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RESEARCH ARTICLE

Rules of creative thinking: algorithms, heuristics and Soviet cybernetic psychology

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Abstract

In the 1960s, creativity became an important category for the Soviet state. Soviet educators and policy makers came to define creativity as problem solving in the service of Soviet automation. At the same time, the introduction of cybernetics, information theory and methods of artificial intelligence (AI) to psychology enabled Soviet researchers to perform quantitative studies of human cognition. The state concern with creative thinking and the cyberneticization of Soviet psychology allowed for the first quantitative studies of human problem solving. These shifts in Soviet society and scientific communities created fertile ground for the creation of Lev Landa's algo-heuristic theory (AHT), a pedagogical method of cultivating rule-bound creativity relying on tools and instruments developed and perfected in information theory and AI research. Drawing on scholarship in the history of algorithmic rationality, the Cold War discourse on creativity as a corporate imperative, and the place of cybernetics-inflected methods in the welfare domain, this article analyses the AHT as rule-based instrument of making creative thinking accessible to the lay mind.

In the 1960s, Soviet scholars, educators and policy makers came to regard the human mind as a crucial economic resource. Concerned about the Soviet future in the era of digital automation, they contended that the Soviet state required a workforce that could build, program, control and maintain computer technology. They came to believe that a highly skilled, well-trained manpower capable of building and operating highly sophisticated technological systems required creative thinking.[1] 'Creative thinking' was an umbrella term referring to the ability to solve previously unencountered problems and reason independently. This article examines how creativity became an object of study in Soviet educational and cognitive psychology: how creative thinking was defined, measured and cultivated in Soviet citizens during the 1960s and 1970s.

Two currents were central to the rise of interest in creative thinking among scientists and officials. The first was the acceptance of the theory of the scientific–technical revolution among Soviet policy makers and social scientists. Historian and sociologist of science Egle Rindzevičiūtė has demonstrated how, during the post-Second World War era, the Soviet Union came to share with Western liberal democracies the discourse on the

1 US mid-century cognitive psychologists offered a similar definition of creative thinking, even though their theory of creativity was linked to the goals of the US mid-century liberal democracy. See Jamie Cohen-Cole, *The Open Mind: Cold War Politics and the Sciences of Human Nature*, Chicago: The University of Chicago Press, 2016.

central role of technoscience in socio-economic change.[2] The roots of this discourse were in the modernization theory of MIT economic historian Walt Whitman Rostow and the theory of scientific–technical revolution. The latter postulated that 'new techno sciences, based on automatic control and digital technologies, lead to the restructuring of society by intellectualizing labour and thus reducing the working class'.[3] With the beginning of de-Stalinization, the Soviet state eagerly adopted the scientific–technical revolution. For example, in 1956, the Communist Party approved a five-year plan that set a goal for Soviet industry 'to fully exploit the ongoing "scientific–technical revolution" in furthering the Soviet economy'.[4] It was in this context of hypervigilance about the USSR's capacity to innovate that Soviet researchers, educators and policy makers came to see creativity as a desired cognitive disposition and as a set of mental operations to be studied and disciplined.

Another historical force that made possible the concentration on creativity was Soviet cybernetics. An interdisciplinary field in vogue in the 1960s and 1970s, Soviet cybernetics was concerned with research on computing and the introduction of quantitative methods to a vast array of human, social and life sciences. Historians Jamie Cohen-Cole and Paul Edwards have established how computing, cybernetics and information theory offered powerful analogies and research tools for studies of human cognition in the United States in the mid-century.[5] In the Soviet Union, cognitive psychology followed the same trajectory: it emerged with the intellectual and institutional support of cybernetics. Previously a purely interpretive field, from the 1960s onwards Soviet psychology of thinking drew on methods of information theory and artificial intelligence to quantify and model human cognition, including creative thinking.

This article is in four parts. The first outlines how creativity became of state importance. The Soviet Party, cognizant of the pressures of technoscientific change, articulated a demand for creativity as a desired mental disposition in the 1960s. That led the Academy of Pedagogical Sciences (APN) in Moscow to revise existing curricula, and develop new ones that emphasized problem solving and independent thinking skills.[6] Nonetheless, committed to cultivating creative reasoning in students, Soviet educators did not attempt to study the workings of the mind. As the second section shows, it was cybernetics that spurred the foray into quantitative studies of the mind. In particular, engineering psychologists first drew on developments in information theory to quantify human decision making. The third section focuses on the research on human creativity and problem solving conducted by Soviet engineering psychologist Veniamin Pushkin. His experimental studies of human thinking led him to claim that the artificial-intelligence program the Logic Theory Machine, created by US scholars Herbert Simon and Allen Newell, did not capture the real human cognitive mechanisms of creative thinking. As the fourth section demonstrates, Pushkin's theory of creative thinking found its way into the methodology of problem solving developed by Lev Landa, his colleague at the Council on Cybernetics and the APN. Named the algo-heuristic theory (AHT), Landa's methodology sought to optimize human problem solving, offering a typology of all problems and the corresponding mental algorithms required for their solution.

2 Egle Rindzevičiūtė, *The Power of System: How Policy Sciences Opened up the Cold War World*, Ithaca, NY: Cornell University Press, 2016, p. 27.

3 Rindzevičiūtė, op. cit. (2), p. 28.

4 Rindzevičiūtė, op. cit. (2), p. 30.

5 Cohen-Cole, op. cit. (1); Paul N. Edwards, *The Closed World: Computers and the Politics of Discourse in Cold War America*, Cambridge, MA: MIT Press, 2010.

6 On maths curricula reform that emphasized creative thinking and took place at around the same time in the US see Christopher Phillips, *The New Math: A Political History*, Chicago: The University of Chicago Press, 2015.

