CHILDREN AND COMPUTERS

Selected papers from the Task Force Meeting *Children and Computers*, Albena, Bulgaria, 3-4 May, 1984

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FOREWORD

The papers in this publication are edited versions of some of the lectures read at a small meeting held in Albena, Bulgaria from 3 to 5 May 1984. The main goal of the meeting was to explore the possibility of starting an activity at IIASA in the domain of computer applications in education in general, and to the education of children in particular.

A secondary aim of the meeting was to identify the potential focus where IIASA could develop a certain comparative advantage in this quite exposed area.

This set of papers reflects the main ideas forwarded and interest in this topic was confirmed by the very lively discussion. The meeting exposed very early the vast scientific areas and disciplines involved in the problem of computers and education; a major reason preventing the needed focussing process taking place, and something that has to be achieved in future activities together with the emerging constituency.

The individual contributions are ordered starting with those of a more general character through descriptions of national programs to detailed case studies.

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CONTENTS

CHILDREN IN AN INFORMATION AGE
(Overview of the Issues)

Tibor Vasko

INTRODUCTION*

The process of education is as old as the human race. All through history this process has become increasingly formalized and socialized (one milestone being, for example, the introduction of compulsory education). These steps made the responsibility of education for the future of the whole society (a nation) more explicit. In spite of the fact that this responsibility has not been questioned for centuries, there are many very recent documents monitoring the disquieting state of the educational process (A Nation At Risk, 1983) and contemplating elaborate measures for its improvement (Pravda, January 4, 1984) to meet the challenges of the future or use the possibilities offered by new technology (Masuda 1972, 1980). These problems seem to be so important that the whole concept of the future in education has been analyzed (Toffler 1974).

Because of its importance, education is an inherent part of development strategies in most countries, industrially developed or developing. Appropriate institutions (ministries) are designing policies aiming to influence the behavior of individual actors in education processes in the desired direction. The efficiency of individual measures taken in achieving the selected objectives is difficult to predict, because processes studied by different disciplines are interacting. Here the systems approach seems to be a well suited methodology. This fact also makes the problem of children and computers an attractive potential topic for study at IIASA.

However, a closer look at the issues is necessary before more concrete suggestions can be prepared.

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SOME SEMANTICS

Wide interest evoked by the intricacies of computer-based education has brought many disciplines to the scene. Because these disciplines have their own semantics and definitions, there is a somewhat polluted terminology. For further exploration, it may be useful to structure the issue in the following way (Valcke 1982):

Computer Aided Education (CAE) concerns:

- learning *about* the computer, e.g., computer literacy, data processing, computer science;
- learning *through* the computer, e.g., drill and practice, diagnostic testing, tutorial programs;
- learning *with* the computer, e.g., simulations and games, problem solving, creative activities.

These activities will soon be significantly enhanced by the results of artificial intelligence research and should lead to the creation of Intelligent Computer-Aided Education (ICAE). One expects, from the use of ICAE systems that the student could use natural language and voice commands and with the results of research in cognitive psychology (directed at modeling human thought and problem solving behavior) these systems may adjust to different learning styles and to a student's prior knowledge (Douglass 1983).

In the literature, Computer *Managed* Education is also distinguished, which refers to applications when a computer:

- makes and analyzes a test for diagnostic or examination purposes;
- routes the student on the basis of former test results;
- stores, interprets, and updates classroom data;
- reports on progress to the persons concerned.

These education computer systems are implemented on different technical bases. We can distinguish:

- time-shared central computers;
- local minicomputers;
- networks of mini/microcomputers;
- independent personal computers, including programmable calculators.

A significant role in the efficiency of the computer systems is played by the necessary accompanying software. Software for use in education systems has to meet some specific requirements dictated by pedagogical and psychological issues.

SOURCES OF INCREASED INTEREST IN CBE

One long-term source of growing interest in CBE is created by increasing scientific and technical development. It is often argued that more than 90% of all the scientists who ever lived on this earth are still alive! Similar forecasts are expressed for the future; for example, it has been pointed out (David, Williams 1979) that for a child born in 1979, therefore celebrating his 50th birthday in 2029, 97% of all man's acquired knowledge will have been discovered in his or her lifetime. The consequences of this fact for education-acquired knowledge are said to be that most of this acquired knowledge will be useless, some worthless and some even incorrect. The logical response to this challenge, which would exist even without the emergence of computers in education, is to change the character of education from the focus on knowledge content to a focus on the process of learning. The question is how to incorporate technology into the educational process in order to enhance the capability of an individual's mind to remain fertile, productive, and creative as long as possible without hitting the barrier presented by the psychologically and physiologically sustainable load.

Pursuing responses to this basic challenge has caused scientists and educators to branch into several spheres of interest to decision makers and policy designers.

POLITICAL AND SOCIAL INFLUENCES

The necessity of educating an ever-increasing population opens up the question of efficiency, costs, and overall policy for educational processes. Conflicts between these issues can easily emerge. Disparities in views, interests, and needs of teachers, parents, administrators, politicians, and technicians, not to mention the interests of students themselves, are already recognized.

The individual levels of policy making generate different signals toward education. Educational requirements deduced from the long-term strategy of development of a particular country could be included in this category of influences. One of the most specific is the "Information Society" strategy of Japan described elsewhere (Masuda 1972, 1980) containing experimental projects in education.

A more recent message from the US President's Commission on Excellence in Education is contained in the title of its report "A Nation at Risk". It cites the idea of an analyst (Paul Coppermann) that

> Each generation of American has outstripped its parents in education, in literacy, and in economic attainment. For the first time in the history of our country, the educational skills of one generation will not surpass, will not equal, will not even approach, those of their parents.

They recommend many measures (divided into five groups) to reattain the supposedly lost excellence in education.

This year (Pravda, January 4. 1984) a major policy paper was presented in the USSR on "Basic reform directions of general and professional schools" initiated by the Central Committee of the Communist Party of The Soviet Union (CPSU). The paper states that the grandoise tasks of the end of the century and at the beginning of the next one will be solved by those who are sitting behind school desks today. Among many recommendations intended to improve the efficiency of education one can mention the task to:

> ...equip the students with the knowledge and habits to use modern computer technology, to secure wide applications of computers in the educational process, to build for this purpose special school and interschool cabinets.

The political and social pressures are often oriented to increase efficiency through cost reducation measures. There are indications that the introduction of computers in education does not always lead to real cost savings (Rushby 1978). The evaluation of computer-based education is not an easy process when one strives to assess the effectiveness and efficiency of acquiring specific skills (Venezky 1983). Soete and Freeman (1984) expressed important views that education and training in a high technology environment are sometimes a more important ("intangible") investment than the physical capital investment and should not be considered as consumption or current cost.

The political and social influences also have global dimensions. These influences have led, for example, to the creation of the World Center for Microelectronics and Human Resources based in Paris. This was where one of the most important experiments took place: that of applying computers to education in a developing country—in this case Dakar (Senegal). The idea behind this experiment was that the time had come when applying computers to various cultures may bring benefits to both donors and acceptors of technology. Numerous critiques and questionings of this idea exist (Dray and Menosky 1983).

ECONOMIC AND TECHNOLOGICAL INFLUENCES

The diffusion of computers into the learning process on all levels of the educational system seems to follow all the problems known from the introduction of computers to other areas; for example, into management organizations. In addition, however, it has its own peculiar problems. So one can identify for example:

- o both the market pull and technology push effects, the latter still being predominant;
- o the problem that designers and manufacturers have in selecting between special custom-made, and the more universal mass-produced equipment;
- o the lag of software development behind the hardware availability. This is valid for high level simple languages (BASIC, COMAL, etc.) or for more sophisticated languages such as LOGO (with graphics) now implemented in truncated form even on microcomputers, but also for special educational programs for teaching several subjects (languages, mathematics, physics, etc.). Not only is the program's efficiency important (as viewed from the point of optimal use of hardware capabilities), but also pedagogical viewpoints should be taken into consideration if learning is to be efficient.

Previously the market-pull was not sufficient to attract enough resources for software development. The situation now seems to be changing. The Creative Strategies International in a recent report (IEEE Spectrum, November 1983, p. 126) predicted that the US educational software industry would grow 48% annually between now and 1987. Predictions suggest that classroom computers may be a focus of software development in the future even if present software development represents only 15% of classroom computer use.

Teachers suggest that most of the small systems offered for education have been developed in computer laboratories without adequate input from pedagogs, so the solution is too technology-bound. This is also the equivalent of quite a common situation in other computer applications where the computer attracts the bigger share of attention and money, while future expansion and integration of the system are more often overlooked.

Obviously, there will be a growing specialization of systems from those for the elementary school environment where one should take into account the absence of the children's reading ability (a problem of interaction) to content-centered computer-based systems (CBS) for the university environment. The optimal representatives of appropriate systems will have to be developed on a multidisciplinary basis and to involve: technicians, teachers, educators, psychologists, and administrators.

EDUCATIONAL PRESSURES

Educational pressures seem to be the least significant, but they may well be the key to the appropriate diffusion of computer-based education. The educational potential of computers has not been fully identified, and most of the focus until now has been on the possible quantitative gains: higher cost-effectiveness of the educational process with computers, more effective use of time, etc. This focus may be the result of economic and technological forces in action.

Important qualitative impacts of computer-based systems can also be identified. Among the most frequently mentioned are:

- The possibility to "tailor-make" instructional procedures in order to respond to individual learning types. Until now much of this has been achieved by using programmed instruction paradigms based on past responses of the student, but alternatives accommodating individual differences are somewhat rigid. One can expect fundamental improvement when results of artificial intelligence research are applied where knowledge representation, processing, and inference are studied. These results will help in modeling the thought process and the process of learning.

