Axel Berg's Legacy in Cybernetics and Education. From the Council on Cybernetics to Axel Berg Institute

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***Abstract* — The history of the Scientific Council on Complex Problem "Cybernetics" of the Academy of Sciences of the USSR created at the initiative of academician and navy admiral, Axel Ivanovich Berg, is covered. Axel Berg's brilliant predictions, relating to the cybernetics development and digital transformation in education are described. The current continuation of Berg's traditions is highlighted.**

***Keywords* — Axel Berg, Scientific Council on Complex Problem "Cybernetics" of the Academy of Sciences of the USSR, SCC, cybernetics, cybernetics and education, programmed learning, digital transformation in education, VNTK «School-1».**

I. Introduction

On 10th April 1959, academician Axel Ivanovich Berg delivered a report on the main problems of cybernetics at the session of the Presidium of the USSR Academy of Sciences (AS). He presented his vision for cybernetics development in the country. The Scientific Council on Complex Problem "Cybernetics" of AS (SCC) was established.

II. Axel Berg – an eminent scientist and science organizer

Axel Ivanovich Berg was born on 29th October (10th November old style), 1893, in Orenburg, in the family of Johan Aleksandrovich and Elisaveta Kamillovna Berg. His ancestors, from his father's side were Swedes living in the town of Vyborg (Grand Duchy of Finland, Russian Empire). His mother was of Italian origin, nee Bertoldi. Johan Berg was a Russian general. In 1914, Axel Berg graduated from the Cadet Corps of Emperor Alexander II and served as a junior navigating officer on the Russian battleship *Tsesarevich*. He participated in World War I as a submarine navigator and then — submarine captain. In 1922, Berg had to leave the fleet because of health conditions, and he fully devoted himself to research and engineering. In 1921, his first scientific papers appeared which focused on issues of radio communication and ultrasonic systems application in the navy.

In 1925, Berg was taken on as teacher of the Naval Engineering School. There, Berg taught radio engineering, wrote a number of textbooks, including the first textbook in the country — *General Theory of Radio Engineering*. In 1930, he was given the title of Professor. From 1935, he also taught at the Leningrad Electrotechnical Institute (LETI). Berg founded a Radio Laboratory in the Naval Engineering School which, in 1932, was transformed into the Naval Institute that he headed until 1937. In 1937, Berg became head of the Navy Research Institute for Radio and Telecommunications.

In December 1937, Berg was arrested, being accused of "vreditel'stvo" (sabotage was referred to in this way in the Soviet legal system). He spent two and a half years in prison, and, in May 1940, he was rehabilitated and restored to his military rank. In 1941, Berg was awarded the military rank of Engineer Rear Admiral.

During wartime, Berg headed a team doing radio detection and ranging work. From 1943 to 1944, he was made Deputy People's Commissar for the Electrical Industry of the USSR. Between 1943 and 1947, he was made Vice-Chairman of the Council on Radiolocation under the State Defense Committee. In 1943, Berg was elected a corresponding member, and, in 1946, a full member of AS.

III. Berg's contribution to the establishment of Soviet cybernetics and computing

During wartime and up to 1953, Berg headed the Central Research Institute 108, which was developing radar equipment. In this closed institute, Berg announced, in 1952, a set of lectures under the title *Cybernetics, a science of the most general laws of control*, then organizing a seminar on cybernetics. All this despite the campaign under the slogan, "Cybernetics is a pseudo-science", taking place in the country at the time! In 1953, an article with the following statement was published in the official journal *Voprosy Filosofii* (*Problems of Philosophy)*: *"Imperialism ideologists are in horror of the active, creative work of human thought, of a human realizing their role in society. That is what makes them devise misanthropic false theories such as cybernetics"* [1].

In 1953, Berg was appointed Deputy Minister of Defense of the USSR and served in that capacity until 1957. During that time, Berg organized several research institutes and computing centers, including the Institute of Radio-engineering and Electronics by AS, which he headed from 1953 to 1955.

On 12th January, 1959, a commission was established to develop a long-term plan regarding *Key issues of cybernetics* following the order of the Presidium of AS. Academician Berg became its chairman. By the beginning of April 1959, the commission developed the first organizational cybernetic document — a strategy for the future — "the long-term

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workplan". It was devised by academician Axel Berg (commission chairman), Prof. Alexey Lyapunov (vice-chairman), Dr. Mikhail Tsetlin (scientific secretary), corresponding member of AS Leonid Kantorovich, corresponding member of AS Vadim Trapeznikov, Dr. Yury Bazilevsky, Dr. Vyacheslav Ivanov, Dr. Nikolay Andreev [2, p. 23]. It is worth mentioning that the commission members held different views on cybernetics and adopting the document was no easy gain.

