JPRS: 18,832

22 April 1963

OTS: 63-21637

CYBERNETICS IN EDUCATION AND AUTOMATION

- East Germany -

U. S. DEPARTMENT OF COMMERCE
OFFICE OF TECHNICAL SERVICES
JOINT PUBLICATIONS RESEARCH SERVICE
Building T-30
Ohio Dr. and Independence Ave., S.W.
Washington 25, D. C.

Price: $.75

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[Following are two translations of articles on Cybernetics. Full bibliographic references are given with the respective items.]

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CYBERNETICS IN RELATION TO IMPROVED EDUCATION AND TRAINING

[Following is a translation of an article by Wilfried Lange in Paedagogik (Pedagogy), no 2, Berlin, February 1963, pages 159-167.]

In the last decade cybernetics has become increasingly important through the rapidly developed dialectical processes of differentiation and specialization of sciences, on one hand, and the unification, integration, and universality of fundamental principles in the sciences, along with the rise of many peripheral sciences, on the other hand. As the product of the interaction of many sciences and as the reflection of certain common fundamentals for all sciences, it is an important general aspect and point of departure for methodological investigation, evaluation, and representation of specific problems of fields. Cybernetic formulation of problems and questions has proven feasible in industry, technology, science, planning and direction of the economy, and in many other spheres of life, thus showing the individual sciences completely new and especially effective ways to solve special problems. This applies to pedagogical research, too.

We as teachers must not expect cybernetics to solve all problems simply and surely, making unnecessary any further investigations or experiments specific to the field. Cybernetics' usefulness is not in replacing particular scientific research and generalization, but in suggesting all-around generalization and thus indicating a basic way.

Pedagogical and didactic investigations based on cybernetics or using its basic precepts and its methodological mathematically exact aids are being instituted at present in the Soviet Union and in other socialist countries, in addition to capitalist states such as France, West Germany, and the USA. Without doubt the application of cybernetics in pedagogical research will contribute to scientifically precise determination and establishment of a series of hitherto merely empirically obtained experiences and methods.

"The tempo of scientific development is increasing; differentiation and specialization also grow... Mankind approaches the moment at which it can no longer completely 'digest' and use accumulated knowledge. To prevent this, the classification of knowledge and the separation of the superfluous must be continually worked at. Knowledge must be uninterruptedly compressed, figuratively speaking." ([Note]: G. Stschedrovizki, "The Technology of Thought," in Press of the Soviet Union, no 146, 1961, page 3309.) This leads to the centers of knowledge and understanding and to a new system of construction of principles.

The experiments of Prof. L.N. Landa, W.W. Dawydov, and others show that more can be achieved than mere mastery of the instruction material in shorter time and in more intensive fashion. They have shown rather that it is even possible to master in shorter time a greater range of instruction material with far higher educational performance by the students than before. The problem, so acute now and in the future, of attaining higher quality of education in relatively shorter time, will therefore be conquered not only through improvement and intensification of instruction (for example, according to the Lipezk example), but also through a new scientifically based establishment and shaping of basic knowledge and its classification in centers of knowledge and understanding.

Using publications of the Soviet press we will indicate in this article some consequences resulting from application of the aspects and methods of cybernetics to pedagogy. We will thereby deal with all three pedagogic problems that concern us, especially at present and in the near future, in the far-reaching construction of socialism in our republic, in the closer connection of school with life, and in the perfection of the uniform system of education:

> The problem of basic knowledge and basic skills, as a pedagogic problem of the system of centers of knowledge and understanding.
>
> The problem of the technology of thought, as the didactical and methodological problem of the student's intensive and effective learning.

The problem of unity of physical and mental activity, as the pedagogical problem of overcoming a one-sided polytechnic training directed toward handwork techniques, skills, and habits, and an occupational education just as narrowly oriented.

THE PROBLEM OF BASIC KNOWLEDGE

The further development of the material and technical bases of socialism, the rapid rise in work productivity because of the highest possible state of science and technology, the production of better quality goods able to compete more favorably in world markets, all cause science to become increasingly a direct productive force. The waxing importance of mathematics, natural and technical sciences, cybernetics, automation, and electronics to the growth of the productive forces of society necessitates close attention to obtain more scientific types of instruction in the sphere of education. This does not mean, however, that in the general polytechnic higher school the students are "to be given all the highest mathematical and scientific knowledge; this is the task of subsequent specialized education" ([Note]: Address of Walter Ulbricht at the 17th congress of the Central Committee of the Socialist Unity Party of Germany, in: "Toward the VIth Party Congress," pages 63-64, Dietz Verlag, Berlin, 1962.)