- Computer-based education is adaptable to the individual student's speed of learning (self-paced learning systems).

- CBE can provide a direct feedback on the state of the learning process which is important information for the teacher.

Many of these benefits are also challenged in scientific literature. There are prestigious studies indicating that computer use has no overall significant effect on student achievements. There seems to be no valid methodology of research delivering comparable and reproducible results. As a solution a model-based application of CBE systems is suggested (Valcke 1982). This model (thoery) should give insight into the education and learning process and should be built by an interdisciplinary team of scientists, teachers, administrators, and policy makers.

There is also an abundance of papers reporting surprising results which have been achieved on exposing young children to various kinds of computer systems. The main reason for these results is the excellent imagination some computer experiments develop in children. This helps them comprehend difficult issues with ease. How to use this natural "resource" children have for acquiring facts, "computer literacy", and to enhance the whole education process is not entirely known.

SOME POLICY RESPONSES

Education is always responsible for the ability of the future society and is, therefore, part of overall policy supporting economic and social development. A fragmented overview of some policy responses of different countries (Hammond 1983) is outlined in the following paragraphs.

United States of America

In the USA pioneering efforts in computer applications have been developed and a clear vision of applying computers to education have been pursued. Numerous studies supported by the government (US Office of Education, National Science Foundation) and several foundations (Exxon, Sloan) have tried to make this vision a reality.

At the same time opposing views were voiced arguing that computers are expensive gadgets which do not increase the quality of education. What is more, rigidily programmed machines may lead to idiosyncracies and cause teachers to select only those problems which can be comfortably taught by computers.

There are excellent analytical studies depicting the real impact of computer based education at college level in the USA (Kulik, Kulik, Cohen, 1980).

In 1983 it was estimated that the number of microcomputers in American schools was over 100,000 which could be taken as an indication that virtually every school in the USA had a microcomputer (in the USA there are 83, 334 public and 21,749 private schools, and 3,453 colleges). However the distribution of computers in schools is not uniform all over the country. In spite of this number of computers there is no overall policy of computer applications, though there are some measures taken to enhance the computerization of schools (for example, 25% tax write-off is available for equipment supplied to colleges).

The distribution of computers depends on individual states. For example, in Minnesota there is one computer for every 50 children. There are states where only 50% of the schools have computers. In some cities the schools are equipped by local microcomputer producers. The situation is different for university education, where some universities already require that a student owns a microcomputer and others are to follow soon. Some of these universities expect to interconnect micrcomputers into networks

(Bereiter 1983). However, in general, affluent children in the USA find more home support for microcomputers than in many other countries.

Japan

Applying computers to education is a part of national strategy in Japan denoted by the term "Information Society" (Masuda 1972). Part of this project was a Computer-Oriented Education in an Experimental School District (cost $266 million). This plan conceived of an experimental school district conducting computer-oriented education in pre-school, kindergarten, primary school, junior and senior high schools, university playing a central role. The plan includes rationalization of school office work, an individual education guidance system, computer-oriented education, and an educational science research center. The project planned to help solve problems concerning future computer-oriented education, measuring the educational effect of the intelligence network, planning a standard education system, and developing a new individual educational system. It was conceived as an educational experiment, permitting objective scientific data collection and analysis of differences between the computer-oriented, private instruction, problem-solving type of educational system and the contemporary group uniform education system.

In the early stages, a computer-aided instruction (CAI) system model classroom has been tested in primary schools under the direction of Tsukuba University; training programs in computer operation and programming were begun in public commercial high schools. But Japanese children are already in contact with computers when they attend kindergartens, which they attend until they reach the age of five (in Japan there are 14,893 kindergartens). From five until 12 years of age they attend elementary schools (amounting to 24,945). This is followed by lower secondary schools (10,780) and then by upper secondary schools. Ninety percent of the population continue their education until the age of 18. In Japan the state-run schooling follows a national curriculum and private schools provide education to 7% of the population.

It is claimed that no other nation's children devote so much time to computers as Japanese children. However, some critical comments have pointed out that education in Japan has been too application oriented, not fostering creative, logical and philosophical thinking. To remedy this is one of the tasks of the new, almost legendary, fifth generation computer project in Japan.

France

The French National Experiment in Educational Computing started in October 1970 but initially focused on secondary education. France is also following a national curriculum, which has the advantage of a coordinated approach with related education of teachers. One of the recent schemes assumes 10,000 computers in lycees. The standard of the future is eight computers and a printer in each classroom.

Great Britain

In Great Britain a sustained effort began in 1973 with a modest budget of £2 million and with the title National Development Programme in Computer-Assisted Learning. In 1981 a new scheme (£3 million) was started to persuade every secondary school to buy a microcomputer. This scheme seems to have been a success: in the first year 80% of state-run secondary schools bought a micro-computer (with a 50% subsidy from the government). In 1982 a similar scheme (estimated to cost £9 million) was focused on 27,000 primary schools.

Other West European Countries

There are schemes for model schools supported by local governments in the Federal Republic of Germany.

Denmark developed its own computer and language (COMOL 80) for implementation into school systems.

Ireland donates an 80% subsidy to 834 secondary schools to acquire an Irish-built computer.

Australia and New Zealand

Similar subsidy schemes are in effect in these countries. In Australia there is a 50% subsidy (up to the sum of $1,000).

In New Zealand a "computer" war even started among the manufacturers when foreign manufacturers wanted to eliminate domestic competition (the Poly microcomputer) by decreasing the prices. The New Zealand government responded by introducing a customs duty on Apple computers (NZ$880).

Soviet Union and Socialist Countries

Computers were introduced to schools very early on, starting at university level in the early 1950s (first generation computers). Later secondary schools also received computers, generally a minicomputer. At the same time the curriculum has been changed, accommodating several courses of programming and computer science on different levels. New specializations have also been introduced.

In the mid-1970s more elaborate schemes were worked out. To illustrate the point, we can describe the scheme approved by the Ministry of Higher Education of the USSR dated January 12, 1978—the so-called "Automated Teaching Systems". The scheme is based on two stages. The first (up to 1982) aims:

- o to develop computer systems custom-made for schools;
- o to start research and development into the psychological and didactic issues raised by the application of such systems;
- o to work out a methodology for developing algorithmic and semantic structures of teaching courses and appropriate

monitoring systems. Among the first are some aspects of physics, chemistry, mathematics, and programming languages;

- to develop languages for teaching, user control languages, and interactive (dialog) programming languages.

The second stage counts with interconnecting the individual functional systems into an integrated network.

ROLE OF INTERNATIONAL ORGANIZATIONS

International organizations are also active in exploring the challenge of computer applications to education. Among the most prestigious are the activities of UNESCO through the project "Joint Studies on Education".

Must interest was raised by the World Center for Microelectronics and Human Resources in Paris, with world renowned scientists on the staff (Seymour Papert, Nickolas Negroponte). In spite of the fact that the gentle and important ideas which led to its creation lost nothing of their topicality from recent developments, one has the impression that somewhow the Center itself may have reached a point of "diminishing returns" due to some specific problems.

SOME THOUGHTS ON IIASA'S POTENTIAL ROLE

From a very preliminary scan of the issues connected with the penetration of computers into the educational process one could conclude that problems are:

- interdisciplinary;
- with a strong social and cultural context; and because of this it seems to be a potential topic for East-West joint studies to be appropriately performed at IIASA;
- embedded in modern technology;
- topical and part of economic and social strategies of national development;
- related to national and regional policies.

One could say that the picture is still unclear at best, with many experiments running, but relatively few producing usable results for consistent policy, especially when longer term perspectives are required.

On the other hand, the volatile and fast-changing situation only extends the spectrum of differing views on the same problem. A recent US National Science Foundation Study "Educating America for the 21st Century" puts education among the national goals and adds that "Almost any statement made today will, therefore, be osolete in a few years, if not months." But there are also dissenting views of eminent specialists. A study carried out for the Carnegie Endowment for the Advancement of Teaching, "High School, A

Report on Secondary Education in America" led by E.L. Boyer, former US Commissioner of Education, for example, states that: "Technology revolutions have failed to touch the schools largely because purchases frequently have preceded planning".

These illustrations also show where the present focus in this field lies. The longer term impact studies hardly left the speculative stage.

From the above one can state for further discussion some preliminary goals for an IIASA project:

1. Prepare interactively with collaborating institutions a state-of-the-art report on computer based education, scanning not only the issues but also the active projects in individual countries and identifying the main actors.

2. Identify a framework for a study on the long-term implications of computers in education. For this some supporting "sub-studies" may be useful, for example, on the development of functional properties of future systems from an educational point of view, on the potential of artificial intelligence research, social and psychological implications, etc.

3. Policy issues connected with computer-based education with an assessment of past policies and some illustrative case studies.

4. Modeling efforts made elsewhere and their potential for policy advice.

From present knowledge it seems reasonable to work sequentially on projects 1-4 and eventually define more precisely each step.

It seems futile to elaborate more on this subject now when the interest of potential collaborating institutions and IIASA National Member Organizations (NMOs) are only very superficially known. It is certain that more involvement with them would bring much-needed input and guidance for more detailed planning steps. This could be accomplished at least in part at this meeting.

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CHILDREN IN THE COMPUTERIZED WORLD: TODAY'S PROBLEM OF THE FUTURE

Ognyan Panov

Humanity is gradually progressing along the long road from physical labor, which depends mainly on the physical abilities of the human body, to highly intellectual labor and creative work that requires principally new materials, equipment technology and the organization of production in order to make full use of the creative capacity of the human brain and to efficiently use the natural resources for fulfilling the growing needs of the population. Computers can make all this possible because they increase the intellectual capacity of man and can thus secure further growth in the efficiency of human labor at rates which have never been seen before.

