A new study of the semiconductor market at the National Science Foundation supports the view that domestic problems may afflict the industry more than competition from Japan. This came to light as researchers worked on a two-part review of the threat to national security posed by imported silicon chips (*Science*, 4 April, p. 12). The President's National Security Council is coordinating one part and the Defense Science Board (DSB) at the Pentagon is running the other. NSF has taken a hand in drafting the security council study.

Researchers scoured the data banks for the latest and best information and were surprised by what they found. If the numbers prove correct, Japanese competition is not the only—or the primary—cause of distress. The turmoil may be due to a general market shuffle in which big companies are pushing out small ones. Thus, under the new trade pact, Japan may be penalized for problems not entirely of its making.

Market analysts divide the chip business into three categories: (i) the importers, (ii) the relatively small companies that specialize in making chips, called "merchants," and (iii) the chip-making subdivisions of much bigger corporations, known as the "captives." Typical merchants are Intel, National Semiconductor, and Advanced Micro Devices. Two major captives are the semiconductor divisions of AT&T and IBM.

According to one NSF expert, "The quality and consistency of the data we've seen are not good, but a significant point has come out. It looks as though the U.S. merchants have lost more to U.S. captives than to the Japanese." The captives have been growing slowly but steadily over the last decade, while the merchants have moved in irregular ups and downs. These smaller merchant companies are severely affected by the peaks and dips in demand, living a marginal kind of existence that makes it difficult to invest adequately in new R&D. The captives now appear to control 45 to 50 percent of the U.S. market. However, the researcher warned that the numbers are weak, because it is nearly as hard to get information on the secretive U.S. captive companies as to learn about the Soviet chip market.

A similarly bleak analysis appeared in a recent a paper by MIT political scientist Charles Ferguson, titled "American Microelectronics in Decline." He wrote that the U.S. industry is "substantially inferior to Japan's in most product and process technologies" because it has never reorganized to meet the new global competition. Instead, it remains "highly vulnerable, fragmented, and poorly suited to intense competition. . . . " Protectionist measures will not help, Ferguson claims, unless they are accompanied by a campaign to restructure the industry.

Ferguson spoke before the Defense Science Board's Task Force on Semiconductor Dependency earlier this year, and the group may have taken his comments to heart. In any case, it has decided to look into the industry's structural problems as well as the military's particular concern for a secure source of supply. Both this DSB report and the National Security Council study are being thorougly rewritten to take account of new data and provide a broader perspective on industry problems. Along with a third report on semiconductors at the National Academy of Engineering, they are scheduled for release in September.

One controversial proposal the DSB may offer in the line of structural reform is that the Pentagon invest in a new "chip foundry." The idea may follow the Japanese model, calling for a large federal subsidy (perhaps $200 million a year for 5 years), but leaving management strictly in private hands. The exact purpose of the foundry has not been settled. In one scheme it would serve as an R&D center for testing new approaches to manufacturing; in another, it would be a shared factory to produce chips designed elsewhere; and in a third, it would serve as a mass production center for advanced memory chips. There are problems with each suggestion, not the least of them political. The Pentagon may not have room in its budget for anything so grandiose.

Meanwhile, Charles Sporck, president of the National Semiconductor Corporation, is trying to interest his peers in another joint manufacturing idea. Interviewed in July by *Electronic News*, he said his efforts were just in the "early stages" and that he was trying to learn if there was any consensus for a joint venture in the industry. He spoke of the need for "an overall integrated development plan" that would enable U.S. companies to compete with Japan by coordinating their manufacturing investments. In the past, he said, the chip makers had been too "fragmented" in their demands on companies that design production machinery. He mentioned no definite proposal but said, "There will have to be government funding in some way."

On 31 July, the government won at least the promise of respite from Japanese competition in the silicon chip trade. It remains to be seen how the U.S. industry will use the breathing spell. ■ ELIOT MARSHALL

Computers in Class At the Awkward Age

Advances in artificial intelligence and cognitive research spur hope of new era for teaching, but question is when

SINCE the first big wave of enthusiasm for the use of advanced technology in education crested 20 years ago, computers have reigned as the brightest hope among all the technologies. The computerized classroom has taken longer to materialize than its advocates foresaw, but advances in artificial intelligence (AI) and cognitive research in recent years have raised expectations that computer-assisted instruction will soon achieve the potential its proponents claim. For applications of such research in the schools, however, it seems to be a case of so near and yet so far away.