In the general-education school it is particularly important to insure that all students assimilate the fundamentals of knowledge and understanding that make possible a further extension and development of education. This involves the highest state of knowledge and skill in fundamentals, and presupposes that the basic knowledge and basic skills are separated and established, with scientifically founded methods, mathematically exact determinations, and analysis based on logic of form and content, out of the total fund of advanced experiences and scientific knowledge.

These fundamentals of knowledge and understanding, as Soviet pedagogues (Skatkin, for example) demanded years ago, must be centers of education. They replace the principle, used previously in our curricula, of joining "fragments of education" from all or nearly all fields of a scientific discipline into a mosaic that we then call the subject.

Previously, the collection of individual educational material took place according to the traditional methods of empirical school practice: some of the obsolete material drops out, and new educational matter is added - all this is done largely empirically according to the pertinent abstraction stage. Empiricism therefore decides whether instructional material is obsolete or whether it will be used for instruction for a few more years.

Cybernetics, with its aspects of information theory, the study of algorithms and the methods of logic of content, of matrix calculation, and of Boolean algebra can help us here. L.B. Itelson ([Note]: "The Use of Mathematical and Cybernetic Methods in Pedagogical Studies," in Sovjetskaja Pedagogika (Soviet Pedagogy), no 4, 1962, pages 45-55; "The Psychological Peculiarities of the Task of a Worker on Equipment in Continuous Chemical Production," in Voprosy Psichologii (Psychological Questions), no 5, 1961.) showed through individual investigations how the use of mathematical and cybernetic methods in pedagogic research, especially in determining the work skills to be learned and a system of centers of the later qualified and at the same time available knowledge, leads to new scientific pedagogical findings.

Determination of basic knowledge and basic skills with scientific precision is therefore necessary, too, because the scientific findings which the individual must use in socialist production and society continually increase. They have now reached an extent that makes it impossible to determine the basic knowledge or the fundamentals of knowledge, abilities, and skills with the aid of empirical selection and evaluation methods.

In addition, many basic scientific findings penetrate different fields of knowledge and scientific disciplines, are used uniformly in many fields of life and work, and appear as centers of integration of scientific knowledge. In most cases, however, these fundamentals of knowledge do not coincide, as far as degree of abstractness and generalization is concerned, with the centers of knowledge and understanding that are to be taught the students in the general education school under the existing conditions of development and education. The problem of simplification appears here; D. Hering ([Note]: Dietrich Hering, "The Comprehensibility of Statements in the Natural Sciences and Technology," Volk and Wissen Volkseigener Verlag, Berlin, 1959), who explained its importance for pedagogic research and practice, sought to solve it with some valuable references to pedagogic methods.

This problem of basic knowledge - broadened and deepened knowledge - is not solely a question of didactic simplication, however. It must find expression in the theory of the curriculum and educational system. What is involved is the new determination of fundamentals of knowledge and understanding that possess the properties of centers. These properties might be characterized somewhat as follows:

1. A center of knowledge and understanding must make possible the process of transfer from one center to another and must initiate it. Basic knowledge is characterized above all by the quality of connectibility and combination into new complexes of knowledge. Cybernetics has established the principal idea in information theory that good performance of an information receiver is to be found not in the number of its components but in the quality of its abilities to select and connect.

The transmission of knowledge or understanding from one center to another depends upon the laws of analogy. We may give an example of how the choice of certain centers of knowledge and understanding make possible analogous transferability: It is known empirically that a student more easily learns the basic skills of milling if he first acquires the firm and solid principles of lathework. There is a similar problem in the choice and proper didactic sequence of basic findings. It is necessary to solve, among others, the questions: What must be taught first? What is the best didactic sequence of basic knowledge to insure analogous transferability and thus more rational, easier, and above all, firmer assimilation of basic knowledge?

This problem occurs particularly in introduction of professional basic education, where it is important to determine scientifically in what subjects - either in the natural sciences, general technical subjects, or theoretical professional subjects - knowledge can be imparted most effectively and in proper didactic order.

