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COMPUTER EDUCATION: AN INTERIM REPORT

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Until 1985, not quite a decade after the beginning of the microcomputer revolution, computers were scarce in the Soviet secondary school system. A few elite schools had taught programming since the 1960s, but the vast majority of children remained ignorant about computers. The same was true of their teachers. Few were prepared when the Ministry of Public Instruction announced early in 1985 that a new course entitled The Fundamentals of Informatics and Computer Technology would become obligatory for all middle schools beginning in September.

Several authors discussed the design and early experience of implementing the new computer course.[1] A double issue of a Soviet journal provided a large number of useful materials concerning it.[2] An American observer gave a first-hand impression of the new course in operation.[3] That the new *Informatika* course represents a bold and risky venture in Soviet education is a point that emerges clearly from this earlier literature. Two aspects of the program were identified as critical: (1) the quality and quantity of educational hardware and software available to schools, and

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(2) the objectives and curricular design of the new course. And it is with these two aspects that this chapter is concerned.

News from the Hardware Front

At its inception, the *Informatika* campaign found the USSR ill-prepared to provide the schools with enough appropriate computers. This insufficiency had both qualitative and quantitative dimensions. Existing computers were ill-suited for educational usage and, in any case, too few were available.

The qualitative shortcomings of microcomputers for educational computing have created problems. Much of the reason for this involves the lag in developing personal computers (PCs). During the late 1970s, the Ministry of the Electronic Industry designed and began production of a wide assortment of microcomputers bearing the Elektronika trademark. Intended for military and technical civilian usages, these machines were software-compatible with the Soviet SM-3 and SM-4 minicomputers which, in turn, were modeled after the PDP-11 computers first marketed in 1970 by Digital Equipment Corporation.[4]

By early 1985 only one PC model was visible on the Soviet scene. That was the Agat, a clumsy clone of the Apple II.[5] Agat's advantages over the Elektronika were its relative ease of use and the huge library of Apple software obtainable from the West. Its weaknesses were manifest. First, it was obsolete. The Agat 8-bit design dated from the mid-1970s; it was slow and restricted in memory capacity.[6] Second, its shoddy quality has been a constant source of user frustration.[7]

Despite the unsuitability of Agat and Elektronika computers for educational use, several thousand of these machines have been delivered to schools since 1984. The option of importing PCs in massive numbers has been considered. That sparked an ardent if brief courtship of Soviet authorities by several Western and Japanese microcomputer manufacturers, including Apple, Tandy, and Commodore among the American firms. The chronic shortage of hard currency combined with Cocom restrictions and a "buy Soviet" sentiment to squelch the idea of massive computer imports. In the end, a few Japanese computers were imported; the USSR purchased some 4,000 Yamaha machines during 1985–86.[8] The advantages of the Yamaha PCs were their high quality and reliability; the disadvantage was that Soviet school children have been forced to communicate with them in English, the only language that the machines "understand."[9]

During the first two years of the Informatika campaign, this limited number of Yamaha PCs has been augmented in Soviet classrooms by an array of USSR and East European machines. The Agat and the Elektronika BK-0010 have comprised the majority of these.[10] The latter have been supplemented, at the margin, by a few Polish and other machines and by permitting students restricted access to academic or industrial computer centers via remote or local time-sharing terminals.[11]

The preferred arrangement for computers in Soviet schools is in laboratories (*kabinety*), which have from 10 to 13 machines. Students are seated at two-person workstations, and the systems are connected via a local area network to the teacher's desk. Each student workstation is equipped with a computer, a monitor (usually monochromatic), and a keyboard. However, it lacks local disk storage and printing capability. The teacher's workstation differs from the students' by having one or two floppy disk storage drives and a dot matrix printer.[12]

Estimating the numbers of computers operating in Soviet schools is made difficult because the data are scattered and incomplete. Nevertheless, some information is available. In September 1986, for example, some 200 computer laboratories were reported to be operating in Moscow, or in about one-sixth of all middle schools.[13] By the end of 1986, the number of such schools was said to have reached 350, with another 700 slated to be so equipped during 1987. A prominent official prophesied that by 1988 all Moscow schools would be so equipped.[14]