IV. The creation of the Scientific Council on Cybernetics

On 10th April, 1959, Berg delivered a report on the fundamental cybernetics concepts at the Presidium meeting of AS. The report was approved and the Scientific Council on Complex Problem "Cybernetics" of AS was created by the resolution № 221. Berg's report was first published in the *Naval Collection.* We quote from the source [3]:

"Nowadays, there is still no generally accepted, exact definition of the term, cybernetics, introduced by Ampère in 1843. Cybernetics can be called a science of goal-oriented control of developing processes. The objective of cybernetics is to increase the efficiency of work in all cases where the human needs to perform control… Automated control does not exclude humans with their knowledge, abilities, fantasies, conscience, feelings, motives, physiological traits, etc. Human activity changes to some extent to control better, using cybernetic methods and electronic automation means and systems. The content of cybernetics consists of information collection, processing and transfer, aimed at improved control in order to achieve the goal.

...Some operations, usually performed by humans, can be automated. But the role of humans does not decrease or diminish at all. On the contrary, the main goal of cybernetics is to help humans increase the efficiency of their control of complex, often fast-paced, hard-to-manage processes". It is remarkable how modern these words sound, being said more than 60 years ago — regarding the development of cybernetics, these were just prehistoric times!

He continues with the justification for the creation of the SCC: *"Firstly, it is recommended to recognize that cybernetic issues have to be considered in all divisions of the AS. Secondly, the Division of Physics and Mathematics has to lead the general development of the research. It is recommended to have a permanent scientific council on cybernetics within the Academy of Sciences".*

A special note in the report was addressing the problem of the officials' resistance to novelties: *"…some scientists and officials reject a priori everything new and unusual which is contained in cybernetics. Established authorities are referred to, who apparently did not use cybernetics and could manage without it, and the communist society is being built quite successfully, even without all these farfetched, idealistic anti-marxist etc., bourgeois tricks. The harm done by all that has been said can be compared only to the harm done by some of our philosophers, who hampered the development of computer systems, under the pretext of somebody attributing ability to think to mathematical machines".* What a depressingly familiar rhetoric and such a modern issue!

The first composition of the Council consisted of outstanding scientists who were already performing cybernetic research or supported cybernetics as a promising new field of research, e. g. academicians Nikolay Bruevich, Anatoly Dorodnitsyn, Mstislav Keldysh, Vladimir Kotelnikov, Vasily Nemchinov, Ivan Schmalhausen; member of the USSR Academy of Medical Sciences, Vasily Parin; corresponding members of AS, Boris Astaurov, Isaak Bruk, Leonid Kantorovich, Sergey Mergelyan, Boris Petrov, Sergey Rubinstein, Vadim Trapeznikov, Israel Gelfand, Andrey Markov, Leonid Voronin and corresponding members of AS, Ukrainian SSR, Viktor Glushkov and Boris Gnedenko. Dr. Alexey Lyapunov, and corresponding member of AS USSR, Alexander Kharkevich, were appointed vice-chairmen, the first scientific secretary was Mikhail Tsetlin. The following sections set to work:

- Mathematics section (chairman Sergey Yablonsky)
- Biology section (chairman Alexey Lyapunov)
- Medicine section (chairman Vasily Parin)
- Linguistics section (chairman Vyacheslav Ivanov)
- Economics section (chairman Vasily Nemchinov)
- Transport section (chairman Ivan Aksyonov)
- Security section (chairman Nikolay Bruevich)

The book by N. Wiener *Cybernetics: Or Control and Communication in the Animal and the Machine*, which was published in 1948, in the USA, was translated and published in the USSR 10 years later, following efforts by Berg [4]. Berg considered it quite an accomplishment of his and lamented the fact that it had not been published earlier.