2. A center of knowledge and understanding must further make the process of interference possible and stimulate it. New centers of knowledge and understanding can be more rationally, easily, and impressively developed and obtained from two or more centers by superimposing individual phases of educational material. Often this happens by itself during creative learning effort of the student; it originates as the result of interfering centers that the student has previously firmly assimilated and now must use in new associations. For example, from the knowledge that direct current can not be transformed, while alternating current can be changed into direct current by a rectifier, it is not possible to solve the problem of changing alternating current into

a low-voltage direct current without rectifier and transformer. Only the knowledge that an alternating-current motor and a direct-current generator can be mechanically paired provides the solution to the above problem, as it is employed in production practice (in arc welding): application of the motor-generator principle to solution of the problem of transformation of alternating current and generation of direct current without rectifier and transformer. Here the principles of reinforcement, distribution, and analogy operate, just as shown by cybernetics in many other similarly working interference phenomena in nature technology, and society.

In connection with the concept of creative and constructive human thought and behavior, cybernetics has added to the nomenclature of psychology the concepts of "superposition," "transmission," "interference," and "coupling" with the aid of newly introduced concepts such as "analogy," "information," and "feedback," and has raised it to a higher scientific stage of generalization. The relationships between the various fundamentals of knowledge can be shown by use of mathematical symbolism and laws. The fundamentals of knowledge can be classified as centers with the aid of logic of content and analysis and synthesis of decision calculations. The study of algorithms finally aids in determining a scientifically based correctness of sequence of succession and juxtaposition of the centers found.

3. Centers of knowledge and understanding must, from what they encompass, be further applicable and useful. Special knowledge, on the other hand, must be imparted in subsequent educational facilities, such as trade schools, technical schools, and universities. This third characteristic of a center does not say that it represents only knowledge on a higher level of abstractness - according to quality of content. It must also possess the characteristics below if it is to receive recognition as true fundamental knowledge.

4. Centers of knowledge and understanding in the sense of basic knowledge and basic skills must be capable of extension and development. They must contain in them the transition to specialized and deeper penetration into the scientific subject. A center of this type must satisfy the objective requirements of transition of learning from the general to the specific and from the concrete to the abstract. Here cybernetics can be especially helpful, with its manner of differentiation of elementary and complicated forms of motion, lower and higher forms of systems (and systems of knowledge), as well as the abstract and concrete stages of knowledge.

In agreement with the Marxian ideas of "ascent from the abstract to the concrete" ([Note]: cf. Karl Marx, "Critique of Political Economy," pages 257-258, Berlin, 1947), cybernetics furnishes new incentives for didactics, which must solve with scientific precision the problem of correct sequence of acquisition of general and specific education and the learning process as a dialectic unit of the abstract and concrete ([Note]: Cf. Behrens, "Methods of Political Economy," page 26 ff, Akademie-Verlag, Berlin, 1952, and W.S. Kasakovzev, "Cybernetics and Relationships between the Sciences," in Soviet Science, Social Sciences Papers, no 10, 1962, pages 1060-1063.)

5. In spite of their existing degree of generalization, centers of knowledge and understanding must already contain tendencies or elements of the specific. At each stage of our uniform educational system learners must be able to return repeatedly to basic knowledge so that they can grasp the newly imparted subject matter ever more deeply. This is possible only when the students assimilate those fundamentals in knowledge, abilities, and skills which already possess tendencies to the specific and to knowledge later to be expanded specific to occupations. At the same time, the specific tendencies contained in general knowledge qualify the students

a) to perform simple practical activities of life and productive work, and
b) to penetrate deeper into the subjects and relationships of practice through independent creative study.

In future, this problem will be of great importance for scientific determination of the relationships of general, polytechnic, and professional education in the polytechnic secondary school.

6. Centers of knowledge and understanding must be capable of being acquired firmly and solidly. This is a problem of their pedagogical selection according to the principles of comprehensibility and systematic perfection of the ability of the students to understand. Previous didactic concepts reduced the problem of comprehensibility only to the capacity, referred to development or education, of reception and processing of information by the students of certain classes or age groups. Cybernetics helps to overcome this one-sided viewpoint.

It has established for animate and inanimate nature the basic theorem that the processing capacity of information does not depend primarily on the capacity of the processing center but upon the processing capacity of the connecting channels ([Note]: W. Ross Ashby, "Introduction to Cybernetics," (Russian), Moscow, 1958).