For thousands of years human progress has been limited and related to the dominant materials used. Today computers make it possible to produce materials with defined properties because they can control the process of synthesis of such materials with a precision that was impossible to achieve before. Fundamentally new opportunities are opened up by the computer, for example, the control of biological processes—the new field in biotechnology. With the help of computers it is possible to optimize the complicated process of contemporary production, including the design phase.

Only a few years ago it became possible for the first time in human history to accumulate, store, and process knowledge and production systems not in the human brain but in an independently operating machine. This is no ordinary means of production anymore, but an element of the new quality of production processes as it provides the knowledge and skills necessary for the production process without the direct participation of human beings. Along with this, computers will change our everyday life: automation based on autonomous processors relieves people from a lot of time-consuming non-productive labor at home. For the first time, real possibilities are created for man to engage only in creative work. The new possibilities opened up by computerization concern not only the fields of production and everyday life, but also the art sphere, where new techniques have appeared which are based entirely on computer systems. It would be a mistake to over prize them or to reject them. Obviously their impact on human consciousness and perception must be investigated in order to avoid eventural harmful consequences.

Computers also influence the human brain especially during childhood, when the individual personality is shaped. Contacts with a new intellect, which supplements the intellect of parents, class-mates and school will have a tremendous influence on the consciousness of children. What is more, contacts with computers are personal and unless these contacts are influenced by society in the proper way we may expect serious distortions which could leave their imprint on many generations ahead. At the same time the contact between children and computers can open new horizons for expanding their potential ability. During childhood it is easier to become used to the highly technical environment of the computerized world without experiencing a "shock of the future", thus avoiding the psychological barrier against the new and unknown. Thus, future generations can prepare themselves for the qualitatively new level of productive forces. The process of adapting man to the new level of technological civilization is shortened.

The equal possibility for participating in creative work provided to both boys and girls through computerization as early as childhood will further accelerate technical progress. Experience shows that children not only learn how to use the computer quickly, i.e., to run available programs, but that they soon also start to develop their own programs for applications that are of interest to them—computer games, programs for learning languages, etc. There are a number of cases when such programs have become a product for sale. What is most important is that through computers children can naturally become involved in productive labor at an early age, i.e., 10-12, without any danger of harming their psychological or physical development, or their studes. New horizons are therefore opened for using children's creativity not only in art but also in science and production.

If the necessary social conditions are created, humanity can use children's creativity to enlarge its creative potential for the benefit of all society. At the same time this will help to socialize children early and increase their abilities in maturity.

What is of greatest significance in the not too distant future of mankind is the possibility of bridging the educational and technological gap (a gap which at the moment is increasing) between the developed and developing countries. This could be achieved by turning cheap microcomputers (so cheap that they could be distributed free in the form of aid) into a natural companion of children all over the world. There is no essential difference in the method of training children and their perception of computers in different countries. The main thing is to find a good way to introduce computers into the social environment of the child.

Of course we should not be utopians and say that most of the present problems can be solved by production and distribution of one or two billion personal computers around the world. The social and political environments both in individual countries and the whole world play an extremely important and one could even say, determining role. This process, however, has two very important and interrelated aspects. On the one hand, the training of good national specialists contributes to radical changes in social and economic relations, and on the other, the new social and economic relations speed up the overall development of the country.

A good example in this respect is Bulgaria. Fourty years ago Bulgaria was on a par with, and in some respects even under, the level of many developing countries. The adopted strategy of developing and strengthening the national economy by relying on national specialists and using the reliable assistance of other countries allowed for such a fast economic and cultural development that Bulgaria now occupies first place in the world in terms of exports of electronic products per head of the population; at the same time it is one of the recognized cultural centers of Europe.

Therefore, the steps made for raising developing countries to reach the global technological level by training their children with the help of computers are a means for a faster development of the whole world which may eliminate the dangerous dependence of the Third World countries on the technology produced in a couple of the most developed nations.

All this, the natural enlargement of the possibilities for using the creative abilities of women and children from a very early age and the preparation of new generations in developing countries for such creative work, will multiply the potential capacity of manking many times and will increase enormously its general progress.

Computers create conditions for competent participation of millions in the solution of complicated management problems which can be analyzed on personal computers if there exists a unified system of social information. This will create the possibility for speeding up the processes of social decision making without increasing the number of people in the administration system. This problem is very topical for Bulgaria because state property is at present managed by working collectives. For this reason a lot of attention is given to quickly creating a Unified System for Social Information.

The problem of the place and role of children in the computerized world can be approached from different angles. I believe the most suitable for research to be carried out and organized by IIASA are the following problems:

- o Teaching children to solve problems and communicate with computers in a systems approach way of thinking.
- o Definition of the requirements of computer systems designed for children and their relation to future computer technology.
- o Investigation of the possible consequences of children's involvement in socially useful creative work through computerization.
- o Investigation of the possibilities for and consequences of children's involvement in artistic activities with the help of computer systems.
- o Development of strategies, approaches and methods for training children to work with computers and for using computers in education.

Naturally it is possible to define other problems and to outline other approaches to their solution in this vast area.

The first problem appears when we look upon computers not as calculators or a means for creating games but as modeling devices. This is the reason why those who work with computers have to be able to think in a systematic way and to apply a systems approach to solutions. On the other hand, the creation of formalized models suitable for machine processing requires analyzing the problems that are modeled. Finally, the very process of reaching a solution requires systematic thinking for interpreting the obtained results.

obtained results. Systematic thinking is a specific form of disciplined and orderly thinking and mathematical science contributes best to training this kind of thinking.

It is necessary to work out examples and approaches for systems analysis of the problems facing children when they familiarize themselves with the world, and of the problems facing the world about which children only learn after they leave school. This is research work which is entirely in the spirit of IIASA studies. It would be particularly useful to find forms of introducing children to the problems investigated by IIASA in the field of global development, such as problems of food, energy, population and environment, etc. This introduction could be made in the form of computer games and could contribute a feeling of responsibility not only to the individual but to all of humanity.

The second problem concerns the technical facilities for computerization and the possibility to ease man's communication from a very early age by the means of computers. Of course, the main stress here should be put on specifying forecasts of computerization.

The third problem concerns software created by children in the process of their communication with computers, and its utilization for socially useful purposes. At present the focus of computerization is moved more and more away from hardware to software problems. Production of special problem-oriented programs is a part of the natural communication between children and computers.

Children today enjoy working creatively on program development. But what is the nature of the problems connected with program writing, and how do we ease the work of children in programming? How can we use the useful software products produced by children? These are only some of the questions which could be answered provided that suitable studies are made at IIASA and the results from such a research program are well analyzed.

The fourth problem refers to the application of computers in art. This problem has two aspects. One is related to the possibilities of stimulating a drive towards artistics exercises with traditional means in children (no matter how paradoxically this may sound at first). This can be done by linking computers to audio-visual means to form an integrated complex, and introducing children to the different kinds of artistic, creative work languages. Another aspect concerns the direct use of computers for developing entirely new types of artistic expression. Synthesizers and computer studios have already established themselves in the musical environments of many nations. The use of contemporary computer systems, although still vague and difficult for children to use, may extend rather than restrict the artistic development of children. To the best of my knowledge, the problems in this particular area have not yet been investigated, or even formulated. Any contribution or exchange of opinions would assist the investigation of this very interesting sphere.

The fifth problem concerns the application of computers in education in general. It is relatively well investigated and all developed countries have done work in this field. IIASA could organize a number of forums on this problem in order to follow the general progress in this field. A general review of the problems in the area of "Children in the Computerized World" shows not only how topical and important they are, but also reveals the role which IIASA could play towards their solution. What is now necessary are the practical steps towards organization of such a program at IIASA.

CHILDREN—FUTURE INNOVATORS

Evka Razvigorova

INTRODUCTION

A discussion like this is related more to what should be done than to what has already been done. Still, we must not forget that for more than five or six years, the use of the computer in the education of children has not only been a subject of theoretical studies and talks, but of concrete experiments. Naturally, the experience gained justifies new discussions and development of new ideas about the future application of the computer in education. On the other hand, education becomes the one unique focus of attention. At this point we must ask our first question: are we looking for ways and methods of strategy development and application into practice for the adaption of children to computerization; is this the only problem we must solve? Naturally, the answer is "No." In this sense, the accumulated experience is an obstacle to our efforts to leave the boundaries of the accepted way of thinking and of our interests.

We have to take into account the scope of the problem if we talk about the future of today's children who tomorrow will live, work and create in a world and society in which computers will be daily companions. We are far from a position to make a thorough analysis of all aspects of this problem. However, it would be sufficient to enumerate the problems and to realize what the effect of their solution will be.

THE WORLD TOMORROW

The microprocessor revolution, or the "silicon chip" revolution leads to a continuous change in new electronic and computer technology. Futurists think that during the next 20 years 80% of the possibilities of this technology has yet to be disclosed. This means, therefore, that after working with the so-called "intelligent machines" and witnessing the enormous advancement in this field over one or two decades, that we only know about 20% of the possibilities of microprocessor technology. If this is true, have we forecasted the dimensions and conditions of tomorrow's world correctly? What will the world be like for those born today who will live in the year 2000; those for whom we make educational strategies today?

Futurists, forecasters, specialists of various fields of science and science fiction writers are all working to find an answer to the above question. But we still do not have the concrete dimensions, or more exactly, the main features of the future living environment. The problem with children in the world of the computer is not only a problem of its use in their education, but a problem of their quick adaptation to new a technique which according to its peculiarities will considerably change existing technologies not only in the material but also in the intellectual sphere. The change in these technologies involves a change in material conditions, communications, relations between the individual and society, relationships within the family, access to information, etc.