At first, the Council worked on a voluntary basis: the structure consisted of a chairman and three assistants. Berg made a big effort for the SCC to acquire the research institution status in 1961. The resolutions of several committees were issued: resolutions of the Central Committee of the Communist Party and the Council of Ministers of the Soviet Union (of 3rd April 1961), a resolution of the Presidium of AS (of 8th September 1961), and, finally, a resolution of the Board of the State Committee for Coordination of Research (of 12th April 1962) that stated: *"Accept the proposal of the USSR Academy of Sciences to organize the Scientific Council on Complex Problem 'Cybernetics' of the USSR Academy of Sciences as an independent scientific research organization..."* [5].

A staff of three people appeared, including Dr. Susanna Maschan, who held the position of Scientific Secretary until 1992, a trusty assistant of Berg the whole time of his chairmanship [6].

Berg attached great importance to *"ensuring publication of broad-scope, first-rate, specialized and popular scientific literature"* [7, p. 18]. In 1961, Berg initiated and edited the series of collections *Cybernetics at the Service of Communism* (issued until 1980) [8], *Information materials of SCC* [9], reviews of Soviet and foreign research in the cybernetics field. Starting from 1958, the collection, *Problems of Cybernetics,* was issued about twice a year [10] *"an outstanding edition of our body of mathematicians, that is widespread and translated into many languages"* according to Berg [7, p.19]. The English translation was published by Pergamon Press [11]. Up to 12 collections *Issues of Cybernetics* were published annually. By 1970, the number of research themes on cybernetics in the SCC plan exceeded 500! By the end of 1970s, 16 sections were active in the SCC, Cybernetics

Institutes were created under the Academies of Sciences of the Ukrainian, Georgian, Estonian and Byelorussian SSRs.

In 1970, academician Berg was invited by the Director-General of the World Organization of Systems and Cybernetics (WOSC), J. Rose, to be vice-chairman of this organization. Prof. W. Ross Ashby became the chairman and Prof. Stafford Beer became the vice-chairman. The 18th worldwide WOSC Congress will provisionally take place in Moscow in 2021 (the year was changed from 2020 to 2021 due to the effects of the pandemic).

Axel Ivanovich Berg headed the SCC until his death in 1979.

Subsequently, the heads (chairmen) of the SCC were renowned scientists and organizers of science, academicians Boris Petrov, Oleg Belotserkovsky, Andrey Ershov, Evgeny Velikhov, Boris Bunkin, Yury Zhuravlev. It must be said that in the 1980s the history of the creation of other institutes with the support of the SCC partly repeated. In 1983, scientists of AS, primarily the vice-president of AS, academician Evgeny Velikhov, managed to convince the country's leadership of the need for forced deployment of work in the field, which over the past quarter century has grown out of cybernetics. In AS, under the leadership of academician Evgeny Velikhov, the Division of Informatics, Computer Engineering and Automatics was created. The following independent research institutes were created on the basis of scientific divisions of the SCC:

- Institute for Problems of Cybernetics (IPC USSR AS), founded in 1983, director — academician Vladimir Melnikov,
- Institute of Computer Aided Design (ICAD USSR AS), founded in 1986, together with the Computing Center of the USSR AS and Moscow Institute of Physics and Technology, director — academician Oleg Belotserkovsky,
- Program Systems Institute (PSI USSR AS), founded in 1986, director — Dr. Alfred Aylamazyan,
- Scientific Research Institute of System Development (SRISD USSR AS), founded in 1989, director — corresponding member of USSR AS Vladimir Betelin,
- Institute of Optical and Neural Technologies (IONT RAN), founded in 1992, director — academician Andrey Mikaelyan,
- Institute for System Programming (ISP RAS), founded in 1994, director — corresponding member of RAS Victor Ivannikov.

V. Berg's predictions

Here is a quote from Berg in 1963: *"Modern cybernetic devices model and control technological processes, plan production, keep records of materials, labor, salaries, control different means of transport, solve complex mathematical problems, translate from one language to another, unriddle ancient and encrypted texts, give out scientific information, solve strategic problems, play chess, etc. Cybernetics has found application in biology and medicine — for the study of physiological, in particular genetic, processes, for the diagnosis of diseases, for the replacement (during surgery or illness) of internal organs with self-regulating devices, as well as for prosthetics. A new discipline has emerged from cybernetics — bionics, which studies the possibilities of using patterns, methods of control, transfer, processing and storage of information, found in living organisms for technology. Finally, cybernetics began to supply sciences that study psyche (pedagogy, psychology, psychiatry, gnoseology) with research methods that should help them, as well as biological sciences, achieve the rigor of physical and mathematical sciences"* [12]. Surely, one can say that Berg was ahead of his time in this publicist text — but he was not mistaken!