The more information channels the student can employ in learning, and the higher the capacity of the different channels of communication, developed by education, exercise, and varied practical activity, the higher is the comprehensibility. The capacity of the information storage and processing center in the consciousness of the learner depends primarily upon the capacity of the channels of communication. This new and scientific aspect of cybernetics assists us to solve many still open questions, especially problems of comprehension. It also contributes to scientifically exact preparation of curricula for the various classes and educational facilities. Finally, the cybernetic viewpoint shows that the problem of comprehension will not be solved exclusively by didactic simplification and corresponding choice of subject matter.

CORRECT TECHNOLOGY OF THOUGHT
- BASIS OF IMPROVEMENT
IN LEARNING

We shall begin from the results of years of experiments of Soviet scientists of the Institute for Preschool Education of the Academy of Pedagogical Sciences: in the 1st grade, pupils solve an arithmetic problem in a manner unusual for us. The 7-year old pupil designates the known quantities by a and b, and the unknown by x. He sets up the equation and gets the result by substitution of numbers.

Even though arithmetic and the four basic types of calculation originated first historically, and algebra as the abstract of the generality of computation laws was not developed until later, this does not mean that in the 20th century school this historical path of human discovery must be repeated in miniature, that is, in the head of the pupil.

The Soviet experiments, beginning as early as the 1st grade with algebra and application of its laws, led to the following findings, among others:

a) In spite of initial difficulties, which can be eliminated in subsequent experiments by discovery and application of the best teaching methods, the pupils learn the mathematical relations more easily in this way and master calculation more thoroughly, firmly, and solidly than through the continual concentrated repetition of basic calculation types during several school years.

b) Because the generality, the algebraic relations between the numbers, is learned first and is continually taken as the point of departure for the specific, which is arithmetical calculation, the pupils early develop the firm ability to survey in a self-reliant and creative manner any problem in arithmetic, no matter how diverse, using the known laws, and to solve the problem correctly after working out the method of solution. This further enables the pupils to apply calculation operations to practical problems. This overcomes the circumstance often observed with our pupils in the 8th or 9th grade, where they suddenly no longer know how to make a calculation involving fractions or to handle a proportion.

W.W. Davydov ([Note]: "Experimental Introduction of Elements of Algebra into the Lower Grades," in Sovjetskaja Pedagogika (Soviet Pedagogy), no 8, 1962, pages 31-43) in giving a detailed report on the progress and results of the experiment, emphasises that the application of operative absence of content and represented relations between the general and the specific, particularly proposed in cybernetics, were the starting points for conception of the experiment.

Analogous conclusions were derived from these experiments for other subjects in whose specific systemization, too, "there are unnecessarily complicated processes..., which are traditionally carried forward from century to century but which could be discarded without harm, or replaced by others simpler and more complete. Geometry, for example, is taught according to Euclid to the present day, under the pretext that it promotes development of reasoning. If the abilities that geometry is supposed to develop are analysed logically ([Note]: By "logically" is meant here not formal logic analysis, but analysis by logic of content, which is the basis of mathematical logic and is used operatively by cybernetics.), it is seen that they could be developed in other considerably shorter and more effective ways; or in any case with a smaller amount of the geometry learned today" ([Note]: G. Stschedroviski, l.c., pages 3310-3311).

Our experiences show that logical analysis, separation of the dross, and arrangement of basic knowledge according to the latest scientific algorithms apply to such subjects as engineering drawing and descriptive geometry; the latter subject is preferably considered the basis for the former. An analysis by logic of content would show that descriptive geometry, like Euclidean geometry, can be learned better and more rationally than through the structure of the antiquated subject material, long rigid in content and form.

The new didactic considerations on the learning and knowledge process of students led to the basis of the modern viewpoint of cybernetics and, using mathematical methods of analysis and synthesis, to deeper understanding of the laws of thought and perception. One speaks of the technology of thought and the learning process - analogous to the processes which technical cybernetics investigates as a matter of course.

Information theory furnishes new viewpoints and isolated facts for the basic proposition that it is necessary to differentiate between systematic and indirect knowledge and that obtained by chance and directly. The dichotomy "indirect and direct learning" can be analogously established. Without claiming or being able to claim to develop a new theory for teaching and learning methods in instruction, cybernetics presents some important suggestions for remarkably simple and effective solutions in didactic problems.