That the schoolchildren in other cities and towns fare usually worse than those in the capital city is evident from the fragmentary data available. Leningraders apparently do rather well; over half of the upper-class students there are said to "have the opportunity for regular interaction with computers."[15] The Sverdlovsk city party secretary reported an inventory of only 40 microcomputers and 1,200 hand calculators in the summer of 1986, although he anticipated the early arrival of 275 "high quality" PCs, enough to equip 27 school computer laboratories.[16] Penza, which is the site of a major computer manufacturing enterprise, does far better with half of its middle schools equipped with computer laboratories by June 1986. Very few rural schools are fortunate enough to have such facilities.[17]

The non-Slavic republics have reported particular difficulties in obtaining computers. To the usual problems of inadequate numbers is added the fact that national languages are seldom "spoken" by the available machines.[18] Armenia reported only 40 computer-equipped schools in late 1986, whereas 250 were required. The Armenians have attempted to remedy their acute shortage by routing an Ikarus bus loaded with 14 PC workstations to Erevan's many computer-deprived schools.[19] A similar initiative in Gagra was frustrated by a fuel shortage and fears of the damage that might be done to the bus and computers.[20] Sixteen laboratories had been organized in Alma Ata by mid-1986, reportedly without computers and even hand calculators; students were said to be computing on their fingers.[21]

The deficiency of computers in Soviet schools has seriously if unsurprisingly impeded the conduct of the new Informatika course. The Minister of Public Instruction, S. G. Shcherbakov, lamented that only 12 percent of all students in the new course were receiving any "hands-on" exposure to computers during the school year.[22] Not until the fourth quarter of 1987 were domestic producers slated to begin delivering the specially designed UKNTs and Korvet school computers (discussed below). Only 58,400 of these machines are scheduled to be received in 1988, enough for 4,500 laboratories. By the end of 1990, the target is for the computer industry to deliver some 400,000 PCs to the schools. By that time, about one-half of the 61,000 Soviet middle schools are to be equipped with computer laboratories.[23]

Pending delivery of the promised classroom computers, something that skeptics fear will not happen, the overwhelming majority of schoolchildren will pass through their Informatika computer literacy course with little or no hands-on experience. Some will learn to program on programmable calculators. Many will lack even those. Supplying computers to the schools remains the most critical challenge confronting those who wish to make the new Informatika course a success.

Acquiring a new, more appropriate computer for schools has proven to be no simple matter for the Soviet educational and industrial bureaucracies. A complicated acquisition process, reminiscent of that followed by the military when selecting a new weapons system, has included the following six steps:

1. Specification of performance characteristics.
2. Negotiation with the computer-producing ministries for the design and production of prototypes.
3. Performance testing of the prototypes.
4. Selection of preferred designs.
5. Organization of mass production.
6. Delivery of computers to the schools.

Many actors played a role in the specification step. Early in 1985 academician Andrei Ershov, the father of Soviet educational computing, published his ideas of how classroom computers ought to perform. At a minimum, he said, such a machine should have 64 Kb of memory, a color display, expandability, and the capability of being networked in a school computer laboratory. It should be highly reliable, basically maintenance free, with easily replaceable parts, and sell for about 1,000 rubles. It should be mass-produced in a highly automated environment under a regime of strict quality control. Finally, since the schools would have no technical staff, the infrastructure of a PC distribution and support system would have to be erected to bear the burden of technical support traditionally (although reluctantly) borne by the users of Soviet computers.[24]

Creating such an educational computer, said Ershov, would be a "tough nut" for the Soviet computer industry to crack. Indeed the design and production of some 400,000 educational PCs by the end of 1990, together with the development of the distribution and support system, is an enormous challenge to Soviet computer producers. One anxious teacher worried that all of this constitutes a grandiose experiment in the field of education, threatening to turn educators and students into "experimental rabbits."[25]

The final specifications for the educational computer bore close resemblance to those propounded by Ershov. Before becoming final, however, they passed over many bureaucratic desks. In early August 1986 the specifications were ratified by the Ministry of Public Instruction, the Ministry of Post Secondary Education, the Academy of Pedagogical Sciences, the Academy of Sciences, the State Committee on Science and Technology, and others.[26]

Publication of the specifications sparked considerable competition among would-be designers. A surprisingly large number of computer designs were proposed in 1985 and 1986. The journals, *Mikroprotsessornye sredstva i sistemy* and *Informatika i obrazovanie*, carried articles advertising the merits of several of them. By late 1986 the competition appeared to have narrowed to two designs, the Korvet and the Elektronika UK-NTs.