What exactly are these changes? How will they develop? How shall we prepare the children of today and of tomorrow to be creative, complete and in high spirits?

Naturally there are publications in this field, but they deal mainly with the problem of the schools of the future and do not consider the environment as a whole. These problems can only be studied in a systematic way with the help of specialists and scientists of different fields of science, i.e., on an interdisciplinary basis.

COMPUTER LITERACY

The development of the technology needed will require a continuous change in knowledge, i.e., it will require continuous training—not only at a certain age, to a specific period of an individual's life, but throughout his life. However, this can only happen if man is literate. Literate in the terms of new technology, literate in terms of the new element in the environment—the computer. For this reason the problem about computer literacy is a problem of the educational system today and has an enormous importance for the development of the future society. Maybe this particular aspect of the problem about children in the computer world has found its widest theoretical and practical development today. Children who are computer literate will adapt quickly and easily to all changes in technology and the environment and will live actively with these changes.

Perhaps the goal in the near future will have to be to turn training in progamming techniques into a basic environment in which the modern concepts of mathematics and logic can be presented and developed by the students into a main subject of the educational system. In the same way as children begin to play with letters as early as pre-school age and step-by-step begin to read and write in the world of stories and pictures, they have to begin to familiarze themselves with the computer and to make friends with it, with the help of the story and the picture. Solving this problem as a main basis of the education system will provide the grounds for future changes, not only in the educational system but generally in the use of the computer and its application.

THE INDUSTRY AND ITS EXPECTATIONS

In many cases modern industrial organizations cannot keep pace with new technologies and products. The technological and product innovations represent a basic problem to the modern manager. This issue can only be solved if the generation that is prepared for the industry today, changes its attitude and approach to the technology of tomorrow. How can this be achieved? First by means of the computer literacy. People who are computer literate are in a favorable environment for aquiring future knowledge about computer technology. But literate people alone cannot be builders of the innovations tomorrow. They must have a creative drive, a systematic thinking and they have to be able to solve complex problems. Therefore, industry is expecting the educational system and training system of today to prepare people who have knowledge, creativity, an innovative spirit, who think in a systematic way and can take an active part in the work.

Industry and managers today, therefore, are interested in assisting and financing the educational system, but apart from the education in computers the system must include creativity, a systematic approach and systematic thinking, which go hand in hand with the technology of tomorrow. Thus, people will be created who will be the future innovators and creative supporters of the scientific-technical revolution.

CONCLUSION

In this report I have tried to consider only three aspects of the problem about children in the computerized world. Three problems whose solution is interrelated and which proves the complexity and the importance of the issue. How shall we proceed in the future? To answer this requires wide interdisciplinary discussion and study and experiments to test theoretical generalizations and methodological recommendations which on their part will become a basis for effective strategies and policies.

I would like here to take the opportunity to issue a warning. The world tomorrow will need people with personalities and integrity, not automats, but people who can use their skills for the benefit of a humane society. Maybe for this very reason we should not talk about children in a computerized world, but about children and computers.

THE MISSING KNOWLEDGE: WHY COMPUTERS IN EDUCATION HAVE SOMETIMES FAILED

Stefano A. Cerri

(An extended abstract prepared from a lecture by Tibor Vasko)

In general, one can say that we seem to be in a transition from the Computer Aided Instruction (CAI) era to the Intelligent Teaching System (ITS) era.

COMPUTER AIDED INSTRUCTION ERA

One can state that this era started around 1960 and was based on the stimulating environment created by the computer (e.g., simulations, games, easy to use languages, LOGO). In spite of more than two decades, the discipline seems to be fuzzy, lacking explicit theory and what's more even lacking theory formation.

Most often, these systems have a rigid instructional strategy (lack of individualization); the courseware is often non-transferable and its preparation is time consuming (one contact hour needs approximately 100 authoring hours). One can conclude that there exists relatively large, but diffused experience on the application of the CAI system. In all these systems, the computer acts as a tutor.

INTELLIGENT TEACHING SYSTEM ERA

These systems date from approximately 1970 and are based on the following components:

- subject matter
- teaching strategy
- student model
- communication interface.

At present, ITS faces several problems and has some limitations. The first problem is the knowledge representation on the subject matter if the field is diffuse. Similar problems also occur with the student model representation. The development of courseware is more costly than for CAI systems. This seems to be the bottleneck on the road to new generations of teaching systems. These new systems should:

- o be developed by experts in education (who need a friendly authoring environment);
- o use intelligent programs;
- o be based on empirical verification (theory of formation);
- o be cheap enough to allow for large scale use.

There is no doubt that such systems may have a strategic importance.

One can, based on the importance, suggest several steps to finding a solution:

- o On technological and social justification, decide whether the application of information technology in education can be considered a *strategic* issue.
- o If it is a strategic issue then launch an exceptional effort to:
  - — discovering or constructing the missing knowledge;
  - — build a suitable framework for the growth of expertise in the field.

These issues require very long-term R&D investments.

- o If there is doubt that such an effort on a national level will be effective then (if politically agreed) international cooperation can be forwarded.

When these principle questions are answered, an operational phase should be worked out. Some premises for a successful project include:

- o making the project economically interesting by involving industry (at the 50% level);
- o developing a financing strategy by optimally distributing the costs to the participants (be it on a national or international level);
- o focussing on long-term results, making immediate use, however, of intermediate achievements;
- o recognizing the technological and social impacts.

The project should be applied, with priority given to basic experimental research (design of prototypes).

It is possible that when several countries and regions are involved, that an Institute such as IIASA can perform a coordinating function. A good suggestion though is to avoid building new structures and to use the existing ones as much as possible.

In conclusion, it is correct to say that in such an important topic as education, one should not be afraid to think big. At the same time care must be taken to avoid misconceptions such as the fascination with gadgets, sacrificing long term objectives for short term gains, and to fully unwind the project only if there are the necessary human and financial resources available.

TEACHING CHILDREN WITH PERSONAL COMPUTERS

I.S. Stanchev, A.A. Marchev and N.V. Marcheva

1. BASIC CONCEPT AND MODULE CONNECTIONS

At the beginning of 1984, a small research team at the laboratory for modeling and systems analysis at the Higher Institute of Economics "Karl Marx", Sofia, with the assistance of the State Committee for Science and Technology, started work on the project Children and Computers. The initial base for this research was the accumulated experience from the use of big computers in training students from the Institute in "Management Science". This included the design of business games, simulation models, algorithms for different causes and varied computer tests.

At the beginning of the research, a concept was worked out with the following main points:

- o to follow the requirements and didactical tasks included in the existing educational program for pre-school children;
- o to accomplish a smooth transition from traditional methods and means to computer training;
- o to apply the modular principle in forming separate programs, taking into account the mutual interconnections between the separate modules;
- o to cover the different task-sets of computer training including the problems connected with the management process itself;
- o to ensure the possibility for consequential enlargement of the bounds of didactical units taught by the computer and transition to higher age groups (elementary school);
- o to ensure that the computers chosen for the technical realization of children's education be easily available at low prices for the next few years.

This last point brought about the choice of the "Pravetz" personal computer produced in Bulgaria. Graphically the concept is presented in Figure 1. In the upper part of the flow chart a decomposition of the problems connected to Computer Based Education is made. The headings of the separate directions are those widely used in this field. Under the direction "Learning with the Computer" the chosen problematic field is "Computer Games." This was done to facilitate a smooth transition from traditionally used didactical games for teaching children to computer games. To ensure the possibility for gradual transition and expansion of the project bounds for teaching children in elementary shcool, the field of "Computer Aided Instruction" was chosen under the direction of "Learning Through the Computer."

From the basic education fields used for pre-school children included in the existing Bulgarian program, the following five were chosen:

- o Introduction to the surrounding world.
- o Language study.
- o Introduction to mathematics.
- o Art (mainly drawing).
- o Music education.

In introduction to the surrounding world, a new theme was introduced which had not existed before, i.e., getting to know the computer, which covers the task of "Learning about the Computer." In this way, the obtained matrix for Computer Aided Education contains 12 modules, which present the tasks for research and practical experimentation in the project.

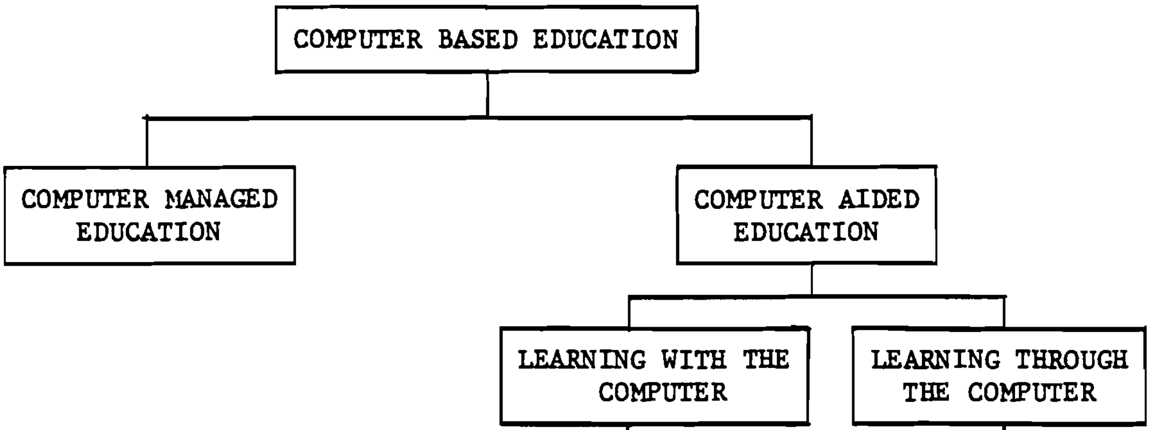
Under the direction "Computer Managed Education" two main problems were defined:

- o The design of tests for finding specific characteristics, level of knowledge, intelligence and specific talents of the children;

- o The design of specific methods for finding the attitude of children and their parents towards the computer and computer education.