The AHT, I argue, was a culmination of the Soviet effort to make creative thinking visible, formalizable and accessible to the masses. Historians have introduced the term 'algorithmic rationality' to describe a ubiquitous mid-century idea that rational thinking could be achieved through the mindless following of rules.[7] This article, however, demonstrates that, in the Soviet Union, despite the ambition to make creative thinking explicit, scholars resisted the idea of reducing human thinking to standardized and uniform algorithms. Lev Landa had to navigate a thin line between making creative thinking explicit and turning it into a mindless process. His prescriptions for creative problems only partially determined one's thinking and bore more of a semblance to what Lorraine Daston describes as 'thick rules' – prescriptions used in early modern arts to refine rather than control reasoning – than to step-by-step procedures.[8] Steven Shapin's argument about the rise of creativity as a corporate imperative in the mid-century is helpful in understanding the epistemological underpinnings of Landa's theory.[9] Shapin argues that the definition of creativity as problem solving articulated by US mid-century leading cognitive psychologists matched Thomas Kuhn's concept of 'normal science', the practice of scientific puzzle solving that avoids diverging from the standard, normal and traditional. From the 1960s onwards, the Soviet Union saw the rise of the same corporate-like discourse around creative thinking, with the major difference being that creative thinking had to serve the state rather than corporate needs in the USSR. Landa's AHT exemplifies rule-bound creativity: it avoids turning creative thinking into a purely mechanical process but also keeps the thinker confined within the established paradigm. Following the AHT prescriptions, the mind thought in semi-autonomous conditions, serving the goals of the state but never putting them into question.

While in the United States, Cold War military funding was central to the growth of research in cybernetics, computing and rule-based approaches to policy making, Soviet work on the formalization of creative thinking existed outside the military infrastructure. Historians have paid sufficient attention to how US defence institutions contributed to the rise of the discourse on algorithmic rationality in the exact, human and social sciences. However, little attention has been paid to how algorithmic rationality travelled from warfare to welfare domains. In reconstructing the history of the AHT and the scientific theories and political moment that made Landa's methodology possible, this article follows the trajectory set by Jennifer Light and Bernard Geoghegan, who have demonstrated how cybernetics was mobilized by the US Cold War technocracy to solve welfare problems.[10] In line with their scholarship, I show how Soviet researchers employed the products of the military–industrial complex, such as information theory and artificial intelligence, to streamline the thinking of lay minds.

Making up creative minds

In the second half of the 1960s, Soviet educators and psychologists became preoccupied with creative thinking. Creativity had previously been an essential category in Marxist–Leninist philosophy. For instance, Vladimir Lenin extensively emphasized the importance

7 Paul Erickson, Judy L. Klein, Lorraine Daston, Rebecca Lemov, Thomas Sturm and Michael D. Gordin, *How Reason Almost Lost Its Mind: The Strange Career of Cold War Rationality*, Chicago: The University of Chicago Press, 2015; Paul Erickson, *The World the Game Theorists Made*, Chicago: The University of Chicago Press, 2015.

8 Lorraine Daston, *Rules: A Short History of What We Live By*, Princeton, NJ: Princeton University Press, 2022, pp. 48–76.

9 Steven Shapin, 'The rise and rise of creativity', *Aeon*, 12 October 2020, at https://aeon.co/essays/how-did-creativity-become-an-engine-of-economic-growth (accessed 5 March 2023).

10 Jeniffer Light, *From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America*, Baltimore: Johns Hopkins University Press, 2003; Bernard Geoghegan, *Code: From Information Theory to French Theory*, Durham, NC: Duke University Press.

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of creative work in socialist society. However, Lenin's views on creativity differed profoundly from how Soviet researchers approached creative thinking in the 1960s. Lenin first and foremost associated creativity with cultural production and a means for disseminating socialist ideology across the newly formed Soviet Union. In the 1960s, however, Soviet scholars turned this ill-defined category into a subject of robust scholarly investigation, defining it as a problem-solving ability central to technoscientific innovation. This definition guided Soviet educators as they were updating the Soviet curriculum to emphasize the teaching of creative thinking skills. The spread and acceptance of the ideas of the scientific–technical revolution among public officials and human and social scientists played a central role in the effort to introduce the teaching of creative thinking skills across the Soviet Union.

In 1966, at the 23rd Congress, the Communist Party proclaimed that the unfolding scientific and technical revolution of the mid-twentieth century would require a new kind of worker. In the next three decades, automatic control and digital technologies would change the character of labour, making physical work obsolete and creating an urgent need for a workforce with high-level competencies and qualifications. At the congress, Leonid Brezhnev especially emphasized the central place of scientific knowledge in the Soviet economy in the second half of the twentieth century, referring to science as 'the major productive source'.[11]

The concern with meeting the needs of technoscientific change resulted in several Party directives to change the Soviet educational system to ensure a steady supply of a highly skilled workforce. These directives included making ten years of secondary education a state-wide requirement by 1970, placing more emphasis on polytechnical education in secondary schools, and teaching school and university students the practice of scientific research.[12] Party directives also prompted the APN (the USSR's central research institute in psychology, pedagogy, curriculum development and educational policymaking) to identify specific means to ensure that Soviet schools and universities could produce the workforce needed for the era of digital automation.

As part of the response to the Party directives, researchers at the Institute of Psychology (a unit within the APN) proposed that to be productive members of Soviet technocracy, students should learn to think like scientists.[13] In particular, APN psychologists suggested that students should master the very cognitive skills at the core of scientific practice: creative thinking, the ability to learn independently and problem-solving abilities. These three skills were seen as integral to each other. For instance, APN psychologist Isaac Lerner, one the founders of the problem-based approach in Soviet education, defined creative thinking as 'an aptitude to make logical proofs, the capacity to reason consistently, and the ability to compare and contrast a problem solution with the task'.[14] Essentially, for Lerner and his APN colleagues, the paragon of a creative thinker was the scientist. Soviet psychologists shared their views. At the 1967 First All-Union Symposium on the Psychology of Scientific Creativity, Lerner's paper was only one of many that proposed that the creativity of the scientific mind came – above all – from its capacity for self-instruction and problem solving.