The Korvet is a classroom configuration of up to 12 PK-8010 student computer workstations networked together and also to one PK-8020 teacher's workstation. Both the PK-8010 and the PK-8020 are members of a new family of 8-bit computers based on a 2.5 megahertz Soviet imitation of the Intel 8080 microprocessor.[27] They are said to be capable of 625 operations per second of the register-to-register type. The PK-8010 student workstation is normally equipped with 64 Kb of RAM, 24 Kb of

ROM, 48 Kb of dedicated graphics memory, black-and-white monitor (512 × 256 pixels), whereas the PK-8020 teacher's workstation supports a monochromatic and/or color monitor, one or two 800 Kb floppy disk drives, a dot matrix printer, and an audio cassette tape storage device. Main memory is said to be expandable to 256 Kb. The detachable keyboard, which accepts input in both Cyrillic and Latin characters, is augmented by five programmable function keys and a numeric keypad that doubles as cursor control. The Korvet's speed is said to be 625 thousand operations (register-to-register) per second, or about 25 percent slower than the IBM PC/XT.

The PK-20X0 operating system is MicroDOS, a Soviet clone of Digital Research's CPM/80. In network mode, the Korvet's operating system presumably will be a Soviet modification of MPM/80. Standard programming languages are said to include a Soviet version of Basic which is compatible with Microsoft's MSX Basic, Pascal, and Rapir.[28]

Soviet authors credit the Korvet's design to Moscow State University's Institute of Nuclear Physics and the Moscow Scientific Research Center for Calculating Machines. The Korvet computers resemble a cross between Radio Shack's color computer and CPM machines of the early 1980s, such as those made by now-forgotten American companies like North Star, Vector Graphics, and Osborne Computer Corporation.

Hopes that serial production of the Korvet would begin early in 1987 did not materialize. Soviet sources indicated that the Korvet passed its required state acceptance tests in early 1987 and that, after necessary design modifications, its serial production was scheduled to begin during the fourth quarter of the year, with Minradioprom as the manufacturer.

On the face of it, an 8-bit CPM machine would seem an unlikely choice for the Soviets as one of their main educational computers. In the past, they have placed heavy emphasis on the quantity and quality of software that they could "borrow" when they were deciding which American computer designs to copy. But in this case very little Western educational software will run under CPM. The Apple II, Commodore 64, and TRS-80, all with proprietary operating systems, were the 8-bit computers of choice for American schools during the early 1980s. In the pre-IBM PC era, the CPM machines held sway only for business applications. Even in that field, they were quickly eclipsed by PC-DOS/MS-DOS machines after the IBM PC was announced in 1981. Why, then, the choice of an 8-bit CPM machine for Soviet schools?

The reason for choosing an 8080A clone as the processor for an educational computer is not difficult to establish. The KR580 series of chips is one that Minelektronprom has learned to produce well and in abundance. That is no minor consideration in a country where mass production of reliable integrated circuits is the exception rather than the rule. The result is that the KR580, despite its obsolete design, is used ubiquitously in the Soviet Union. But if the choice of the KR580 is explicable, why not emulate the TRS-80, which used the Zilog Z-80, itself an Intel 8080 workalike, and for which an abundance of educational software is available, rather than produce a machine that looks more like the Northstar Horizon? The conjectural answer here is that the Korvet is to be coproduced with the Soviet PK 8001, which is slated for professional use in noneducational areas and where the abundance of CPM software is a definite advantage.

The second new Soviet educational computer is the Elektronika UK-NTs.[29] To be manufactured by Minelektronprom, this machine represents a further evolutionary step in the class of Soviet computers that trace their ancestry to DEC's venerable PDP-11. The UK-NOs hosts two Soviet 16-bit K1801VM2 microprocessors, one responsible for central processing, the other for control of peripherals. Memory consists of 32 Kb in each of ROM and RAM.[30] An additional 96 Kb serves its bit-mapped display. The standard configuration includes controllers for up to four 400 Kb or 800 Kb floppy disks, 48 Kb audio tape cassette, parallel input-output, and sound generator. It also includes a local area network interface. Although the machine's operating system is not MS-DOS, it appears capable of writing and reading data files in Microsoft format.