The analysis of the interconnections between the modules shows the existence not only of horizontal connections, which ensure continuity and smooth transition from traditional methods of teaching to computer games and consequently to programmed education, but also vertical connections with considerable importance. The design of computer games on elementary mathematical ideas and concepts in geometry, for example, is connected with art—drawing with a circle, square, triangle, etc., which is necessary for games connected with *knowledge of the surrounding world.* The last module has a dominating importance as it uses the results of a great number of modules—"musical education", "language study","introduction to mathematics" and "art." In essence, this module assumes the creation of complex computer games with a special place for games used to introduce the computer itself. They will develop on the basis of accumulated experience from the design of traditional deductive games to games for presenting the computer.

The working hypothesis used consists of introducing computer teaching in the general program, as a result of which the children will learn to read and calculate in the last fourth group of pre-school education. This is a precondition for applying programmed education with individual computers in elementary school.



SUBJECT	TRADITIONAL GAMES	COMPUTER GAMES	COMPUTER AIDED INSTRUCTION
1. Introduction to the surrounding world	Analyze existing methodics	A scene and sequence of scenes	"Planet" "Animals"
including: Forming of basic computer knowledge	Didactic games: new element in the education program	"A trip to computer land"	PC programming
2. Language study	Analyze existing methodics	"The playfull letters"	Methodics for computer-aided instruction with appropriate software and course ware will be a designate of the future.
3. Introduction to mathematics	Analyze existing methodics	"Calculus" "Ma Eraser and the Pencil" "Figure City" "Children's Flatland"	
4. Art (mainly drawing	Analyze existing methodics	"Pine-wood" "The Tiny Architect"	
5. Music education	Analyze existing methodics	"The Singing Notes"	

Figure 1. Decomposition of the problems connected to computer based education.

A system for measuring the motivation and interest of the children is important for starting the experiments with a personal computer. Another side of this is the work done with the children's parents by the research group and teachers from kindergardens. The good planning and organization of these measures helped to easily overcome the existing psychological barriers.

2. DIDACTICAL TASKS AND THEIR REALIZATION

On the basis of the developed conception, the research group in the laboratory started to work on the practical side of the project. First, the main methods for teaching in the chosen five fields were analyzed. Special attention was given to the didacting games used. The next step was programming and the hardware and to experiment with them through computer games with the children. At the same time, work was started on the design of different didactic games for introducing the computer to the children.

For each module of computer games, didactic tasks were formulated which can be achieved on a computer practically. At the same time these tasks were arranged and tied to the working hypothesis and the module interconnections. The following tasks were formulated for each module:

1. *Introduction to Mathematics.* This module had priority in relation to the others.

- o Orientation in space (concepts of up, down, left, right, movement, stop, diagonal movement, determination of object positions, etc.).
- o Work with sets (common particularities of the elements, order in a set, operations with sets, etc.).
- o Work with natural numbers (introduction to digits and numbers, the connection number—power of the set, comparison of numbers, greater, lesser, arithmetic operations, the signs, +, -, =, and calculus).
- o Comparison and measurement of an object (using one dimension, two dimensions, etc.).
- o First notions of geometry (geometrical figures—circle, square, rectangle, triangle, etc.).

Important in the design of these games was the programming design of "The Pencil" and "Ma Eraser." Most of these didactic tasks have already been realized. Together with the experiments, the programs have been improved and supplmented.

2. *Musical Education.*

- o Development of the feeling for rhythm (introduction to different rhythms).
- o Development of the feeling for the pitch of a note (reproduction and differentiation of notes).
- o Forming simple melodies (using one voice) with the use of different notes in length and pitch.

- o Writing and recognizing notes in a scale (connected with the previous tasks).

For this module a complex program was designed that writes notes with different lengths on staves together with their interpretation by the computer.

3. *Art.*

- o Development of creative imagination and graphical-way of thinking.
- o Development of visual memory and the feeling for proportion and composition.
- o Inciting individual expression and viewpoints in reproducing real objects.

For the time being, this module will use the programs created for geometrical concepts. Through different combinations of regular geometric figures, the children will make their drawings. With programming and technical improvements, the functions of this module will be expanded.

4. *Language Study.*

- o Recognition of the different letters of the alphabet.
- o Realization of vowels and consonnants in connection with the role in pronounciation.
- o Analysis of words in which the vowels and consonnants change or appear wrongly.

This module is the least designed, as there is a need for additional pedagogical research and new conventions in connection with our hypothesis.

5. *Introduction To The Surrounding World.*

- o To expand the content for the ideas and concepts of the objects in the surrounding material and social reality.
- o To direct children to important points in objects and phenomena.
- o To learn to generalize and to make judgements and deductions.
- o To understand the relation of cause and effect.
- o To teach observation and inquisitiveness.

The module's complex character and the inclusion of all the results from the other modules needs special attention for the design of the corresponding computer games. Firstly, different scenes from real surroundings are taken that the children can put in motion and add to. Secondly, through building a sequence of such scenes, a game interpretation is given to specific stories with the possibility of adding new details and development. Some games, designed by the producers of micro-computers, can be adapted for the needs of this module.

To determine the attitude of children and their parents to the computer, questionnaires were designed (see Appendix 1), and a *multi-dimensional scaling*, using different elements corresponding to the different criteria, was used to determine their attitude to computer education.

The second task in the project Computer Managed Education related to the design of tests for determining the character specifics, knowledge, intelligence and specific talents. The first step here is the design of a program set for the personal computer "Pravetz" (or INCO-2) to ensure processing of a large set of tests. Our idea is that the programs be managed by the data so as to permit processing the tests, differing in volume, content and use. The teacher (or in general, the user) will choose the necessary program and load the test of questions and figures, as well as the comments needed for analyzing the test results, the type of statistics needed and so on. Gradually with programs for the "Pravetz", all types of tests will be designed to complete the classification scheme shown in Figure 2. Each combination of the values of the classification elements determins a processing program and a class of tests with which it can be processed.

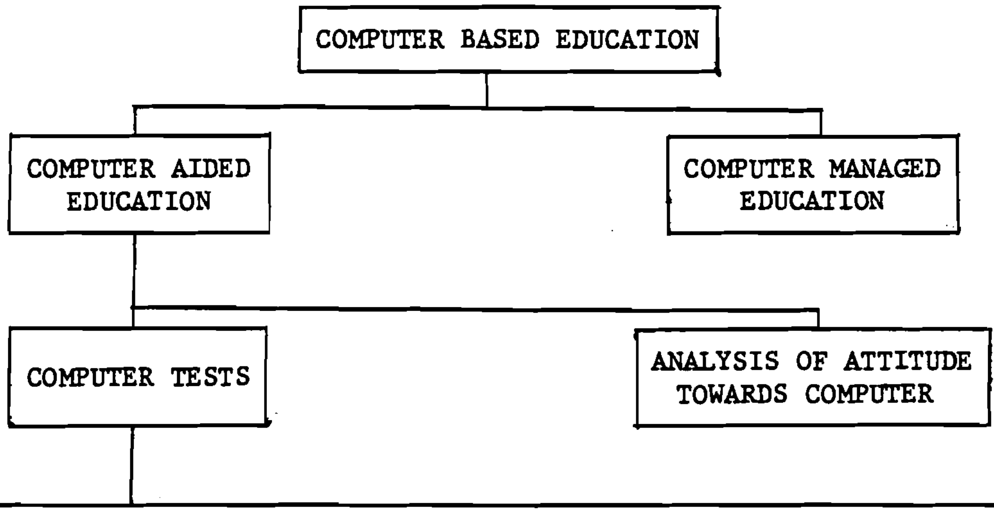
3. FUTURE PROCESSING AND RESEARCH

Together with improving the methods and software for different modules of the computer games and tests (Figure 1), the future development of the project will include:

- o Adaptation of existing computer games for teaching small children.
- o Designing software for program education (CAI) on a "Pravetz" personal computer.
- o Developing a system for courses in programmed education of children in the age group 8-10.
- o Realizing an interface between "Pravetz" and conventional video systems for developing an integrated audio-visual teaching complex.
- o Introducing artificial intellect elements in computer systems for education.

The last two directions are especially interesting. Connecting the personal computer to a video system will provide for using the advantages of both systems: the programming possibilities of the computer and the possibility to show moving objects with natural sound and color on the video system. Such a teaching complex can be used for the modules featured in Figure 1, but has special importance for Introducing the Surrounding World.

The principles and methods, evolved in connection with artificial intelligence systems will permit the development of self-perfecting teaching programs, which during teaching will analyze the specifics of the person being taught and will themselves then adapt and change to these specifics. Even more, they will accumulate the experience of many people during teaching and will be able to discover new laws and master the taught material. They will then be able to use these laws for their own improvement, achieving higher efficiency for their teaching process.



Classification Characteristic	Values of Classification Characteristic	
	Variation 1	Variation 2
1. Number of answers to a question	Exactly two	More than two
2. Number of evaluation scales	Exactly one	More than one
3. Answer weights	All answers are equally weighted	Answers have different weights
4. Existence of analysis and comments on the test results	Without analysis, comments and instructions	With analysis, comments and instructions to the tested persons
5. Length of questions	Short (up to 256 characters)	Long (up to 960 characters)

Figure 2. Test classification scheme.