Interesting ways of acquisition, storage, processing, and retrieval of information are found in the design and testing of "self-learning" automatic machines. Since this path of information corresponds to teaching and learning in school instruction, it occurred to use the common didactical way of learning of events in the "self-learning" of automatic machines. The machine was to be "instructed" to remember five different numbers (0, 1, 2, 3, 5). It was to be able not only to recognize the prototypes in written or printed figures but to perceive the correct figures in every case from a multiplicity of very differently written, printed, and artistically portrayed figures.

School instruction often is conducted so that from the many different forms of a given phenomenon only the typical and generally valid form is differentiated and the essential characteristics that constitute the content of the phenomenon to be explained are taught about it as the so-called prototype. This is done in grammar instruction and in biology instruction, or for example, in discussion of machine elements in polytechnical instruction. A machine element is first shown, then the essential characteristics are traced out and explained - and in conclusion the specific varieties and particulars of a few special designs are described as deviants from the prototype.

This "characteristics method" was also used in training the automatic machine for the five numbers. After the machine had repeatedly reviewed the characteristics of 40 different written, printed, and illustrated figures, and it could be assumed that its "memory" possessed the pictures of the five figures accurately differentiated from each other, it was supposed to recognize 160 differently written samples of each figure (in total, five figures times 160 = 800 cases) as the figures in question. There were many mistakes, however - up to 25% of the cases.

Another type of teaching was then used, one which had not previously been employed to any extent in didactics. The workers at the Institute for Automation and Telemechanics in Moscow called it the "congruence method" ([Note]: W. Trapesnikov, "Cybernetics and Automatic Control," in Press of the Soviet Union, no 38, 1962).

This type of teaching is based on the following concepts: to enable a student to comprehend a phenomenon in its essential characteristics, content, and features and to assimilate it solidly as new knowledge, it is not enough to show the characteristics and essential aspects of the phenomena with corroborative repetition for a few specific cases. It is better, instead of analyzing characteristics, with subsequent repetition for special cases and examples of application, to show immediately the congruence of various representatives of the phenomenon in question. The pupil - an automatic learning system in our example - comprehends from the congruence of the various optical images of the phenomena wherein lies the essential and how the essential and general characteristics differ from the specific and non-essential.

In the experiment with the "learning" machine it was found that the learning process could be conducted incomparably faster through this "congruence method" than through the "characteristic method." When the 800 differently executed figure images were then given to the machine nearly all figures were correctly deciphered and identified, with only four errors this time.

Even though the result using the "congruence method" turned out so convincingly, it does not yet follow that this process would necessarily be as successful in every case in the human brain, or with the student under instruction. It is undeniable, however, that these new cybernetic methods of teaching and learning with automatic systems are partly transferable to higher forms of living control systems and to the controlling processes of teaching and learning in school instruction, as well.

Whoever considers this conclusion overdrawn will at least be convinced that it is obvious even today in many subjects of instruction how the narrow teaching methods, oriented to formal logic, especially the analytic characteristic method, can not reproduce the actually existing transformations and specific relationships. This characteristic method often results in inability of the students to comprehend and understand complex phenomena appearing in concrete reality, as exemplified in practical solution of application tasks, in experiments, and above all in the productive work of the students. On the other hand it must be stated that, for example, in the polytechnic curriculum the increasingly more often used type of teaching of knowledge-transmitting work (assembly work, switching and measuring exercises, and comparative tests) is analogous to the "congruence method."

We now finally turn to a pedagogic and didactic problem that is gaining importance, especially with the introduction of professional basic education.

CREATIVE MENTAL WORK - A PRIMARY PREREQUISITE FOR MASTERING MODERN PRODUCTION

The progressive pedagogic ideas, particularly the experiences of Soviet pedagogues and the generalized results of school practice in the socialist countries say that development of superior skills and the general scientific and technical knowledge necessary for practical work are both important. A student with high general education and good general technical knowledge more easily and quickly assimilates the work techniques to be acquired.

Cybernetics reaches similar conclusions from another aspect. In several work analyses, for example, L.B. Itelson ([Note]: "The Psychological Peculiarities of the Task of a Worker on Equipment in Continuous Chemical Production," in Voprosy Psichologii (Psychological Questions), no 5, 1961), Prof. A.A. Ljapunov and G.A. Schestopal ([Note]: "Algorithmic Description of Control Processes, in Matematitscheskoje Prosveschtschenija (Mathematical Instruction), no 2, 1957), showed how the intellectual abilities of the worker in modern mechanized and automated production markedly enlarge and improve the radius of effect of his physical work skills.