The concern with the importance of science and creativity for Soviet economic growth remained relevant in the 1970s. In 1971, the APN presented a plan for developing Soviet

11 '23 s″ezd KPSS i zadachi shkoly' (23rd KPSS Congress and the tasks of education), *Sovetskai͡a pedagogika* (Soviet Pedagogy) (1965) 5, pp. 3–12.

12 Until 1966, the Soviet state required only eight years of secondary education; the additional three years were designated only for the particularly promising students.

13 S.R. Mikulinskiĭ and M.G. I͡Aroshevskiĭ (eds.), *Nauchnoe Tvorchestvo* (Scientific Creativity), Moscow: Nauka, 1969, pp. 10–17.

14 I. I͡A. Lerner, 'Poiskovye zadachi v obuchenii kak sredstvo razviti͡ia tvocheskikh sposobnosteĭ' (Search problems as a pedagogical method of developing creativity), in Mikulinskiĭ and I͡Aroshevskiĭ, op. cit. (13), pp. 413–18.

schools over the next thirty years. It set the cultivation of creative thinking in students as its primary goal, noting that Soviet education must be reoriented towards teaching the methods of scientific reasoning. The plan called for secondary education to cease being a 'warehouse of ready-made facts' and, instead, to strive to ignite the excitement of scientific pursuit in young Soviet citizens.[15] Even outside the APN, the focus on cultivating Soviet cognitive resources was a fixture of the Soviet state. In 1973, the State Committee for Science and Technology launched a Complex Research Programme on Scientific and Technical Progress and Its Social and Economic Implications to identify the fields of science and technology that would contribute to Soviet economic growth from 1976 to 1990. The programme outline highlighted that economic growth and technoscientific progress hinged on Soviet citizens' aptitude for creative thinking.[16]

Cybernetics and cognition

While APN researchers were committed to the development of creative-thinking skills in Soviet citizens, their work had little to do with understanding the mechanisms of human cognition. Limited to the formulation of new teaching methods and curriculum development, the nature of APN work reflected the dominance of educational concerns in Soviet psychology. Essentially, in the 1960s, Soviet psychology remained a pedagogical discipline. Its disciplinary status changed only in 1972, with the opening of the Institute of Psychology at the Academy of Sciences (AN) of the USSR in Moscow, the centre of Soviet civilian research. The formation of the new institute signified that the AN now recognized psychology as a discipline with the potential for tangible contributions to Soviet Big Science.[17] However, the first step toward distancing psychology from pedagogy and bringing it under the aegis of the AN had occurred ten years earlier, in 1962, with the opening of the Section on Psychology at the Council on Cybernetics at the AN. A young institution itself, the council was formed in 1959, during de-Stalinization, with the mandate to coordinate the development of civilian computing and introduce mathematical methods to all Soviet fields of the natural, human and exact sciences.[18] The Section on Psychology and Cybernetics sought to 'cybernetize' Soviet psychology by offering institutional and intellectual support for research that employed quantitative methods of analysis to understand human cognition, an emerging area of study in the Soviet Union during the 1960s and 1970s.

The council's director – admiral and professor of electrical engineering Aksel Berg – held a special interest in psychology. In the introduction to the 1961 programmatic collection of essays *Cybernetics in the Service of Communism* (*Kibernetiku na Sluzhbu Kommunizmu*), Berg identified psychology's value for cybernetics as being twofold. On the one hand, psychological studies of human learning, problem solving and pattern recognition could aid in the design of computers that would mimic these functions of the

15 'Materialy po Probleme Razvitii͡a Sovetskoĭ Shkoly na Blizhaĭshie Trid͡tsat' Let - 1971' (Proceedings on the Problems Related to the Development of Soviet School - 1971), Gosudarstvennyĭ Arkhiv Rossiĭskoĭ Federat͡sii (hereafter GARF), f. 10049, op. 1, d. 1466.

16 Gosudartsvennyĭ Komitet Soveta Ministrov SSSR Po Nauke i Tekhnike (State Committee for Science and Technology of the Council of Ministers of the USSR), 'Postanovlenie ot 8 ianvari͡a 1973 goda №3/5 o napravlenii i pori͡adke raboty po zavershenii͡u podgotvki kompleksnoĭ programmy nauchno-tekh progressa i ego sot͡s-ekonom posledstviĭ na 1976–1990 gody' (Bylaws, 8 January 1973 #3/5. Direction and the order of the final research stage of the program on scientific and technical progress and its social and economic consequences in 1976–1990), GARF, 8 January 1973, f. 10049, op. 1a, d. 1827.

17 B.F. Lomov, 'Novyĭ institut psikhologii' (New institute of psychology), *Voprosy Psikhologii* (Problems of Psychology) (1972) 5, pp. 155–9.

18 On the cybernetization of Soviet science see Slava Gerovitch, *From Newspeak to Cyberspeak: A History of Soviet Cybernetics*, Cambridge, MA: MIT Press, 2004.

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human mind.[19] On the other, knowledge about the human mind and behaviour was instrumental in the proper design and introduction of automation to Soviet industries.