Finally, we have to say that computerization of education is not a new technique using old methods. With its introduction, the computer changes the methods and forms of teaching. This is as an objective and one way process as that to computerize all spheres of human activity. This process is not the result of one persons wish, neither can it be stopped by somebody's wish. It reflects the development of scientific and technical revolution. As a result of this development, the world of tomorrow will be a strongly computerized world. Every human being will be in contact with computers every day. In this world, the use of computers will be normal activity, while programming an element of basic education. A person who is unable to program will be in the same situation as an illiterate today.

For these and other reasons the preparation of children today for the computer world of tomorrow is not only a change in the technical basis or methods of education, but an extremely important element in the strategy of moving towards the future.

APPENDIX 1: CHILDREN'S QUESTIONNAIRE

1. Do you like computer games?
2. Does mummy (daddy) know you play with the computer?
3. What do mummy and daddy say about you playing with the computer?
4. Which of the games do you like most? Why?
5. What don't you like in the game? Why?
6. Was it easy for you to learn to play with the computer?
7. What was hard for you?
8. Would you like a computer at home?
9. What are you going to do with it?
10. Have you ever seen a computer until now? Where? When? How?
11. Do any of your relatives (or your parents) work with a computer? Who?
12. Have you ever told your friends about the computer games? Whom? What?
13. Do you know what is inside the computer?
14. If not, would you like to know?
15. Do you want to make your own computer?
16. Would you like to work with a computer when you grow up?

APPENDIX 2: PARENT'S QUESTIONNAIRE

1. What is your child's impression of computer games?
2. Why is it so in your opinion?
3. What is your attitude towards the use of a computer for teaching your child?
4. Which of the games made the strongest impression on your child?
5. Does the child encounter problems during computer training?
6. If you had the possibility would you aquire a personal computer for teaching your child at home?
7. If "yes" how would you use it?
8. Has your child had the opportunity to encounter a computer? Where? When? How?
9. Is there a member of your family who works with computer technology? Who?
10. Do you know the operation principle of computer technology?
11. Would you like to learn?
12. Would you like your child to learn something more about the computer?
13. Would you approve your child's wish to make his own computer?
14. Would you direct your child towards a profession connected with computer technology?

APPLICATIONS OF COMPUTERS IN EDUCATION IN AUSTRIA

Erich Neuwirth

1. INSTITUTIONAL PREREQUISITES

1.1. Austrian Schools Using Computers

Computers regularly are used only in post-compulsory schools in Austria, i.e., only by pupils at least 14 years old. At this stage there are three main types of school which lead to university access:

- o General Schools (for university access only, four years).
- o Technical Schools (for university access and training to technician, five years).
- o Commercial Schools (for university access and training for middle management functions, five years).

There are also post-compulsory vocational schools not leading to university access lasting three or four years:

- o Technical Schools
- o Commercial Schools

Additionally there are a few very specialized vocational schools, e.g., for tourist-trade or domestic science. There is also a school for data processing at technical level, but this school is not a major success. Some technical schools are teaching courses about data processing for graduates of technical or general schools.

1.2. Curricula for Computer-Related Subjects

Most naturally the strongest accent on computers is found in technical schools and the use of computers is twofold: learning about computers and using computers in different subjects. Learning about computers is usually restricted to two hours a week for one or two years, but use of computers for technical calculation is made rather often. The subject "data processing" is mandatory in these schools.

In commercial schools (fifth year form) computers are mostly used for accounting and text processing and are heavily used for these subjects. In the last two years the subject "data processing" for itself also is taught for two hours a week. Commercial schools (third year form) teach "data processing" for three hours a week in the last year.

In general schools, "data processing" is not mandatory and the use of computers is in its beginning stages. For these schools there is a curriculum for "electronic data processing" for two hours a week for four years, but only as an optional subject.

1.3. Contents of the Curricula

The curricula edited by the Ministry of Education and Arts are very unspecific and in all cases roughly state that "the aim of the subject is to promote knowledge and ability to solve different problems with the aid of computers." Furthermore it is stated that the different phases of analyzing a problem should be taught. There is no explicit mentioning of any computer language and nowhere the curricula are concerned about the impact of computers on society. This form of curricula leads to no uniform teaching of data processing, but on the other hand, leaves teachers much freedom in the choice of their subjects.

The curricula of the technical schools state examples of the use of computers in different subjects (mainly for numeric calculations). In the commercial schools computers are embedded in the courses on short-hand-writing, typing and text processing.

1.4. Availability of Computers in Schools

Computer availability is best in commercial schools. Every one of these schools (there are 100 in total) has at least ten micro-computers with a twin-floppy disk drive in a special classroom. Technical schools (of which there are roughly 40) mostly are equipped with mini-computers with six to ten terminals, but some of them have microcomputers like the commercial schools.

General schools are not so well-equipped. Only one-third of these 300 schools do have computers. In many schools these machines were bought from donations from the parents. Just now the Ministry of Education is preparing an invitation for tenders with the aim of buying four microcomputers with twin-floppy disks and a printer for every general school. According to the plans these computers should be installed by the end of 1985.

2. IMPLICATIONS OF COMPUTERS ON THE EDUCATIONAL SYSTEM

As can be seen from the curricula the Austrian education system did not put a heavy accent on computers in the last ten years. In the technical and commercial schools computers were installed mainly because of the strong interest of employers in those schools. Computers mainly are used as a tool for increasing productivity for rather elementary working processes (e.g., type-writing and numerical calculations). Direct teaching about computers is allocated only very little time; therefore a deeper understanding for computers as a very universal tool which can be adapted to one's problems is not given. Only in the last two years some groups of teachers have formed a group which try to organize meetings about general problems of computers and socieity.

The Ministry of Education is also doing much publicity work about computers in schools and together with some major companies is organizing children's programming contests. Now there is the strong opinion that everybody leaving school and having gained university access should know enough about computers to use them as a tool for different applications and slowly this opinion is beginning to influence the daily work of schools.

Since—as already stated—two-thirds of the general schools do not have computers, these aims are just being formulated and hopefully will be reached at least partly in the next few years.

3. TEACHERS TRAINING

Until now there has been no compulsory training for teachers of data processing during their studies at university. There are courses about the subject organized by school authorities which can be attended voluntarily; but most of the teachers are self-taught. This naturally leads to some problems. Because of this self-teaching of teachers—and a heavy influence of commercial lobbies—BASIC is by far the most-taught computer language, PASCAL is second; FORTRAN is taught in some technical schools; and LOGO is almost nonexistent. Also self-taught teachers tend to put strong accents on languages instead of ideas, and for example, often spend very much time for assembler languages also in non-technical schools.

The situation is growing better, because from this year on every student planning to be a teacher of mathematics, physics or chemistry has to hear lectures about computer science and also to pass examinations on this subject. During the last two years a "computer subculture" has evolved in these subjects: interested teachers are exchanging demonstration programs and making use of the computer as an "intelligent blackboard" and so the children can get accustomed to computers as part of their daily life. Following a very strong demand, the universities are also organizing post-graduate courses for teachers of mathematics, physics, and chemistry. There also exist plans for such courses for teachers of other subjects.

4. COMPUTERS IN NON-SCHOOL EDUCATIONAL PROJECTS

As already mentioned, computers in schools are institutionalized only in non-compulsory schools and for children of at least age 14. Since many parents feel that their children should learn about computers as soon as possible there is a growing demand for additional computer courses. The Austrian Computer Scoiety (a scientific society) is organizing computer camps for children during their holidays. Being organized by computer scientists these courses try to present the computer as a tool for assisting the thinking process and not only as a numerical machine. Therefore, the language used in these courses is mostly LOGO. On the other hand, there are courses organized by commercial companies with the aim of producing "little programmers" and these courses mostly teach BASIC with very commercial applications.

5. PERSPECTIVES FOR THE FUTURE

During the last year, public opinion in Austria has changed its attitude towards computers. Now there is general consent that everybody should know about computers. This fact has led the educational system to recognize the importance of the teaching with and about computers. At present the approval of teaching about computers is conventionally oriented on using computers rather uncreatively for data processing. Only during the last year has a public discussion about the impact of computers on society begun and some teachers are beginning to discuss these problems with their pupils. Hopefully, our education system will shift its main aim from teaching how to use computers to how can computers be used with maximal gain for society.

APPLICATIONS OF COMPUTERS IN EDUCATION IN HUNGARY

Zoltan Zamori

In Hungary, we have some preliminary results as regards the deployment of computers in public education. The impetus to initiate such investments came from an early analysis of the consequences of the rapid development of a decisive technology, namely that of microelectronics. That is, we started not from the needs of the educational system itself, which might have caused us to look for some efficient means in computers, but we were forced to move due to the effects of the so-called "technology push". This kind of motivation needs perhaps some explanation, especially in front of an intellectually and not purely technicallyoriented audience.

We had the following reasons:

- o Logic or switching networks are, in a certain sense, nearly omnipotent—as it is long known.
- o As a novelty, however, they can inexpensively be implemented either as dedicated networks or as univeral programmable computers due to the extremely productive planar technology.
- o The enormously high and ever increasing output of this technology is in search of a competent and broad market; such a market was found most easily in today's youngsters of perceptive age.
- o The captivated youngsters brought up with their own computers in the countries of high technology will define the material basis of the future, utilizing their computers in every kind of automation.
- o We have no wish for our youngsters to be disengaged from the shaping of the future, hence we must provide them with equal, or pseudo equal opportunities, if not with computers of their own, then at least with computers in their schools.

- o We thus introduced computers into schools not as a means of more efficient teaching, but as a means of familiarizing children with the unavoidable tools of their decent later production activities.

These are the guidelines in short for a country with restricted resources like Hungary. In a more affluent society computers simply appear in each home as a presentable and seasonable plaything without any mediation of the school. Our primary short term task with a few computers in schools is to offset this screaming drawback in a field of considerable importance and consequence.