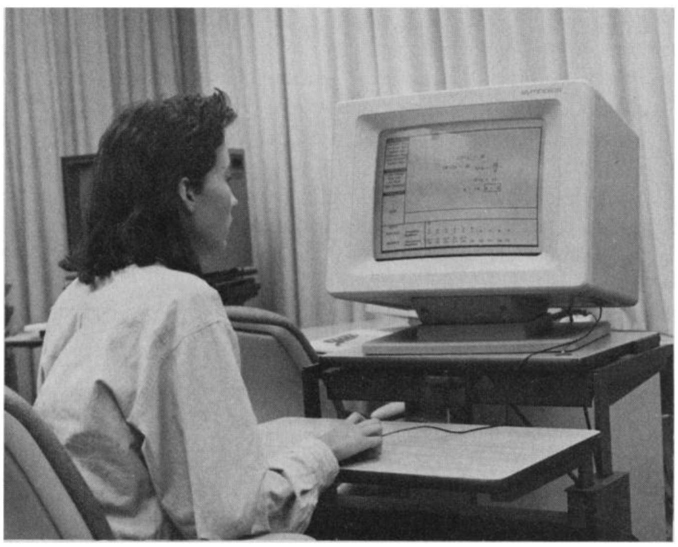
In contrast to business and the military, where AI ideas are already being put to use, AI applications in education are still confined almost exclusively to research laboratories. Two practical questions for the schools are whether AI ideas can be translated into software that will make a real difference in the classroom in the near future and whether computer hardware capable of running such software will be available at costs the schools can afford. School organization and operating attitudes will also affect the transfer.

The main issue is whether computers can be made to teach in the sense of guiding the student through subject matter the way a capable teacher can. From the beginning of work on computer learning, a main aim has been to create a fully interactive relationship between student and machine that will put the computer at the center of instruction.

A clear perspective on when AI will move from the lab to the classroom is hard to establish. AI researchers working on education tend to emphasize the strides made in AI and cognitive research and sometimes give the impression that the move is in the offing. On the other hand, AI has its doubters, some of whom argue that inherent limitations will indefinitely block the attainment of more ambitious goals.

The subject has always been controversial, but the new optimism about electronic learning has generated a more public discussion of the pros and cons. Yale AI researcher Eliot Soloway acknowledges that it is a time of "tremendous exhilaration, tremendous pessimism."

Among AI researchers, mainstream opinion on where things stand accords with the assessment of Alan Collins, of Bolt, Beranek & Newman, a pioneer in the use of computers for instructional purposes, who describes the field as in a "transition stage."



The Rand Corporation

Acuter tutor. *Under development at the Rand Corporation is this intelligent tutor in algebra for use in schools. Computer is a LISP machine, a type favored by artificial intelligence researchers.*

If past experience with computer instruction is any guide, the transition could take a long time. With the more than 16,000 school districts in the country continuing to operate with duly vested autonomy, the adoption of innovative technology is always a piecemeal, halting process. And the overpromising on technology in the past could understandably make school authorities twice shy in the future.

In the 1960's and early 1970's, instructional technology, as it was then called, was heralded as opening the way to a new era in education. Classroom television, language laboratories, and "teaching machines" of various kinds were in vogue. Experimentation was backed by federal funding fueled by post-Sputnik anxieties and then Great Society aspirations.

By the early 1970's the bloom was off the boom. In the case of computers in education, school systems found the hardware too expensive and the software inadequate. Computer-assisted instruction did find a place in the classroom with so-called drill and practice regimes, most of which amounted to useful but limited computerized workbooks. And many school systems began to offer computer literacy classes, which in most cases consisted of instruction on computer use and elementary programming. But by the late 1970's, inflation and recession pushed schools into a period of financial stress that permitted little margin for innovation.