Defining cybernetics as the science of control in large systems, Berg emphasized that despite automation, humans would remain a crucial element of large industrial and technological systems, for they would continue being responsible for their ultimate control.[20] Instead of making human labour obsolete, automation would make it more complex, supplying humans with even more challenging programming and management problems. Psychology, Berg maintained, provided cybernetics with the knowledge necessary to build a harmonious symbiotic relationship between humans and machines.[21] Here his views were consistent with Soviet Marxist ideology, which viewed technology as a means of perfecting 'human natural capacities', meaning that machines could expand human powers but never fully replace them.[22]

The Section on Psychology and Cybernetics consisted of three commissions, all of which understood human cognition as information processing, where the mind codes, transforms and transmits information.[23] The first commission worked on mathematical simulation of human verbal reactions and neural activity. It was headed by neurophysiologist Evgeniĭ Sokolov and then, beginning in 1964, by psychologist Evgeniĭ Boiko. Psychologist Lev Landa directed the work of the second commission, overseeing research on the analysis of human learning and problem solving in terms of logical structures. Such analysis was instrumental in the development of special instructional algorithms to order how humans acquire new information and solve problems. Finally, the third commission – directed by Leningrad psychologist Boris Lomov – focused on engineering psychology, a subfield concerned with designing and introducing automated technology to complement human capabilities.[24]

Engineering psychology was described by Lomov as a fundamental discipline responding to the state's pressing concerns of automation. It emerged at Leningrad State University (LGU) thanks to the efforts of Lomov and Boris Ananiev, his teacher and then senior colleague.[25] Both were educated at a time when Soviet psychology lacked the status of an independent discipline: Lomov defended his dissertation at the LGU's Philosophy Department in 1954, while Ananiev was a graduate of the Vladikavkaz Pedagogical Institute in North Ossetia, a Soviet Republic in the Caucasus mountains. Ananiev moved to Leningrad in 1928, a year after completing his postgraduate studies. There he joined the Brain Research Institute, founded by Russian neurophysiologist Vladimir Bekhterev in 1907. In 1944, Ananiev moved to LGU to found the chair of

19 Aksel Berg, *Kibernetiku Na Sluzhbu Kummunizmu* (Cybernetics at the Service of Communism), Moscow: Energiia, p. 17.

20 On the rise of system thinking see Agatha C. Hughes and Thomas Hughes, *Systems, Experts, and Computers: The Systems Approach in Management and Engineering, World War II and After*, Cambridge, MA: MIT Press, 2011; William Thomas, *Rational Action: The Sciences of Policy in Britain and America, 1940–1960*, Cambridge, MA: MIT Press, 2015.

21 Aksel Berg, *Kibernetika, Myshlenie i Zhizn* (Cybernetics, Thinking and Life), Moscow: Mysl', 1964.

22 Berg, op. cit. (19), p. 33.

23 Soviet cybernetic psychology pretty much resembled the US information-theoretic approach to the studies of the human mind. See Margaret A. Boden, *Mind as Machine: A History of Cognitive Science*, vol. 1, New York: Oxford University Press, 2006, pp. 286–9.

24 On the role of computing and cybernetics in the development of American engineering psychology during the Cold War see Edward Jones-Imhotep, 'Maintaining humans: electronic failure and human nature', in M. Solovey and H. Cravens (eds.), *Cold War Social Science: Knowledge Production, Liberal Democracy, and Human Nature*, New York: Palgrave Macmillan, 2012, pp. 225–43; David A. Mindell, *Between Human and Machine: Feedback, Control, and Computing before Cybernetics*, Baltimore: Johns Hopkins University Press, 2003.

25 Li͡udmila Karpenko (ed.), *Istorii͡a Psikhologii v Lit͡sakh* (The History of Psychology: Personalities), Moscow: Per Sė, 2005, p. 278.

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psychology in the Philosophy Department, where Lomov would defend his dissertation. About two decades later, in 1966, the two established the first Department of Psychology and Laboratory of Engineering Psychology in the Soviet Union, at LGU.

Engineering psychology provided a major stimulus for the growth of studies in human cognition within the USSR. Lomov and his colleagues upheld that automation required an understanding of how human cognition compares to machine capabilities. Focusing on the work of human operators – railway and airport dispatchers, pilots and locomotive engineers – Lomov's lab worked to establish which aspects of operating, maintaining and overseeing industrial equipment should be delegated to machines and which should be left to humans. Should humans be mere recipients of computer-generated commands? Or should computers be tasked only with supplying humans with data so that the latter can make decisions using their rational judgement? Should machines be made to oversee their own work, or should evaluating their functionality be a domain of human expertise?[26]

To answer these questions, Lomov and his colleagues at LGU drew on developments in information theory to perform the first in the USSR's quantitative experimental studies of human memory, perception, attention and decision making.[27] In particular, they were concerned with how operators processed information from monitors, sensors and other equipment. For instance, Lomov's lab measured the correlation between the bits of information received by an operator and the time the mind needs to process them, calculating the exact range of seconds required for tactile, audio or visual information.[28]

Modelling problem solving: a debate over heuristics

Retaining his professorship in Leningrad, Lomov could visit Moscow's Council on Cybernetics only monthly during the 1960s.[29] However, he was far from being the only member of the council who employed quantitative methods to understand human cognition. His council colleague, Moscow-based engineering psychologist Veniamin Pushkin, also studied the cognitive mechanisms of operators. A doctoral graduate of the Philosophy Department at Moscow State University, Pushkin held his primary appointment at the APN, which, as shown above, was the centre of Soviet pedagogical research on problem solving and creative thinking. However, unlike most of his APN colleagues, Pushkin studied problem solving through the lens of engineering psychology rather than pedagogy: he sought to understand the cognitive mechanisms that allow railway and airport dispatchers to optimize transport flow. The work of the dispatchers, he upheld, was a paragon of highly complex problem solving for which, most of the time, operators have no ready-made instructions, algorithms or prescriptions to follow. Pushkin viewed problem solving as a characteristic of productive thinking that leads to