Speaking of the gift of scientific foresight that Berg certainly possessed, one can recall his words at a conference on programmed learning in 1971: *"In the history of cognition of the world, man had several revolutionary leaps that sharply threw development forward. Perhaps, the first of them was the creation of the alphabet two and a half thousand years ago; another one was the invention of printing in the middle of the XV century. I highlight those moments in the development of human culture that are associated with the emergence of new, increasingly advanced means of disseminating information.... the creation and use of electronic computers is the next leap along the same path, a leap which is immeasurably greater than all previous ones. I argue that the possibilities and results of using computers in a wide variety of areas of society, including the education system, are enormous. It is difficult, if not impossible, to determine everything that will come into the life of mankind together with the widespread use of computers.*

Now it is fashionable to talk about an excess of information. Certainly, the volume of knowledge is growing, but the methods and means created by humans to collect, store, process, transmit and use information are also simultaneously expanding. All these are different sides of the same process. And in all cases known to me, information overload occurs where they do not use modern methods that help to avoid it.

It is more than that. In a number of areas of human activity, we face rather information hunger. Returning to pedagogy, let me remind you, for example, how little the teacher knows about what each student understood and learned in the lesson" [13].

These words of Berg, on the one hand, echo the theses of the lecture of Lev Vygotsky [14], where he speaks of a radical change in human thinking, communication, activities and learning, taking place thanks to information revolutions. On the other hand, they echo our current ideas about an extended mind [15].

VI. Berg and digital transformation in education

The breadth of Berg's original interests and his ideas about the role of cybernetics in society allowed him to anticipate many of the processes taking place today. One of them is the use of cybernetics (read — digital technologies) in education. Here is what Berg said and wrote in 1963: *"Everyone who taught is familiar with the feeling of a teacher who is forced to feel some kind of average variable of preparation, attentiveness, abilities of his listeners and students. This is a huge art, requiring a lot of effort, energy, constant study of the audience and personal qualities of students. But no matter how you "average" over the qualities and data of the audience, there will always be students systematically getting behind and ahead of others. The ideal of a teacher is to engage with every student individually, to individualize the process of teaching and education. But usually there are dozens of students in the audience or classroom. It is extremely difficult,*

almost impossible, to control their absorbing of knowledge, especially daily... It is impossible to individualize teaching without constant assessment...

The time has come to equip teachers with technical means for a wider and faster process of transmitting information to students, for more effective control over study, for individualization of learning. Pedagogical science, while maintaining all its specificity, should today rely on the achievements of mathematics, mathematical logic, electronics, information theory, engineering psychology, and cybernetics. It is not a should, it is a must!...

The use of electronic machines allows you to explain new material at the same time... to hundreds of listeners in different ways, depending on how a group of listeners responds to a particular material...

The importance of the teacher, in these conditions, is not diminished but increased. They will have to solve methodological problems, understand more deeply the educational psychology, analyze the reasons for the falling behind, prepare individual programs... The teacher is still a psychologist, educator, master of pedagogy. But he is also the conductor of those machines that transmit information and control the learning process. He is the ruler of the machines" [16].

In his radio address he said: *"Programmed learning can and should increase the activity of university students and pupils, ensure that their attention is concentrated on the material being studied. It presupposes in essence an individual approach to the teaching of people with various backgrounds and abilities….*

Programmed learning should reduce teaching time. It should free the teacher, laboratory assistant and professor from tedious and monotonous work (labor) and free up time for professional development and for creative work. It should allow more people to be taught with a given number of teachers. But at the same time, the opportunity opens up to eliminate the so-called average approach to students and a differentiated approach to them.... It should contribute to the objectivity of assessments of academic performance in exams and tests, exercises, calculations, acquisition of abilities and skills. There is reason to believe that not age, but the background of children should underlie the content and method of presenting individual disciplines" [17].

It is incredible, it was not written and said today. Individualization of education, a change in the role of the lecturer and the teacher in school, the need for retraining teachers, machine learning as an artificial intelligence technology — Berg spoke about these currently absolutely vital development trends almost an era ago... Personalized learning is the formation for each student of his own educational trajectory. The mandatory achievement of all goals is the basis of effective education, one of the most promising areas of development of a modern school.