The basic idea is contained in the following:

Mechanized and automated production processes run at especially great speed. To make the correct decisions at a given instant, the worker must react quickly after reception and mental processing of the corresponding information signals from the measuring and indicating instruments, sounds, or other signal sources. This applies analogously to the maintenance man (plant mechanic, plant electrician, and technician), who in trouble-shooting must decide as quickly as possible in accordance with a rationally devised system of algorithms (rules for finding a solution). Increase in reaction speed is subject to physical limits, however. Dexterity differs, for example; it can be improved by exercise as well as by long-term discontinuous repetition of practical operations. It is advantageous to rely primarily upon discontinous repetition of work operations, as they occur in plant operation, and not solely upon didactically organized practice (possibly in the training shop).

Perception, decipherment, and conversion of the signals, as well as their application to the object of control, represent a series of physical, psychic, and biomechanical processes that span time. This results in an objectively caused delay in the action of the worker which can not be compensated for by dexterity or work skill, no matter how well-trained he is. In the time interval the parameters of the relatively rapidly moving production process have changed. The motor activity occurring, with its delay of a few tenths of a second, no longer occurs at the right time, and often can conjure up unexpected consequences. What should be done then?

For one thing, skill in thought, judgment, and conclusion can be improved by intellectual training. The worker becomes more flexible mentally, perceives information more quickly, understands its content faster, and thus imparts the control signals to the machine sooner.

In addition, the worker can become trained to maintain in readiness various communications channels for multiple incoming signals. This presumes a high capability in knowledge of various laws and phenomena for complex production processes. The worker must not only know machinery, measurement, and natural sciences, but in addition his sensory organs must be well-developed. This ability to increase the handling capacity of the channels of communication can be improved by systematic and diverse exercise.

The statements above show that work carried out in an orderly manner presupposes a certain level of developed physical and mental skills. This is not enough, however. The decisive role in the controlling and regulating system for industrial processes belongs to the creative mental ability of man. The chief requirement for mastery and direction of modern industrial processes is a high level of general scientific, cultural, and polytechnical education, coupled with the ability to learn and work in creatively and responsibly conscious fashion.

Soviet scientists are engaged in investigation of these complicated relationships between thought and operative reaction speed, and between high quality of worker education and the improvement of his work techniques. The question involved is the "laws of discovery of algorithms of control by humans on the basis of conscious planning, evaluation of the situation, and the course of the process. ..." ([Note]: L.B. Itelson, l.c., page 52).

The worker who is educated to a high degree, who scientifically understands the technological process, and who was able to work out in all-round scientific fashion the problems appearing in practice, can react faster and thus does react in correspondence with the modern industrial process. He becomes a genuine ruler and director of industrial processes. He does not merely depend upon the information received and upon its processing, but his high education and scientific ability allow him to survey with scientific foresight process changes occurring, to recognize various phases of the process in proper combination, and to predetermine the effects to be expected. He is mentally creative in his work - and this counts for more than a very rapidly reactive work skill which is limited physically and causes delay.

With these ideas we close the far-reaching loop of thought that began with the problem of basic knowledge and its propagation in the scope of the uniform system of education and now ends with the proof that a constantly improved high level of education, a continually broadened qualification, and an improved training for creative mental work constitute the bases of development of the future producers of modern socialist production. Scientific and technical progress requires all workers, especially our students, to be trained for creative work, independent study, and utilization of the high values of science and culture.

The pedagogy of the socialist school must take into account these requirements of broad construction of socialism, of successful scientific and technical progress, and of elevation of the cultural accomplishments of the worker. Armed with the philosophy and methodology of dialectical materialism, relying upon the investigations of of Soviet pedagogues and scientists as well as upon the practical experience of our own schools, but also using effective new scientific methods, we must further develop pedagogy, didactics and methods. Pedagogical research can no longer neglect the scientifically exact methods of mathematics, logic of content, and cybernetics.

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CYBERNETICS - AUTOMATION -

NATURE OF WORK

[Following is a translation of an article by Prof. G. Klaus, National Prize Winner, Berlin, in Feingeraetetechnik (Precision Technology) no 3, Berlin, March 1963, pages 97-98.]