The UK-NTs' bit-mapped screen driver generates 640 × 288 pixels and eight tones from a 32-color pallet. In standard text mode, it provides 24 lines of 80 characters (8 × 11 pixels) and in large character mode, it produces lines of 40, 20, or 10 characters. Both Latin and Cyrillic alphabets are supported.

Its specifications make the Elektronika UK-NTs seem an interesting computer. Its software will be compatible with members of the mini-microcomputer family used most widely in Soviet process control and other technical applications. That family includes the SM-4, Elektronika-60, Elektronika BK-0010, DVK-2M, and many others that trace their roots to the PDP-11. The UK-NTs is said to be considerably less expensive than its predecessors. It will be manufactured by Minelektronprom and was scheduled to enter serial production during the second half of 1987.

If and when the Korvet and the UK-NTs classroom configurations are mass-produced and distributed, Soviet schools will be in receipt of respectably powerful educational computers that are roughly comparable to the Apple II+ or TRS-80. If these machines operate reliably up to their specifications, they will undoubtedly meet the requirements of the new Informatika course. Their selection as classroom machines illustrates some maxims of Soviet computer technology strategy:

1. Use technology that has been tried. Components used in the Korvet and the UK-NTs are not only old technology by world standards, they are old by Soviet standards. But they have the advantage of being familiar, and, most importantly, domestic industry has mastered the art of producing them.
2. Use technology that is widely employed in Soviet industry. This factor naturally is correlated with the first. The USSR counts it a virtue that the first computers that schoolchildren will encounter are close relatives of those most widely employed in industrial production.
3. Improve technology incrementally. Following a pattern observed in other areas of technology, from military weapons systems to automobiles, the Soviets have abjured qualitative leaps in computing technology. They prefer instead to innovate gradually via marginal improvements in familiar designs.
4. Acquiesce in technological followership. By choosing the Korvet and the UK-NTs, the Soviets have selected computers for the 1990s that embody American technology of the 1970s.
5. Avoid risk. This is the common strategic thread that runs through all of the preceding points.

Longer Term Outlook for Soviet Educational Computers

The present deployment of computers to Soviet schools comprises the first of a three-step educational computing plan that will span the period 1986–2000. This plan was formulated in 1985 and early 1986 and its three quinquenia correspond to the 12th, 13th, and 14th Five-Year plans.[31]

As indicated above, during stage one (1986–1990), Soviet schools are supposed to receive some 400,000 PCs, or enough to equip 30-35,000 computer laboratories. Planners intend to increase the number of these laboratories to 100,000 by 1995, and to more than 120,000 five years later.

In the long-range plan, such "first-generation" classroom computer networks as Korvets and UK-NTs, as well as the earlier KUVT-86 together with individual machines such as the Agat and BK-0010 are called UVT-1 systems.[32] In addition to the basic network configurations, the Soviet computer industry is supposed to deliver an assortment of equipment to make computers more useful in subjects other than those in Informatika. Such equipment is to include enhanced storage devices, minirobots, interfaces to physics and other laboratory equipment, and modems.

During the 1991–95 time period, a new generation of 32-bit hardware (UVT-2) is supposed to appear as the production of UVT-1 equipment winds down. The head of Minpros' computer administration says that this second generation of Soviet classroom computers are slated to be: ". . . quite powerful professional distributed computing systems with powerful graphics capabilities and a wide assortment of peripheral devices. They will connect to regional computer networks and have high capacity external memory devices."[33]

No useful purpose would be served by speculating here about what the second generation of Soviet educational computers might look like. If the past is any guide to the future, domestic industry will be more than sufficiently challenged in trying to meet its quantitative assignment for first-generation machines.

To fulfill the 1990 targets, USSR industry will need to increase the production of PCs for school use by an average annual rate of more than 50 percent during the 12th Five-Year Plan. By 1990 the annual number of PCs delivered to the schools will need to be about 200,000. Assuming that Soviet school computers have useful lifetimes of five years, annual deliveries would need to increase gradually to about 270,000 by the end of the century to meet the targets for the next decade. Figure 3.1 displays a graph of the estimated numbers of school computers in place each year and numbers to be delivered annually, if the announced long-range plan is to be fulfilled.