26 B.F. Lomov, *Chelovek v Sistemah Upravlenija* (The Human in Control Systems), Moscow: Znanie, 1967, p. 7.

27 B.F. Lomov, *Chelovek i Tekhnika: Ocherki Inzhenernoy Psikhologii* (The Human and Technology: Essays in Engineering Psychology), Leningrad: Leningrad State University, 1963. Certainly, Soviet scholars were interested in human thinking even before the 1960s. In fact, Russian and Soviet psychologist Lev Vygotsky was trying to develop his theory of mind as early as in the beginning of the twentieth century; and his disciple Serguei Rubinstein was studying the role of mental activity in the formation of thinking patterns in the 1940s–1950s. However, it was the emphasis on quantitative methods and the deployment of methods and concepts of information theory that set Lomov and his colleagues' approach to human cognition apart from the work of their predecessors. On the latter see David Joravsky, *Russian Psychology: A Critical History*, Oxford: Blackwell, 1989; Loren R. Graham, *Science, Philosophy, and Human Behaviour in the Soviet Union*, New York: Columbia University Press, 1989; Sergeĭ Rubinshteĭn, *O Myshlenii i Puti͡akh Ego Issledovanii͡a* (On Thinking and Its Development), Moscow: Nauka, 1958.

28 Lomov, op. cit. (26), p. 42.

29 In 1972, however, at the invitation of Aksel Berg, Lomov moved to Moscow to direct the newly established Institute of Psychology at the AN.

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solving a previously unencountered problem. Responsible for the development of new methods and patterns of activity, productive thinking allows an individual to orient to new circumstances.[30] Essentially, for Pushkin, productive thinking was the definition of creativity.

Like his colleagues at the Council on Cybernetics, Pushkin employed quantitative methods in his research. To formalize problem solving, he turned to US research on heuristic programming, a dominant approach to artificial intelligence (AI) in the mid-century that modelled how human minds manipulate symbolic information. From the Greek, the adjective 'heuristic' means 'serving to discover'. Heuristic rules were first formulated by Hungarian-born Stanford mathematician George Polya. He maintained that mathematicians rarely use only deductive reasoning; on the contrary, they often perform mental shortcuts and employ guesswork.[31] His famous textbook *How to Solve It* presented a set of heuristic rules to introduce students to the art of taking such shortcuts. For instance, the book taught students how to identify patterns in solving different proofs, build analogies with other problems, and work backwards from something they suppose is true.[32]

Computer scientist Allen Newell, one of the founders of the symbolic AI approach, took classes with Polya at Stanford in the early 1940s. When he collaborated with Herbert Simon at the RAND Corporation in 1958 to build their information processing program the Logic Theory Machine (LTM), both sought to create a computer program that would use the same kinds of heuristics that humans do.[33] As historians Stephanie Dick and Hunter Heyck have shown, a decision tree model of problem solving was at the heart of the LTM: the program tested different solution variants to move from the original problem to sub-problems.[34] The program gained acclaim for its heuristic rules, which allowed it to minimize the number of tested variants, an approach that came to be named 'heuristic programming'. Far from being the only approach to AI in the mid-century, it was, nonetheless, the best-known among the Council on Cybernetics psychologists.[35]

With his disciplinary background in experimental psychology, Pushkin found Simon and Newell's claims about the parity between the LTM and the mind to be poorly supported. It troubled him that the LTM – a model of the human mind, as Simon and Newell argued – was developed without any experimental studies of human cognition. Even though US scholars created thinking-aloud protocols documenting their thinking process and the reasoning of students solving mathematical problems, Pushkin found those insufficient for a comprehensive understanding of human thinking.[36] It seemed

30 Veniamin Pushkin, *Evristika i Kibernetika* (Heuristics and Cybernetics), Moscow: Znanie, 1965.

31 Stephanie Dick, *After Math: (Re)Configuring Minds, Proof, and Computing in the Postwar United States*, Cambridge, MA: Harvard University Press, 2015.

32 George Pólya, *How to Solve It: A New Aspect of Mathematical Method*, Princeton, NJ: Princeton University Press, 1945.

33 Translating Polya's verbal rules into computational rules was an enormously difficult task. Ultimately, Simon admitted he and Newell never succeeded in implementing Polya's heuristics computationally. See Dick, op. cit. (31), p. 76.

34 Stephanie Dick, 'Of models and machines: implementing bounded rationality', *Isis* (2015) 3, pp. 623–34; Hunter Heyck, 'Defining the computer: Herbert Simon and the bureaucratic mind – part 2', *IEEE Annals of the History of Computing* (2008) 2, pp. 52–63, Hunter Heyck, *Age of System: Understanding the Development of Modern Social Science*, Baltimore: Johns Hopkins University Press, 2015.

35 On AI approaches different from heuristic programming, see Stephanie A. Dick, 'Coded conduct: making MACSYMA users and the automation of mathematics', *BJHS Themes* (2020), pp. 205–24; Jonathan Penn, *Inventing Intelligence: On The History of Complex Information Processing and Artificial Intelligence in the United States in the Mid-Twentieth Century,* Cambridge: Cambridge University, 2020; Lucille Suchman, *Human–Machine Reconfigurations: Plans and Situated Actions,* Cambridge: Cambridge University Press, 2007.