In connection with the XXIInd party congress, the 14th plenary meeting of the Central Committee of the SED [Sozialistische Einheitspartei Deutschland; Socialist Unity Party of Germany] has prepared a series of documents of great importance for the development of our German Democratic Republic. The concepts of cybernetics and automation must be emphasized in connection with the viewpoints discussed in the deliberations of the 14th plenary meeting, which took full account of the fact that science is increasingly becoming a direct productive force. This is nowhere more clearly shown than in the sphere of the concepts designated by the two terms above, cybernetics and automation.

The precedence accorded cybernetics in the program of the KPdSU [Kommunistische Partei der Sowjetunion; Communist Party of the Soviet Union], adopted by the XXIInd party congress, should also be noted. It reads, for example:

"The transition to completely automatic control systems will be accelerated, cybernetics, electronic computers, and control systems will be widely employed in production processes in industry, construction, transportation, research, planning and designing, accounting, and administration" ([Note]: Program of the Communist Party of the Soviet

Union, p. 67, Dietz Verlag, Berlin 1961.).

The especially interesting fact should be emphasized here that cybernetics is mentioned in the same series with automatic control systems, computers, etc., that is, with instruments of production. Cybernetics is itself a productive force! As historical materialism shows, however, productive forces finally determine the social aspect of production. Therefore an evaluation of the social changes that accompany automation must begin with an evaluation of the technical changes that this phenomenon brings with it. It should accordingly first be stated that the concept of automation has several aspects. Initially there is an automation which we may call automation based on mechanical causality ([Note): Mechanical causality: linear consequence of cause and effect). This is the form of automation that leads to the so-called transfer machine, in which a given pro uct passes through a series of machines, each specializing in a single or at most a few operations. This form of automation therefore replaces the worker's division of labor by the machine's division of labor. It is manifest that an automation form of this type is rational only where mass production is involved. What was previously valid at the level of division of labor in manufacturing is valid at the machine level here: the degree of specialization depends upon the extent of production. Establishment of automated factories on this basis has its peculiar problems, principally to be viewed as inherent rigidity and inflexibility of the installation. This is also true to some extent at the machine level, as is well known to us from the development of life. The more specialized is a living organism the smaller are its chances of surviving a change in its ambient conditions. This means then that a one-sided specialization is equivalent to deficient adaptability to possible changes in conditions; in terms of industry, completely automated factories consisting of groups of units each of which is specialized in a highly definite type of production become worthless if any social conditions require a basic change in production.

Production in these facilities can be compared in its method of operation to an electronic computer working on a rigid preselected program, that is, a so-called sequence machine.

We know, however, that even today there are higher-type machines, adaptive machines as they are called, that do not follow a rigid program but suit their behavior to past events at any instant. These are the variable-program electronic computers. They have their analogy in production, where the question arises of how automation is to be introduced when small lots of workpieces, devices, or apparatus are to be made. It is obvious that an assembly line with 100 special machines can not be built to make a lot of 10 or 100 devices. In this case the building of an industrial analog to the variable-program electronic computer is a way out. As far as the operating components are concerned, the elements of this new type of automation already exist - in machines such as the all-purpose lathe or universal miller. If these machines were grouped and controlled by a variable-program electronic computer, it would be possible to automate even those factories that must produce a multiplicity of types.

This second form of automation is entirely realizable today.

The objection against universal application of automation in industry, expressed somewhat as follows: automation is applicable only where one or a very few types are mass-produced, thereby disappears.

In principle, the second form of automation, based on fundamental concepts of cybernetics, can produce individual complicated workpieces. The first form of automation makes semi-skilled and unskilled workers largely unnecessary and requires a qualified although numerically very small group of skilled workers in maintenance groups and in supervisory personnel. Although this applies equally to the second form of automation, the latter has an additional effect that is present in elementary fashion in the first form but now appears fully for the first time. This second form of automation requires as its normal worker the qualified technician, engineer, physicist, or mathematician. It requires a number of basic researchers and even more researchers who can creatively apply the results of basic research to production practice.

Of especial interest in this connection is the fact that modern highly productive technology changes the very nature of work, as Walter Ulbricht himself emphasized in his address at the 14th plenary meeting:

> "As a result of the changed character of work and its increasingly technical aspect, the inner need to work for the common good, freely and in

accordance with individual abilities, will develop in all members of society, thanks to their high conviction."

([Note]: The XXIInd Party Congress of the Communist Party of the Soviet Union and the Tasks in the DDR [Deutsche Demokratische Republik; German Democratic Republic], p. 14, Dietz Verlag, Berlin, 1961.)

