. See Kamien and Schwartz, op. cit., footnote 13. The authors studied many industries (but nor educational technology) and conclude that ". , . inventive activity does not typically increase faster with firm size, except in the chemical industry . . . [and] research and development activity . . . appears to increase with firm size up to a point and level off or decline." Accounting explicitly for the effects of bureaucratic organization leads to the finding that size alone cannot account for innovative capacity. See Oliver Williamson, *Markets and Hierarchies* (New York, NY: Free Press, 1975); or R. Nelson and S. Winter, "The Schumpeterian Tradeoffs Revisited," *American Economic Review*, vol. 72, No. 1, March 1982.