A computer-based and computer-managed education are among the goals of lower priority. The main task should be the means to acquaint our pupils with the computer and its application possibilities through the demonstration of games, programming of simulations, and the interfacing to external devices to model various measurement and control functions.

THE BROADEST MARKET FOR COMPUTERS

In the fall of 1977 there was a meeting of the leading representatives of the semiconductor industry in Palo Alto, California. There, Gordon Moore, the President of Intel Corporation, displayed a diagram showing the yearly change of the output of the whole semiconductor industry expressed in units of digital functions, which is the common name for a logic gate or a memory bit, each comprising 1 to 4 MOS transistors. This plot is shown in Figure 1. Up until 1976 one can see the actual data for the number of functions delivered by industry. Beyond this year, the curve is a simple extrapolation drawn with the assumption that the then prevailing rate of development persists for a few further years. Hence from this extrapolation we would get 10^{15} digital functions for the year 1985. That is an immense figure! Calculating with the current population of the world, it means a quarter of a million logic functions (gate or bit) per capita (for all ages of all nations).

Realizing this magnitude, the industry gave way to despair. Not because of the high figure itself, but because of the clear hopelessness to find customers for such an amount of logic functions with not entirely trivial usage. Not everyone would be a customer for an open-ended logic system, e.g., for a logic network or a programmable computer. Nevertheless, the industry felt capable and well disposed to deliver that many functions for the year quoted, which happens to be one year from now. So they set out to analyze the forecasts of all conceivable uses. A watch contains a thousand gates, a calculator ten thousand. Only computers may contain memory bits by the million. On a large scale the computer could be the ultimate incarnation of the multitudes of gates and bits being produced.

But who cared then with computers? The professionals. But the vast majority of *all* the consumers were completely uninitiated and almost hopeless. Did it mean for the capable—non polluting, not material- and not energy hungry—industry, that all their further efforts would be in vain?

Then, after all possible market assumptions, it slowly became clear that the very needed receptivity and willingness for the mass use of computers looked most promising in the case of children. They showed and do show the purest desire for knowledge, the vivid curiosity matched with the

Figure 1. Number of logic functions (gate or bit) produced yearly.

necessary—but in busy adults only rarely present—readiness for any challenging mental investment. Hence, computerized games and inexpensive personal computers appeared on the market in their millions.

WATCHING THE YOUNG ONES

Up until now, the number of personal computers released is well above ten million. By a rough estimate one-tenth of them are in the hands of professionals, a quarter of them are used as small business computers with canned or turn-key application programs supplied with them, and all the rest are in the hands of children.

It is the last group that is in our focus of interest. These computers, and the subsequent hundreds of millions coming soon, make ready the next generation for the mastering with well-drilled proficiency the future means of all kinds of production and servicing activities. To take part in the changing production processes with firm fundamentals, or simply to watch them from outside, as a drop-out of the automated world, seeking pastimes in newly created unproductive and hopefully nondestructive spheres, but with dignity, knowing exactly what is going on in the technocracy around.

This indispensable familiarity will be imparted by the home computers sold in quantity from now on, and by robots as "the toys on duty" from the second half of this decade, both sold by the ten million like the Rubik cubes or the Lego and Märklin (Meccano) sets before. But notice, please, that there is an unprecedented feature of these new toys compared with those of the past. The existing home computer and the coming robot of the playrooms is not the pale copy, the truncated effigy, the emulating parody or the grotesque mockery of the real thing, of the professional specimin—like the Märklin/Mecaano or the Lego were—but the self-same system applied by the very professional. With the same processor, the same memory, keyboard and display. Actually, the display is already color and lightning-fast for the young profane, but only black and white and miserably slow for the sacred professional.

It is not we, but our children that are challenged by those of the more advanced nations. We are in charge only to call into being the preconditions.

PROVISIONS FOR OUR YOUNG

There used to be a time lag of six to ten years in the proliferation of new products between Hungary and the leading world. That was the case with nylons, the ball-point pen, calculators, and many other commodities.

Within six years we cannot afford to provide one million computers for the young tenth of our population as will be done with no problem in an even higher proportion in each country that is better off*. Hence, if we do not want to tolerate a lag of about ten years in this vital point at issue, then what we can do is to concentrate our finite resources. Here the schools come into the picture. Not clubs or circles, but schools attended by everyone. Schools, initially in the role of windows or showcases to demonstrate in the first place not the calculating, but the controlling power and the programmability of the computer.

They will certainly be used later or even now in the role of educational aids as well, but it would be a mistake to enforce such a confinement now, when they have appeared only incidentally in the schools. (They should have appeared in the playrooms.)

This is what our Computer Aided Education (CAE) priorities are: learning about and with the computer and only later through the computer, using the semantics of the "Overview of the Issues" circulated in advanced by IIASA.

INITIAL GOALS WITH COMPUTERS IN OUR SCHOOLS

The primary goal is the demonstration of the wide application possibilities of the computer, of its programmability and its means of access, i.e., interfacing. We may not introduce a dedicated, regular and compulsory new subject for this purpose. But we might try to distribute the duties among a few established subjects, such as mathematics, physics and technique.

Mathematics should deal beyond its customary and familiar topics with the function of logic gates, with the elements of logic networks and with programming.

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*England, for instance, now has approximately two million computers in the hands of their children.

Physics originally has the duty to make known the physical observables (quantities), to give the classic methods for their measurements and to state the explored relationships between them. Our proposal for the expansion of the subject material is to describe at the introduction of each observable those novel and up-to-date sensors and transducers (more and more monolithic semiconductor devices) which permit their computerized, i.e., automatic measurements. In any closed-loop control system the parameters (physical and other quanitites) continuously and automatically have to be measured.

Technique is a new subject in our primary (since 1978) and our secondary (since 1981) schools, yet without considerable recognition and popularity. Its objectives (environment; systems; function, process and structure; material, energy and information transfer are the key words) were defined well before the advent of the accessible computers, hence they did not get enough emphasis (around 5% in the text-books). Here we have a good chance to extend the contribution of various computer applications, here we should speak about their operation and about the ways of their connections (interfacing) to the characteristic external devices and processes to be controlled.

The elaboration of the concept and details of all these subcurricular of high concern requires the contribution of devoted professionals along with the related teachers. Our Institute for instance is involved in such an undertaking with the voluntary assignment to develop a concise and handy digital laboratory for the demonstration of interfacing of the computers to the conceivable devices to be automated.

The preliminary results of these efforts will be demonstrated at the meeting.

CURRENT FACTS

In the past decade 1500 million Forints were spent on such computers which were installed in educational institutions, the majority of them mainframes and minicomputers, serving mainly our universities. One US Dollar corresponds roughly to 50 Forints, hence this total sum amounts to about US$30 million.

In that period some ten secondary schools were equipped with minicomputers to expose them to the youngsters and gain some experience where the dedicated teachers undertook the extra efforts required for such experiments.

Noticing the appearance, growing popularity and power and the decreasing price of the personal computers, our Institute, involved in computer techniques, initiated a significant, at least by our measure, investment of the government to install personal computers in the schools. Hence, last spring more than 1,000 microcomputers appeared suddenly in the secondary schools. They are of various origin. The majority of them were produced in Hungary of component kits coming from the Far East (Z-80 processor, 16kByte RAM, 14kByte ROM, Basic language, built-in cassette recorder). More than 200 ABC--80 type computers came from Sweden in exchange for Hungarian made tape recorders used by them. All of them were financed from the state budget. Since last year an increasing number of Sinclear ZX-Spectrum and Commodore 64 have been bought by the schools themselves to satisfy the children's demand for computer generated graphics, color, and audio effects.

MICROELECTRONICS IMPACT ON EDUCATION IN CZECHOSLOVAKIA

1. COMPUTER USE IN EDUCATION IN CZECHOSLOVAKIA
   Frantisek Plasil

2. TRAINING IN MICROELECTRONICS
   Bretislav Benda

1. COMPUTER USE IN EDUCATION IN CZECHOSLOVAKIA

In Czechoslovakia, increased attention is payed to the applications of computer technology in education. This can be shown by the activities of the Ministry of Education, unviersities, secondary schools, etc. The particular approach selected depends on the level and type of school.

In grammer schools only simple calculators are used at present. However, a basic information on modern electronics is included in the curriculum as a part of polytechnic courses, and the use of more sophisticated (programmable) computers are being prepared. In several secondary schools minicomputers have already been installed. Single board computer systems are used in some special oriented courses. At present secondary schools are supplied with personal computers with display, keyboard, tape recorder and BASIC in PROM. In the near future the total amount will reach a level of several thousands.

Computers at the university level were introduced very early in the 1950s. At present, most of the mainframes and minicomputers of larger configuration installed in universities are in computer centers on campus. In big cities large centralized computer centers have been established which serve several universities. On dedicated departments computer classrooms with mini and microcomputers are being built. For education in computer science there appears the necessity to procede from the classical time-sharing systems to distributed systems created by networks of personal minicomputers.

As an example we can present a project of a terminal classroom at the Computer Department of the Faculuty of Electrical Engineering in Prague that is being implemented at the present time. This project assumes the education not only of programming in various high-level languages, but also subjects where it is necessry to go down to hardware such as operating systems, peripheral devices and computer networks. Also the education in hardware design, where specific devices have to be attached to a developed system, can take place in this classroom.

From these requirements it follows that in similar cases a classical time-sharing system cannot do, because essential parts of its operation system must remain untangible.

An essential feature is also the fulfillment of the requirement that students become acquainted with one specific system. This can be satisfied better by a computer system based on a set of microcomputers and furnished with some simple operating system—e.g., CP/M, than some large mainframe where to penetrate into the operating system is a task only for a privileged system programmer.