36 V.N. Pushkin and D.N. Zavalishina, 'Psychological matters in the symposium "Cybernetics in the Service of Communism"', *Soviet Psychology and Psychiatry* (1963), pp. 53–8, p. 56. On the transformation of thinking-out-loud

to him that Simon and Newell were much more invested in developing logical rules than in understanding the mind. His position was that the development of any program emulating human cognition had to be pre-dated by 'the discovery of the psychological laws of thought' through experiments that would 'model thinking activity in work'.[37]

Pushkin's experimental studies led him to a more complex model of human thinking. In the first half of the 1960s, he conducted a series of experiments on chess players trying to find a winning combination, tracking their eye movements with a camera.[38] As an engineering psychologist, Pushkin considered chess playing a perfect model of how human operators control large systems: deciding on the next move on the chessboard boils down to the same cognitive mechanisms that dispatchers use when optimizing aeroplane flow.[39] These studies allowed Pushkin to conclude that, unlike Simon and Newell's LTM, the human mind does not narrow the search field to test solution variants; instead, it constructs 'a dynamic information-processing model of the external world'.[40]

Perfected in collaboration with mathematician Dmitrii Pospelov and philosopher Vadim Sadovskii, Pushkin's theory of 'dynamic information processing' postulated that to solve a previously unencountered problem, the mind identifies the elements of the problem to establish a problem space; then, as it establishes the relations between problem elements, it creates a mental model of how these elements relate to each other. For example, to decide on the next move, a chess player identifies relevant figures on the board and then establishes the relationships among them. Pushkin's experiments showed that chess players make repeated eye movements between the figures they determine to be problem elements. He interpreted the movements as evidence that, when solving a creative problem, the mind first expands the search field and then, instead of testing individual problem solutions, deals with a multitude of possible solutions at once. In Pushkin's theory, Simon and Newell's neat decision trees had little to do with the actual messiness of human cognition.[41]

In line with his approach to human problem solving, Pushkin maintained that if heuristic programming truly wanted to emulate the mechanisms of human creative thinking, it had to focus on formalizing how the mind creates a dynamic model of a problem, and especially how it establishes the relations between different elements of a problem

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protocols into computational rules see John E. Laird and Paul S. Rosenbloom, 'In pursuit of mind: the research of Allen Newell', *AI Magazine* (1992) 4, pp. 17–45, p. 25.

37 Pushkin and Zavalishina, op. cit. (36), p. 58.

38 His experimental studies were documented in V.N. Pushkin, 'Heuristic aspects of the "man-large system" problem', *IFAC Proceedings* (1968) 4, pp. 715–21; Dmitriĭ Pospelov, Veniamin Pushkin and Vadim Sadovskiĭ, 'Ėvristicheskoe programmirovanie i evristika kak nauka' (Heuristic programming and heuristics as a science), *Voprosy Filosofii*, 1967, pp. 45–56; Veniamin Pushkin, *Ėvristika i Kibernetika* (Heuristics and Cybernetics), Moscow: Znanie, 1965. On chess and AI see Nathan Ensmenger, 'Is chess the drosophila of Artificial Intelligence? A social history of an algorithm', *Social Studies of Science* (2012) 1, pp. 5–30. In the 1960s, Simon also intended performing experimental studies and even applied for a grant to purchase a camera to track eye movements of human subjects solving problems, but it is unclear whether that led to any experimental research. See Hunter Crowther-Heyck, *Herbert A. Simon: The Bounds of Reason in Modern America*, Baltimore: Johns Hopkins University Press, 2005, p. 261.

39 Veniamin Pushkin, 'Psikhologicheskie osnovy postroenii͡a obuchai͡ushchikh sistem' (Psychological principles of teaching systems development) in Yu. I. Klykov (ed.), *Voprosy Kibernetiki: Cheloveko-Mashinye Obuchai͡ushchie Sistemy* (Problems of Cybernetics: Human–Machine Teaching Systems), Moscow: The Academy of Sciences of the USSR, 1979, pp. 8–39, 16.

40 Pushkin, 'Heuristic aspects of the "man-large system" problem', op. cit. (38), p. 718.

41 According to Slava Gerovitch, the realities of Soviet material and political life – namely the lack of choice as a political and economic category – could have shaped Pushkin's model of human problem solving. See 'Artificial intelligence with a national face: American and Soviet cultural metaphors for thought', in Francesco Bianchini (ed.), *The Search for a Theory of Cognition: Early Mechanisms and New Ideas*, Amsterdam: Rodopi, 2011, pp. 173–94.

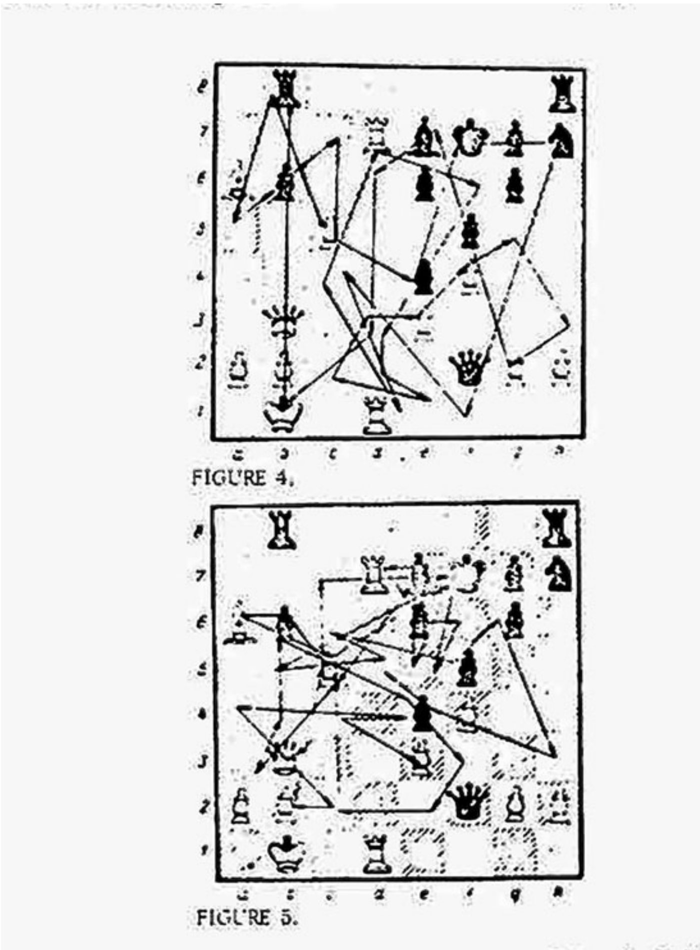

Figure 1. Pushkin's diagram documenting the patterns of eye movements in chess players searching for a winning combination for white. © 1968 International Federation of Automatic Control. Reproduced with the permission of IFAC from V.N. Pushkin, 'Heuristic aspects of the "man-large system" problem', *IFAC Proceedings Volumes* (1968) 2(4), pp. 715–21, Figures 4–5.