Can they do it? To put the Soviet task into an American perspective, it is useful to note that Apple Computer Corporation will ship more than 500,000 Macintosh computers in 1987 alone.[34] To deliver half that number of educational PCs by 1990 would not seem to strain unduly the capacities of Minelektronprom and Minradioprom, even if the schools take only 40 percent of total Soviet PC output. On the other hand, the USSR

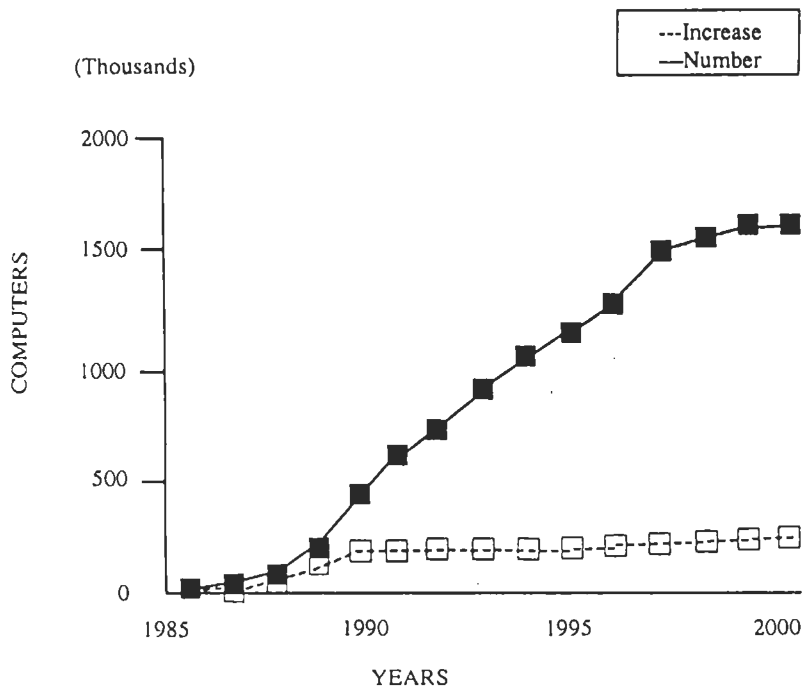

Figure 3.1. Planned Number of Computers in Soviet Schools. (Source: Estimate is computed from material in Uvarov, A., "EVM na puti v shkolu," *Informatika i obrazovanie*, 1986:1, pp. 13–17.)

record of mass producing highly reliable consumer electronic products is hardly encouraging.

A Paucity of Educational Software

Not much educational software is available in the Soviet Union. To be sure, most school computers support such beginner languages as Basic and Pascal. The new Korvet and UK-NTs are said also to provide Rapir. Beyond these languages and programs written locally, the most common software seems to be a myriad of computer games acquired from Japan and the West.[35]

As presently constituted, the Informatika course requires little software beyond an initial programming language. "Hands-on" experience for students is limited to writing and running these and other programs in Basic or Rapir.[36]

But the fact that the Informatika course requires only a programming language hardly means that the Soviets pay no educational price for their paucity of classroom software or even of general purpose packages such as word processors, spreadsheets, and data base managers. The software shortage means that the school computers are, in effect, special purpose instruments whose usefulness is limited to a single course. So long as that shortage persists, both students and teachers of other courses will find little reason to learn about computers and their potential contributions to learning.

The Soviet software industry is universally retarded, due to a general lack of incentives for developers. An underdeveloped system for protecting intellectual property rights, combined with impediments to private or cooperative software development, have stunted the USSR software industry for many years. Educational software development has suffered even more than management or industrial software, because there has been no market for it. The dilemma is familiar; no educational software is produced because no one wants it, and no one wants educational software because its paucity prevents people from developing a taste for it.

The Soviets have responded to the software shortage in typical fashion. They have created institutions. One of these is the new Institute of Programming at the Academy of Sciences. This body, organized in 1985 and headed by A. K. Ailamazian, is located in the ancient Russian town of Pereslavl'-Zalesskii. Among its charges is to develop software for Soviet schools.[37] Another newly created institution is the Scientific Technical Institute of Informatics and Computer Science at the USSR Academy of Pedagogical Sciences, oragnized in 1986 and headed by I. M. Bobko. It is located in the *Akademgorodok* (Academic City) at Novosibirsk and its scientific guru is none other than academician Andrei P. Ershov. Among its main tasks are those of developing educational software and of propagating good software developed in the schools.