In the early 1980's, the advent of microcomputers made increased computational power available at a cost the schools could afford. More than a million personal computers were estimated to be in use in the schools by 1985. Applications had not stood still. The boundaries of computer-aided instruction have expanded beyond drill and practice. Software is now available for a variety of games and simulations designed to advance teaching, particularly in math and science.

Although an estimated 10,000 educational software items are available, their quality is acknowledged to vary wildly. Most school districts lack personnel with the expertise to discriminate among the products on the market. In the case of the better software programs, evaluations may indicate that such software enhances instruction, but by and large cannot show convincingly that the improvement is more than marginal.

When AI-influenced systems become available, the attitudes of teachers and teacher organizations will be germane. Resistance could arise from reasons ranging from computer fear to predictions that the computer will replace the teacher. And despite the likelihood that hardware costs will continue their incredible shrinking pattern, the investment required will daunt many school districts.

AI applications in business and the military have outpaced those in education in part because such organizations have the resources to invest in systems that are often designed specifically for them and that they see as cost effective. Many of the new AI systems being used in business for a variety of troubleshooting and decision-making tasks are based on AI research on building expert systems, a way of organizing the knowledge of experts to enable nonexperts to solve particular technical problems. A prototypical application was in medical diagnosis.

In the schools, interest has been strong in so-called intelligent tutors, which have many of the same research bloodlines as expert systems. Widely cited as the sole example of such a system ready for classroom use is one developed at Carnegie-Mellon by a group headed by John Anderson (*Science*, 26 April 1985, p. 456). The system, a geometry tutor, is designed to enable the student to learn high school geometry through interaction with the computer tutor. The role of the teacher in the class, says Anderson, is to be available to help if the student is not getting the idea from the tutor. The tutor, not yet in the public domain, underwent a trial run for 3 months in four tenth-grade classrooms in Pittsburgh during the last school year. Results were encouraging but a systematic evaluation was not made. The geometry tutor is due for an 8-month trial in more classes starting 1 October with a systematic evaluation being made.

Anderson's group is also wrestling with one of the serious problems of knowledge-based systems in the schools—the cost of hardware. AI researchers typically use LISP machines, so-named for the symbolic programming language, which is the AI lingua franca. Anderson and his colleagues, in fact, have also produced a LISP tutor to teach programming. Such machines have come down rapidly in price in recent years so that they are obtainable for $10,000 or less. But this still puts them out of reach of ordinary school district budgets. Anderson says his group is working with the geometry tutor "to get it on an economical machine," namely a personal computer schools can afford.

Intelligent tutors are a main target of the skeptics. A widely noted recent critique came in an article "Why Computers May Never Think Like People," in the January *Technology Review*, by Hubert and Stuart Dreyfus, brothers who are professors, respectively, of philosophy and of industrial engineering and operations research at the University of California, Berkeley. Like most critics of AI, the Dreyfuses reject the basic paradigm of AI that uses information processing as the model for human thinking and learning. The Dreyfus brothers allow that computers can serve as valuable tools in many realms, including education, but deny that machines can acquire human know-how.

In questioning the AI approach to tutoring, they attribute to AI researchers a belief that teachers' understanding of their subject and their teaching of it depends on knowing facts and rules. "Rather, expert teachers learn from experience to draw intuitively and spontaneously on the common-sense knowledge and experience they share with their students to provide the tips and examples they need." In the Dreyfuses' view, computers can teach only novices or, at best, competent performers.

What has changed to make proponents of AI more confident? John Seely Brown, head of the Intelligent Systems Laboratory at Xerox Palo Alto Research Center (Xerox PARC), is often referred to and deferred to as having a broad view of the field by people in it. Brown says that a fruitful line of AI inquiry has been pursuit of "the knowledge that comprises expertise . . . the attempt to learn how the novice approaches a problem as opposed to the expert." Five years ago the effort went into trying to build programs that replicated expert behavior. Brown says researchers are beginning to appreciate what he calls metacognitive skills, "skills that allow you to pick up new knowledge and monitor one's own use of this knowledge." Researchers asked what it would mean to take what a student has done in attempting to solve problems and create a "cognitive audit trail." This may be done, in effect, by "kibitzing" with students as they try to solve problems by using their own reasoning strategy, says Brown. When a student gets stuck, says Brown, it is possible to critique how he or she got stuck in the first place. Observing this "useful floundering" and seeing where students go wrong has enabled researchers to find patterns relevant to intelligent tutoring systems. Soloway at Yale takes a similar approach in his work to identify the misconceptions that trip up novice programmers when they seek to apply more advanced programming concepts. Brown thinks that making their audit trail visible to students and enabling them to reflect on it is a step toward answering the criticism of the Dreyfuses and others.