The above mentioned project is therefore based on the use of the operating systems CP/M and MP/M types. It is supposed that a special emulator board will be designed on which the signals of various buses will be emulated. Thus, the proposed terminal classroom will be able to be used in most courses of the computer science curriculum.

2. TRAINING IN MICROELECTRONICS*

An activity which runs parallel to computer applications in general and professional schools has been launched through the Czechoslovak Scientific and Technical Society which is regionally organized. There are 39 regional centers equipped with microcomputers, staff and necessary literature.

Three types of standard courses are in use: basic, improvement and special courses. Basic courses are modularly built into four levels:

- o for decision makers and administrative workers;
- o for personnel without the knowledge of digital technology;
- o for personnel with the knowledge of digital technology;
- o for personnel with basic knowledge of microelectronics.

Taught at these courses are the architechture of available microcomputers, programming in assembly and higher languages (Basic, Fortran, Pascal) and how to develop an applicable system.

Until the end of May, 1984 more than 10,000 people have participated in these courses, including designers, economists, qualified workers, but also students from secondary schools and universities.

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*B. Benda (1984) Training in Microelectronics. Czechoslovak Scientific and Technical Society, Prague. Internal Report.

TEACHING INFORMATICS IN THE FIRST CLASS OF JUNIOR HIGH SCHOOL ACCORDING TO THE RESEARCH GROUP ON EDUCATION SYSTEM

Rumen Nikolov and Bozidar Sendov

The main goal of the educational system in Bulgaria is to form people with integrity. This goal is the starting point of the activity of the Research Group on Education. The group acts under the direction of the Bulgarian Academy of Sciences and the Ministry of Education with Academician Sendov as leader. The ambitious project for an educational reform it carries out spread to all stages of the Unified Secondary Polytechnical School.

The integral approach is used as a base for the education (Sendov, et al., 1983). Because children tend to see the world as something whole and unified, education should not oppose this view but should support and develop it further. The aim is to ensure an interrelated acquirement of knowledge based on generality, similarity, analogy in objects and phenomena different at first sight. The children are enabled to apply the acquired knowledge and skills in another field by solving problems which arise on their own.

The adopted approach is quite suitable for teaching informatics. It begins formally in the first class of junior high school—when the computer comes to the classroom for the first time. During the first four years of education they have been acquainted with some basic notions of informatics and have made use of them. Texts have been coded and decoded, the notion of algorithm and variable assigning statement have been introduced. Most of the rules are given in the form of algorithms (e.g., addition, substraction, multiplication and division of long numbers, finding the greatest common divisor and the least common mulitplier, etc.). Some basic information on structures (a table, a binary graph) have been acquired and used in an appropriate way. Calculators have been used as well.

Teaching informatics in the first class of junior high school is a natural extension of the algorithmic approach having already been established in numerous activities. Moreover, it turned out that teaching informatics affords the best opportunity for a natural integration of all other subjects. Such was the main goal when writing the testbook in informatics for the first class of the junior higher school (Nikolov, 1983). The language LOGO has been chosen as a programming language due to its good properties for that purpose.

Teaching informatics aims at:

- o acquiring knowledge of up-to-date microcomputers;
- o acquiring the basic LOGO constructions;
- o learning to solve and to understand the solutions of problems related to the other subjects;
- o stimulating the pupils to formulate problems according to their interests and solve them.

During the course in informatics the pupils are stimulated for a collective work and an active intercourse. They are acquainted with the computer by means of programs prepared in advance. These are training games, some of which illustrate natural laws and phenomena known from other subjects. After having acquired the necessary knowledge of LOGO the pupils could vary these games or create similar ones. For instance there exists a program showing by animation the law of uniform rectilinear motion S = V.t. Two parameters being set, the computer gives the third and displays the concrete motion. The main LOGO instructions FORWARD, BACK, RIGHT, LEFT, etc., are easily learned since English is also taught. Using these instructions the pupils could draw on the display, which is very interesting for them in general and introduces them to the study of programming. At the beginning it consists in writing a sequence of instructions which are performed immediately and result in interesting figures. After that these instructions form procedures which are named. The possibility of using procedures with parameters is shown. Thus the computer "learns" new instructions carrying out algorithms described by the pupils.

To teach informatics by programming graphic objects is very suitable for beginners since the results of the operations performed by computer are displayed directly. When applied to solving problems in other school subjects, LOGO is acquired more thoroughly. In order to increase the field for application some extensions of the language are used enabling music to be progammed and simple animation to be made.

Some problems considered in the textbook are listed below:

- o equations with one unknown, extraction of roots, finding the greatest common devisor and the least common multiplier, drawing graphs of functions, finding the sum of an arithmetic progression, transforming numbers in different positional systems;
- o drawing geometric objects and measuring them, drawing symmetrical and similar figures;
- o problems related to distance, velocity and time, force, mass and acceleration, work and energy, illustrating some natural laws and phenomena graphically or by a simple animation;
- o presenting some atoms and molecules graphically or by simple animation;

- designing and using different letters;
- illustrating the sense of the sentence by simple animation;
- taking part in computer games imitating dialogs with the computer in a natural language;
- using the computer as "intelligent" typewriter;
- composing tunes by computer and synchronization of music and colors;
- using the computer as a drawing tool.

A variety of problems is given after every topic considered in the textbook. This enables an individual approach according to the pupils interests. The applications considered above show to a great extent the opportunity to use the informatics in all the fields of human activity. The pupils showing special interests in a given field of study could extend their knowledge by applying it mainly in that field.

Using such an approach we hope that there will not be students remaining passive when learning informatics.

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MINIROBOTS AND CHILDREN'S CREATIVITY

Bozhidar Katsarov and Vesselin Georchev

The increased rates and growing scale of computerization of modern society bring qualitiative changes in the life of the individual, in his (her) relationship with other persons and/or institutions, in the possibility and ways of self-realization in the field of studies, work and recreation. Computerization brings about a number of complex problems related to the overall preparedness of the young generation for a full-blooded life in the conditions of a high degree of computer use, stimulates the search for new ways of early and effective socialization of the computer. An indispensible component of this process is children's involvement in various creative activities oriented towards the development and application of the computer and computerized techniques. An effective tool for that purpose are minirobots alias non-industrial robots.

The number of minirobots used in the developed countries has greatly increased lately. Their relative share in Great Britain exceeded 70% in 1982 according to research made by the British Robots Association. This has been determined by the necessity to robotize a number of monotonous technological operations which do not require particular precision or manipulates heavy loads. The simplified mechanical construction and control of minirobots, the standard technology of manufacture and their low price (US$700 to 2,500) are responsible for the mass implementation of minorobots in industry and are a prerequisite for their wide use in education. Typical minirobots are: Mini Mover and Teach Mover of Microbot, USA; Rhino-EX-2 of Sandhu, USA; Cobra RS of Securia, FRG; Armdroid 1 of Colne Robotics, UK; Move Master of Mitsubhishi, Japan; Hikawa of M.T. Hikawa, Japan; and the Robco family developed by ITCR which is being put on the production line.

The minirobots are usually of an articulated or linear kinematic structure and electro-mechanical drive easy to study and comprehend. Their construction is light and safe for the operator, as motors of suitable power and light materials are used in the mechanical units. They are controlled by a personal microcomputer with developed software, including the programming in algorithmic languages on a high level with extended versions for the purpose of robot control. The use of a personal computer with extended peripheral equipment as controller enables the development of new programs of control and expansion of the algorithmic languages with new macrocommands specific to robot activity.

These and some other minirobot characteristics make them effective and purposeful tools for children's creative activity as follows:

- o visualizing the whole planned process from the entry of the command via its processing by the computer, to achieving the objective: the driving and performing mechanisms. Every stage can be watched and performed at the required speed.

- o Synchronized development of the abstract thinking (development of new control programs and new algorithmic languages) and the practice-oriented thinking (new application and new constructions of minirobots).

- o High potential to attract various elements of the children's material and intellectual world within the scope of the minirobot activity respectively ample possibility to develop the children's creative imagination, hence a relieved spontaneous socialization of computer techniques.

Children can use a minirobot in their creative activities—in play and in solving practical tasks, in developing control programs and algorithmic languages and in interfacing two interacting minirobots.

The combination of the three orthogonal dual directions outline eight areas of creative activity, e.g., developing a sport fencing control program for two minirobots. A wide range of creative tasks can be generated and tackled in each area. The effective instruction through creativity poses a number of problems, part of which are still unclear at present, while no solutions have been found yet even for those problems that are clear. The experience in the field of instruction through creativity, acquired mainly in the higher education establishments, has to be adapted to the characteristics of children in different age groups.

The following program of research and experimentation of minirobot implementation in the training of children in a computerized world is to be considered:

- o Study of the minirobot ability to stimulate and help realize the children's creativity.

- o Development and experimentation of an instruction program for initial minirobot training for children of different age groups.

- o Development and experimentation of an educational-creative syllabus in one of the eight areas of creative activity; formulation of a pedagogic and methodological approach to education through creativity on this basis.

- o Preparation of guidelines for the compilation of educational-creative programs in other fields of creative activity.

- o Phased guideline development; defining and further up-dating of the pedagogic and methodological approach.

- o Generalizing the experiment results, up-dating the educational-creative programs and software, preparation of teachers' manuals.
- o Developing a program for mass use of minirobots in education, including a teacher-student feedback system.

The implementation of this program will involve long-term work of a team of engineers, pedagogs, psychologists, and sociologists and the assistance of competent authorities: the State Committee for Science and Technical Progress and the Ministry of Education as well as wide international cooperation required by the importance of the matter and the invariability of the problems involved and their solution in different countries.

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