space.[42] Pushkin had an uneasy relationship with formalisms. While Newell and Simon's LTM was inadequate, he found more promise in research on dynamic programming, often described as 'semiotic programming' in Soviet literature. Dmitrii Pospelov and Yurii Klykov, both professors of mathematics at the Moscow Institute of Physics and Technology and the Moscow Engineering and Physics Institute, the two prestigious Soviet technical universities, were the best-known practitioners of this approach in the USSR.[43] They emphasized modelling the multitude of relations between the system's

42 Pospelov, Pushkin and Sadovskiĭ, op. cit. (38), p. 52.

43 Yu. I. Klykov and D.A. Pospelov, 'Model'nyi yazik dlya upravlyayushchei vychislitel'noi sredy' (Modelling language for a control computing medium), in E.V. Evreinov (ed.), *Trudy Simposiuma 'Vychislitel'nye Sistemy'* (Symposium Papers 'Computing Systems'), Novosibirsk, 1967. On the development of dynamic programming in the US see David Hounshell, 'The medium is the message, or how context matters: the RAND corporation builds an economics of innovation, 1946–1962', in Hughes and Hughes, op. cit. (20), pp. 255–310.

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elements and breaking it into a range of subsystems interconnected by information channels.[44] While Newell and Simon's LTM presented problem solving as a top-down hierarchical process, dynamic programming offered formal tools to capture the distributed nature of human thinking, where information can flow back and forth from different elements. Pushkin thought that Pospelov and Klykov's approach was 'considerably closer to the real process of problem-solving in man than are the programs of Newell, Shaw, and Simon'.[45] However, his final verdict was that the existing logical schemata still could not entirely capture the workings of the mind.

Lev Landa's algo-heuristic theory: creative thinking for any mind

Although responding to the pressing matters of Soviet automation, Pushkin's work was of a fundamental character. Nonetheless, his ideas still found a practical application, as they became instrumental to the creation of the theory and methodology of problem solving developed by his colleague Lev Landa. Landa joined the Section on Psychology and Cybernetics as it opened in 1962 to coordinate research on programmed instruction, a promising new field at the intersection of education, psychology and cybernetics.

Established in the 1940s by the US behaviourist B.F. Skinner, programmed instruction (initially unrelated to cybernetics) was created to apply the principles of behaviourist psychology to improve human learning. Skinner proposed breaking down learning material into small incremental units, testing students' comprehension of each unit and allowing them to proceed only after they gave the correct answer.[46] Referring to the sequence of units as 'programs', Skinner commissioned their development only to specialists with training in behaviourist psychology and the taught subject. The program was then delivered by a teacher, a special textbook or mechanical teaching machines, which Skinner built in the 1950s. Programmed instruction, Skinner argued, was a scientific method of making learning a rational and controllable process.[47]

Skinner's ideas arrived in the Soviet Union in the early 1960s, a time when Soviet scientists were encouraged to integrate Western theories and approaches into their research.[48] The ideas of rationality and control appealed to APN scholars, but other behaviourist premises were at odds with Soviet ideology. Soviet scholars could not accept how behaviourism blurred the line between human thinking and basic reflexes, ignored the role of social factors in human behaviour and learning, and offered a model of the self entirely dependent on external conditions.[49] Since cybernetics operated with concepts of feedback and control, terms also central to programmed instruction, Soviet scholars replaced behaviourism with cybernetics as the organizing theory of programmed teaching and learning.

Soviet cybernetics-inflected programmed instruction (or *programmirovannoe obuchenie*) came to be more concerned with the teaching of rational methods of problem solving than with instilling specific knowledge. Landa became interested in reasoning methods during his graduate studies at the APN Institute of Psychology. His 1955 dissertation,

44 Yu. I. Klykov, *Semioticheskie Osnovy Situat͡sionnogo Upravlenii͡a* (Semiotic Foundations of Situational Control), Moscow: Moscow Engineering and Physics Institute Press, 1974, p. 3.

45 Pushkin, 'Heuristic aspects of the "man-large system" problem', op. cit. (38), p. 719.

46 Ekaterina Babintseva, '"Overtake and Surpass": Soviet algorithmic thinking as a reinvention of Western theories during the Cold War', in Chistian Dayé and Mark Solovey (eds.), *Cold War Social Science: Transnational Entanglements*, Cham: Springer International Publishing, 2021, pp. 45–72, 48.

47 Ekaterina Babintseva, *Cyberdreams of the Information Age: Learning with Machines in the Cold War United States and the Soviet Union*, Philadelphia: University of Pennsylvania, 2020.

48 Babintseva, op. cit. (46), p. 49.

49 Babintseva, op. cit. (46), p. 50.

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'The psychology of reasoning-methods formation (based on how seventh- and eighth-grade students solve geometry proofs)' examined cognitive operations used by secondary-school students to solve mathematical proofs. People, he explained, usually concentrate on *what*, not *how*, they think; in other words, they care about *knowledge*, ignoring the kinds of *operations* that their minds perform upon knowledge.[50] His dissertation, on the other hand, was the first effort in the Soviet Union to make explicit the cognitive operations behind problem solving.