The development of educational software is in its infancy in the USSR. The *Shkol'nitsa* (schoolgirl) package stands alone as an example of a piece of educational software that has achieved anything resembling nationwide acceptance.[38] That package includes the following components:

An interactive, screen-oriented text editor.
Robik and *Rapir*, two computer languages for beginners.
Shpaga, a graphics system.

Programmer's tools and utilities.

In addition, Shkol'nitsa contains "hooks" onto which may be hung educational programs applicable to various academic disciplines such as physics, chemistry, and others. Enveloping all the tools and programs is the Shkol'nitsa shell that purports to define an entire user environment.

The first version of Shkol'nitsa was developed in Novosibirsk during the period 1975–78. Its principal authors were A. P. Ershov and the late G. A. Zvenigorodskii, a brilliant junior member of Ershov's school of educational software developers at Novosibirsk, who acknowledge Shkol'nitsa's indebtedness to *Logo* and *Smalltalk*. The package was developed initially on the BESM-6, but its more recent improvements and implementations have been on the Agat, the Apple II, Riad, and newer classroom computers.

No evaluation of Shkol'nitsa is possible without some hands-on testing. Since the authors have not yet had an opportunity to do that, not much more can be said about the package other than to remark that it seems interesting and reports indicate that it is being used here and there in Soviet schools. Perhaps the most remarkable thing about Shkol'nitsa is that it remains so lonely on the USSR educational software scene.

Controversy About the Direction of Soviet Educational Computing

The earlier articles by Judy and Lommel (1986) and Kerr (1987) described the narrow focus of the new Informatika course on the logic of developing algorithms. This narrowness stands in sharp contrast to educational computing as it has developed in the United States. Kerr expressed it well in the following:

> There is little of the exploratory quality that characterizes most American courses in the subject; rather, there is a strong emphasis on learning how to think logically and how to make a computer do a very specific set of tasks that are seen as directly related to a student's future job. While Western enthusiasts extol the value of *Logo* as a way to learn logic without being taught logic explicitly, Soviet students will learn logic first—*without* computers—and then apply their learning in a very prescribed way to the use of computers as tools.[39]

This narrow focus of the Informatika course has become the subject of a major controversy in Soviet educational computing circles. The issue arose sharply in a public discussion surrounding a "program" for the course that was published as a guide for prospective authors hoping to enter the competition for designing a new textbook to replace the preliminary book edited by Ershov and Monakhov.[40] The new program preserves all the stress on algorithms and programming that characterizes the present version of the course.

The mounting cry from Soviet teachers and educators is that the narrow focus on algorithms and programming is harmful. It neglects the fact that most students will be users of computer software, not developers of it. Therefore, the argument continues that the goal of the Informatika course should be to teach students how to use packaged software such as word processors, spreadsheets, data base managers, and so on. At best, the critics claim, the present course is creating dilettante programmers. At worst, they say that the dry and abstract subject matter of the course is alienating students from computing, which is precisely the opposite of what is intended.

Ershov and other proponents of the algorithmic approach to educational computing respond that algorithms and programming are and should remain central features of the course. They fear that abandoning or diluting those features will rob the Soviet Informatika course of its rigor and turn it into the thin gruel that they perceive most American educational computing to be.

To foretell the outcome of this controversy is difficult, but we suspect that Ershov and his allies will eventually lose. The American experience is that educational computing initially was the preserve of mathematicians and computer scientists cut from the same cloth as Ershov. Early American school textbooks in computing effused no less algorithmic zeal than present Soviet ones.[41] As microcomputers began to filter into American schools, homes, and offices, most people quickly shifted their interests from learning to program (few ever had such an interest in the first place) to learning to use the burgeoning supply of off-the-shelf software for applications that they wanted to do in their personal and professional lives.

In conclusion, many things about USSR computer circumstances are different from those in the United States. They do not have the abundance of PCs that we do, nor are they likely to have such plenty in this century. Nevertheless, we think the pressure will be to broaden the base of computer usage in Soviet schools from its present algorithmic and programming narrowness. As the new machines gradually make their way into the schools, they will also gradually be used as computational and informational tools in other academic courses and, eventually, as interactive teaching/learning devices.