It is on following up on such insights that much current AI research on education is concentrated. Support comes primarily from federal agencies, principally the National Science Foundation and the Office of Naval Research. NSF has a strong track record in support of research on computers in education, having, for example, served as a major patron for the development of the BASIC and LOGO computer languages. The foundation's program was centered in its education directorate. With the decline of the directorate in the 1970's and its eclipse at the beginning of the Reagan Administration the activity languished. It was revived when the directorate was reconstituted midway through the Reagan first term. Grants awarded under the applications of advanced technologies program totalled $7.5 million in 1985.

The program director, Andrew G. Molnar, says that the NSF strategy takes into account that the development of new technologies requires a decade or more. He notes that research in cognitive science underwent a fairly recent "paradigm shift." The focus of learning how experts solve problems changed from knowledge to the thinking process.

NSF hopes to identify the most promising research conjectures. Molnar says that "for the first 2 or 3 years we had an open agenda. We told researchers 'no holds barred.' We expect that 3 or 4 years will tell us which ideas work." The plan then is to scale up the successful projects and make them usable in the schools. Molnar says the foundation is determined that such a project will have to be proved "dramatically better. If we find that it is not effective or is marginally effective it will be discontinued."

The small size of the research community working on applications of AI and cognitive science research in education—Molnar estimates the number of active researchers at about 100 worldwide—is a limiting factor. And for that small group, development funding and consultancies offered by business and the military are much more lucrative than what is available for research for the schools. The lack of interest so far on the part of vendors of both hardware and software in participating in the development of new educational technology embodying AI content could prove troublesome when the time comes for dissemination. So even if the critics are confounded and the prophets ultimately confirmed in their vision of the results of AI research being brought into the classroom, the practical problems are likely to mean some delay on the threshold. ■

JOHN WALSH

The Chesapeake Bay's Difficult Comeback

A major cooperative program to clean up the nation's largest estuary will cost billions and faces many scientific uncertainties

Solomons Island, Maryland

ON a hot summer day as the Patuxent River merges lazily with the Chesapeake Bay, marine scientist Christopher D'Elia is studying one of the most perplexing problems related to the cleanup of the nation's largest estuary. The University of Maryland researcher is examining whether nitrogen wreaks as much havoc in the Bay's ecosystem as phosphorus. If it does, as D'Elia's studies of the lower Patuxent indicate, the cost of the Bay's cleanup might be increased by billions of dollars.

Uncertainty about the role of nitrogen is one of several factors that complicate a major, 2-year-old effort to clean up the Bay. There are other significant scientific questions to be answered, tough regulatory decisions to be settled, and a multitude of local, state, and federal agencies and advisory committees to coordinate. As Lee Thomas, administrator of the Environmental Protection Agency, recently noted at a Senate hearing, "It has taken years to pollute Chesapeake Bay; it will take years to clean it up."

The Bay, which is not only the country's biggest estuary, but one of its most productive, stretches over 64,000 square miles, ranging 200 miles north to south and 4 to 30 miles wide. More than 150 creeks and 8 major rivers empty into it. It is a center of tourism and sport and commercial fishing, and its shores are the home of an ever-increasing number of people.

For decades, the Chesapeake Bay has also been a dump for raw sewage, toxic chemicals from factories, and fertilizer and livestock waste from farm runoff flowing from the region's tributaries. In 1983, a 7-year study released by the Environmental Protection Agency confirmed the fear of many that the Bay is suffering badly from pollution. Among the EPA findings: high concentra-