Sometimes he was even more emotional: *"What have you been doing for the past 6000 years? When I start reading pedagogy textbooks, I am wondering who the crazy one is: me or the authors. The only method ruling is 'chalk, a chalkboard, a cleaning cloth'"* [18].

Having formulated these fundamental principles for himself, Berg began to embody them with his inherent energy and organizational abilities. In 1964, Berg headed the Joint Scientific Council on the problem of "Programmed Learning" at the Ministry of Higher and Secondary Vocational Education of the USSR. In 1966, he participated in the First All-Union Conference on the problem of "Programmed Learning", held at the Moscow Power Engineering Institute.

At the same time he understood that the content of education had to be changed radically: *"I flatter myself with the hope that sometimes these new mathematical disciplines* [Berg means mathematical statistics, theory of probability, operational analysis, theory of games, linear and dynamic programming] *will be included in our archaic school curricula. But while scientists and teachers break lances in wordy battles with the ministries, I am compelled to explain the meanings…*" [19].

VII. Berg's affairs and traditions today

Currently, the intellectual and organizational successor of the SCC is Axel Berg Institute of Cybernetics and Educational Computing of Federal Research Center "Computer Science and Control" of AS, its director is academician Alexei Semenov.

At the end of 1970, young mathematicians Valery Vardanyan, Grigory Amirdzhanov came to the SCC, in 1984, Alexei Semenov, then Sergey Soprunov, Tatiana Rudchenko joined them. They felt the issue of education as the most important. In this, they were supported by the leadership of the SCC, its chairman academician Oleg Belotserkovsky, vice-chairmen Yury Vishnyakov and Ivan Gukasov, scientific secretary Susanna Maschan. Alexei Semenov became the organizer and member of the team (which included Anatoly Kushnirenko, Gennady Lebedev, Alexander Shen) that, under the leadership of Novosibirsk academician Andrey Ershov, the ideologist of the computerization movement of schools of the USSR, created the first domestic computer science textbook for mass school, published with a circulation of more than 3 million copies [20].

On the basis of SCC in 1988, under the leadership of academician Evgeny Velikhov, with the participation of Yury Vishnyakov, the Temporary Scientific and Technical Team "School-1" (VNTK "School-1") was organized, the deputy head of which was Alexei Semenov. Academician Andrey Ershov also played a key role in the work of VNTK "School-1" — he was chairman of SCC from 1987 to 1988. The team worked in close cooperation with the Office of Computing of the USSR Ministry of Education, which was then led by Dr. Alexander Uvarov. The work of VNTK "School-1" for decades to come has determined a number of important areas in the development of Russian general education.

The SCC and VNTK "School-1" have established international contacts important for us, in particular, with the Problem Group in Education of academician Blagovest Sendov in Bulgaria and the research group of Prof. Seymour Papert at the Massachusetts Institute of Technology [21, 22]. In the late 1990s, cooperation with UNESCO began [23, 24]. These contacts have largely formed our understanding of the problems of modern education.

In the late 80s, the first experimental Moscow school telecommunications network MoSTNet was launched on the basis of SCC, which allowed students of one and a half dozen schools to participate in international telecommunications

research projects [25]. Research and pilot projects, carried out on the basis of this network, laid the foundation for the methodology on how to organize training telecommunication projects [26], including i*EARN [27].

In VNTK "School-1", experimental pilot projects were launched to create new content of education for primary school in mathematics, computer science and language. Created on the basis of these projects under the leadership of academician Alexei Semenov, computer science courses for primary and secondary schools are widely used today in Russian schools [28, 29, 30]. Work is also underway to create a new integrated course "Mathematics and Informatics" for primary school.

In the development of the ideas of Prof. Seymour Papert, the employees of the SCC, under the leadership of Sergey Soprunov, translated into Russian and adapted the computer environment of LogoWriter (LogoMiry), created a new environment of PervoLogo, which plays today an important role in the teaching of computer science and basics of programming in elementary school and even in kindergarten [31].

Valery Vardanyan, Ivan Gukasov, Tatiana Rudchenko, Alexei Semenov, Alexander Uvarov continue their work at the Council for Cybernetics — today at Axel Berg Institute of Cybernetics and Educational Computing of Federal Research Center "Computer Science and Control" of the Russian Academy of Sciences. In such trying times for Russian science, they continue the legacy of Axel Berg, believing that **Cybernetics** has not said its last word yet, including the sphere of education.

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