The speed with which all this happens will depend on Soviet success in meeting and exceeding present plans to supply computers for schools. Equally important, it will depend on a satisfactory solution to the problem of producing, distributing, and supporting educational software in the USSR. Last, but far from least, it will depend on how well teachers are trained in educational computing and on the ingenuity with which Soviet curriculum designers weave computing into the fabric of ordinary course plans.

Despite all the difficulties confronting it, educational computing in USSR middle schools has been launched. Its champions, particularly Andrei Ershov, keep the computer campaign charged with energy. If not all of its champion's hopes have been realized, its accomplishments have been greater than the skeptics expected. As it continues to unfold, the educational computing campaign seems likely to make a significant impact on Soviet education and society.

Notes

1. R. W. Judy and J. M. Lommel, "The New Soviet Computer Literacy Campaign," *ECTJ: Educational Communication and Technology Journal*, 2, no. 34 (Summer 1986), 108–123; S. Kerr, "Soviet Applications of Microcomputers in Education: Developments in Research and Practice During the Gorbachev Era," *Journal of Educational Computing Research*, 1, no. 3 (1987), pp. 1–17.

2. B. B. Szekely (ed.), *Soviet Education*, 28, no. 10 (August-September 1986).

3. J. L. Hoot, "Computing in the Soviet Union," *The Computing Teacher*, 14, no. 8 (May 1987), pp. 8–10.

4. M. Phister, *Data Processing Technology and Economics*, 2nd ed. (Santa Monica, CA: Digital Press, 1979), pp. 350.

5. L. D. Bores, "Agat: a Soviet Apple II Computer," *Byte* (November 1984); R. A. Stapelton and S. Goodman, "Microcomputing in the Soviet Union and Eastern Europe," *Abacus*, 3, no. 1 (1985), pp. 6–23.

6. Its KR588 microprocessor is a Soviet imitation of the Motorola 6502 processor used in the Apple II. Details of the Agat are provided by A. F. Ioffe, *Mikroprotsessornye sredstva i sistemy*, no. 1 (1984), pp. 56–60.

7. See, e.g., "Zaboty shkol'noi informatike," *Uchitel'skaia gazeta* (April 5, 1986), p. 3.

8. The Yamaha computer uses the Intel 8088 microprocessor or one of its clones. It employs Microsoft's MSX operating system and is at least partly compatible with the IBM PC.

9. *Uchitel'skaia gazeta* (April 17, 1986), p. 2.

10. The Elektronika BK-0010 is a small, single board "home computer" whose outward appearance is similar to the British Sinclair PC. It employs the 16-bit Soviet K1801BM1 microprocessor and provides a "Chiclet" keyboard, 32 Kb of RAM, 32 Kb of ROM, plus serial (RS-232) and parallel ports. It accommodates 256 Kb of cassette storage on an ordinary audio tape recorder. Video output is 24 lines of 32 or 64 characters on color monitor or television. Its instruction set and architecture are compatible with the Elektronika 60, which, in turn, derives from the American PDP-11 via the Soviet SM-4 minicomputer family. First produced in 1985, it was initially priced at 840 rubles. Limited numbers were sold at Elektronika retail stores in Moscow, Minsk, Leningrad, and a few other cities. S. N. Kosenkov et al., *Mikroprotsessornye sredsrva i sistemy*, 1 (1985), pp. 22–25.

11. The Polish Metranex computers used by Moscow schoolchildren are said to enjoy a reputation for high quality reliability. See *Uchitel'skaia gazeta* (July 30, 1986), p. 1.

12. Designs for school computer laboratories are specified by Minpros. See *Informatika i obrazovanie*, no. 3 (1986), pp. 5–17.

13. *Uchitel'skaia gazeta* (September 25, 1986), p. 2.

14. See the interview with V. V. Men'shikov, deputy chief of the Moscow city executive committee in *Uchitel'skaia gazeta* (July 7, 1987), p. 2. Men'shikov's term *displeinye klassy* is a broader category than *kabinety* since it includes terminal-equipped classrooms as well as those with microcomputers. His 1987 numbers, therefore, are not strictly comparable with the number of kabinety previously given.