Since work determines the nature of man, this statement also means that the very nature of man is changed. Not only will the new technology that is spoken of here provide us in the not too distant future with an abundance of material goods, but of equal importance with this change is the change in the nature of man, a change very closely coupled with the concepts of cybernetics and automation.

In other words, the dynamics of development of productive forces now presses from the technical side toward that which the classicists of Marxism described in their early days as elimination of the alienation of mankind. The change of work into creative effort can not be overestimated in its social effect. According to the concept of historical materialism, the nature of work at any time determines the nature of man. People who do only stereotyped, monotonous work during the workday are on the average not able to turn to a completely different and creative world in their leisure time. Activity in the private garden, chess club, or elsewhere is but a poor substitute.

Karl Marx and Friedrich Engels studied this problem in detail in their early writings. Work that is monotonous and stereotyped in its nature readily causes humans who must perform it to think in monotonous and stereotyped fashion on all planes of life. These are the very persons, however, who are relatively easily duped by the enormously developed information machine of their oppressors. It is not too difficult, with persons of this type, to control a formally democratic capitalist state in such fashion that the capitalists obtain all that they seek. For this very reason the responsibility of the communist and workers' parties in capitalist countries has grown, and the task of bringing social consciousness to the working masses is more important than ever.

The propaganda of the fascist dictatorships directs itself largely to the worker who is shaped by stereotyped and monotonous work in monopoly capitalism, and into whom a few influencing catch phrases are continually pounded. The technical and productive basis of a true socialist democracy, on the other hand, requires creative work, in which the worker is deeply involved with his living powers. Only this kind of work can built the all-around harmonic personality of the socialist man.

This must be repeatedly emphasized when we speak of the meaning of cybernetics and its technical applications for the further shaping of the socialist order of society.

A new Soviet work on this states:

> "Establishment of the material and technical basis of communism, complete mechanization of processes involving high expenditure of labor, and extensive mechanization and automation based upon thorough electrification of the economy will change productive culture completely. Monotonous and wearisome work will gradually disappear. Automated systems of machinery require training of highly qualified labor forces able to set up and control the equipment and to direct complicated machine operations. Mental functions become obviously predominant in the work of these men."

([Note]: Manewitsch, I.L., "Elimination of the Differences between Mental and Physical Labor," in <u>Soviet Science</u>, no 12, 1961, page 1340.)

These effects must be heeded in future technical and scientific education. Neither the technical schools nor the schools of general education - the latter are certainly excluded - can be given the task, in view of the dynamism of our development, of imparting to their students merely a limited capability of work and a limited amount of factual material on subjects. Although this must certainly be done, it can no longer be the chief point. It is necessary to keep in mind the difference between the evolution of the occupational work of a qualified technical worker of a few decades ago and that which will be a normal case shortly.

Several decades ago it was customary for a lathe operator to learn lathe work as an apprentice, journeyman, and finally as a skilled worker, eventually becoming a master workman. During his lifetime his tool, the lathe, continually changed, of course, but no matter what the individual improvements might be, the basic features of his work remained constant within relatively narrow limits, so that it was possible to retain largely the educational forms for this calling, or to make only slow and gradual changes. Now, however, it will happen increasingly more often that certain trades will disappear, i.e., it will be quite common for a given skilled trade to be completely antiquated only a few years after the worker involved has become fully qualified as a skilled worker in the calling. From the historical viewpoint the following qualitative stages can be established for this theme:

1. Learning of a trade in the factory through gradual accumulation of practical knowledge, mastery of certain tricks of the trade, and constant observation of the behavior and method of work of the older qualified fellow-workers.

2. Preparation for an occupation by learning special work methods in technical schools or similar fashion. This second stage is a higher stage because it does not adhere to the specific instance but to a certain degree includes the general case, and thus can follow within moderate limits a change in productive forces.

3. Determination of a general method of automated production (that is, the elementary principles of cybernetics, among other things). This method is more powerful than mere collection of facts; it is also elastic and more than an accumulation of experiences. Even more powerful than the method of execution of a given task is the ability to learn new methods, or expressed mathematically and approximated to our cybernetic theme: the algorithm ((Note: exact description, instruction for solving a given type of problem), which permits solution of the entire group of problems, is more powerful than the ability to solve individual problems. A comprehensive theory of algorithms, permitting not only understanding of individual algorithms but also design of new algorithms depending upon circumstances, is even more powerful than the individual algorithms.

(To be continued)

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