15. *Uchitel'skaia gazeta* (January 10, 1987), p. 3.

16. *Ibid.* (August 7, 1986), p. 1.

17. *Ibid.* (June 17, 1986), p. 1.

18. For an expression of Georgian resentment on this point, see V. Akhaliia, in *Uchitel'skaia gazeta* (April 8, 1986), p. 3.

19. *Ibid.* (September 9, 1986), p. 1, and (October 30, 1986), p. 2.

20. *Ibid.* (August 12, 1986), p. 1.

21. *Ibid.*

22. *Ibid.* (September 2, 1986), p. 1.

23. See the speech by S. G. Shcherbakov, in *Uchitel'skaia gazeta* (March 4, 1986), p. 3, and that by his deputy A. Korobeinikov, *ibid.* (August 22, 1987), p. 2.

24. A. P. Ershov, *Mikroprotsessornye sredstva i sistemy*, 1 (1985), p. 2.

25. *Ibid.*

26. I. Driga, *Informatika i obrazovanie*, 2 (1986), pp. 66–69.

27. Information about the Korvet is from E. P. Velikhov et al., in *Mikroprotsessornye sredstva i sistemy*, no. 1 (1986), pp. 34–36; M. Sulim, A. Lazarev, and V. Safonov in *Informatika i obrazovanie*, no. 1 (1986), p. 74; E. P. Velikhov in *Vestnik Akademii Nauk, SSSR*, no. 7 (1987), p. 28; Driga, *Informatika* (1986) and no. 2 (1987).

28. MSX is an operating system designed by Microsoft for a series of Japanese PCs. It is not used in the United States. Rapir is a beginner's programming lan-

guage developed in Novosibirsk. See Judy and Lommel, "New Soviet Computer," p. 118.

29. UK-NTs are the initials for *Uchebnyi komp'iuter, nauchnii tsentr*, or "Educational Computer, Scientific Center." Information on this computer is from A. N. Polosin et al., in *Mikroprotsessornye sredstva i sistemy*, no. 6 (1986), pp. 14–16; and Driga, *Informatika*.

30. Driga, *Informatika*, states that the UK-NTs has 128 Kb of "user accessible" memory.

31. For more details of this plan, see A. Iu. Uvarov, in *Informatika i obrazovanie*, no. 1 (1986), pp. 13–17.

32. KUVT stands for *komplekt uchebnoi vychislitel'noi tekhniki* (configuration of educational computer technology). KUVT-86 is a classroom configuration of BK-0010 computers intended to serve as a temporary stopgap until the Korvet and UK-NTs become available. See A. Denisenko, in *Informatika i obrazovanie*, no. 2 (1986), pp. 69–74. The letters UVT are the initials of *uchebnaia vychislitel'naia tekhnika* (educational computer technology).

33. Denisenko, *Informatika*, p. 17.

34. *Infoworld* (October 19, 1987), p. 6.

35. These computer games have gained great popularity among Soviet young people. This phenomenon is viewed by some adults as a good thing because it attracts students to the computer. Others view it with alarm because of the ideology of acquisitiveness and violence said to permeate these foreign games. See A. Shmelev, in *Informatika i obrazovanie* no. 1 (1987), pp. 85–92.

36. See the two-volume preliminary textbook by A. P. Ershov and V. M. Monakhov (eds.), *Osnovy informatiki i vychislitel'noi tekhniki* (Moscow: Prosveshchenie, 1985, 1986).

37. See M. Sokolovskaia, in *Uchitel'skaia gazeta* (January 17, 1987), p. 4.

38. See G. Frolova, "'Schoolgirl' is Coming to School," translated in *Soviet Education*, 38, no. 10–11 (August-September 1986), 39–46; and G. A. Zvenigorodskii et al., in *Mikroprotsessornye sredstva i sistemy*, no. 1 (1984), pp. 50–55.

39. Kerr, "Soviet Applications" (1987), p. 15.

40. See "Programma kursa osnovy informatiki i vychislitel'noi tekhniki," *Mikroprotsessornye sredstva i sistemy*, no. 2 (1986), pp. 86–89.

41. See, e.g., *Algorithms, Computation, and Mathematics: Student Text* (preliminary edition), prepared by the School Mathematics Study Group at Stanford University with the support of the National Science Foundation (1965).