Cybernetics, especially control theory, became a natural intellectual ally of his work.[51] According to cybernetic theories of control, automatic control requires breaking down the process into elementary steps, with 'the initial, intermediate, and final stages of the process as well as the operative factors which determine its course at each stage' made visible.[52] This is exactly what Landa did in his approach to programmed instruction – identifying the most elementary cognitive operations that allow the mind to arrive at a solution to a problem. However, whereas control theory was concerned with developing algorithms for machines, Landa focused on algorithms for humans. Comparing his work to that of Newell and Simon, he stated that while their LTM was 'a precise program of operations' for the JOHNNIAC mainframe computer, his precise programs of operations were developed for humans.

Landa employed mathematical logic and information theory to ensure that his algorithms offered the most rational mental paths to problem solutions.[53] In particular, information theory aided him in calculating how a learner could get a maximum amount of information, removing uncertainty, while performing the minimum possible number of mental steps. For example, Landa used Claude Shannon's logarithmic formula to measure uncertainty (H) $H = p_1 \log p_1 - p_2 \log p_2 - p_3 \log p_{3 \ldots} p_n \log p_{n.}$ to calculate an algorithm for solving a middle-school problem in Russian grammar.[54] A typical exercise lists sentences and asks students to which, out of five syntactic types, each of these sentences belongs. Landa marked sentences with letters to designate whether they did or did not have a characteristic such as having a subject, predicate, predicate in the first or third person, or predicate in singular or plural. Calculating the probability of each characteristic he concluded that it was most likely that a simple sentence would have a subject. Hence the first step students needed to do was to identify whether a sentence has a subject in order to decrease the uncertainty.

In the second half of the 1960s, like many other psychologists at the APN and the Council on Cybernetics, Landa became interested in creative thinking and its teaching. The result was his algo-heuristic theory (AHT), which offered a comprehensive classification of all possible cognitive operations accompanying human mental activity. Landa argued that all problems encountered by the human mind can be broken down into four types: algorithmic, semi-algorithmic, heuristic and semi-heuristic. To solve each in the optimal way, the mind needs to employ corresponding mental operations: algorithmic or heuristic problems should be solved with algorithmic or heuristic procedures, and so on. According to the AHT, heuristic problems required the most creative thinking, while algorithmic problems and mental procedures were the most uncreative.

Landa's AHT synthesized distinctive Soviet and American approaches to artificial intelligence. Like Pushkin, Landa believed that Simon and Newell's Logic Theorist failed to

50 Lev Landa, *Instructional Regulation and Control: Cybernetics, Algorithmization, and Heuristics in Education*, Engelwood Cliffs, NJ: Educational Technology Publications, 1976, pp. 60–1.

51 On the history of control theory, see Mindell, op. cit. (24).

52 Landa, op. cit. (50), p. 113.

53 L.N. Landa, 'Opyt primeneniâ matematičeskoj logiki teorii informacii k nekotorym problemam obučeniâ' (An attempt to apply mathematical logic of information theory to some instructional problems), *Voprosy Psikhologii* (Problems of Psychology) (1962) 2, pp. 19–40.

54 Landa, op. cit. (53), p. 25.

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account for human creative thinking. Nonetheless, he thought that they offered a comprehensive account of algorithmic and semi-algorithmic operations and even called their heuristic programs incomplete algorithms, noting that they highly determined the problem-solving process.[55] On the other hand, in Landa's opinion, Pushkin's theory captured creative thinking most successfully. He used an example of the 'Mark Twain problem' described by German gestalt psychologist Karl Dunker in 1926. When Huckleberry Finn dressed as a girl and entered a stranger's cabin, he was greeted by a woman; eventually his reaction to being called a girl's name and inability to thread a needle made her suspicious. Dunker asked, what should the woman do to determine if she was dealing with a boy or a girl?[56] Landa explained that to solve this problem, one would need first to identify two fields in which to search for a solution: '1) actions which could put him (her) in typical circumstances in which the two sexes behave differently, and 2) actions which could put him (her) in unusual circumstances in which boyish behaviour (the woman suspected that she was dealing with a boy) would be evoked'.[57] Thus Landa argued that solving creative problems required the discovery of a new conceptual field, agreeing with Pushkin that creative thinking cannot be described as 'limiting the field of choice and the number of alternatives chosen and tested'. To solve a creative task, Landa explained, the mind needs to cross 'the boundaries of one field into a new field, one not given beforehand and not suggested by the problem'.[58]

Landa's typology of problems and corresponding mental procedures classified heuristic problems as truly creative. To assist students in solving them, he developed heuristic prescriptions that offered a nudge toward the discovery of the appropriate course of action: 'examine the object from various vantage points', 'recall a similar problem', 'try to apply some other method if the previous one was not successful'.[59] These offered hints but did not necessarily guarantee a solution.

Next were semi-heuristic problems and corresponding cognitive procedures. Similarly, one needed to discover a new conceptual field which may contain a solution. But unlike heuristic problems, one may use prior experience in solving semi-heuristic tasks. For instance, for someone with previous experience of tricking an individual into revealing their real gender, the Huckleberry Finn problem would become a semi-heuristic one.

Semi-algorithmic problems and mental procedures were next on the continuum of more or less creative problems and cognitive operations. These present a conceptual field within which one can search for a solution using a trial-and-error process, as described by Simon and Newell. Landa's prescriptions helped one limit the number of tested alternatives. Everyone who followed semi-algorithmic prescriptions solved such problems correctly, even though their solutions were not identical.[60]

According to the AHT, algorithmic problems and mental operations were most remote from creative thinking. Solving an algorithmic problem does not require choosing between different alternatives or discovering a new conceptual field, but simply following the rules offered by an algorithmic prescription. Finding the common denominator of two numbers is an example of an algorithmic problem. To solve such a problem, one needed to follow an algorithmic prescription that fully determined the solver's thinking.

55 Landa, op. cit. (50), p. 109.

56 K.A. Dunker, 'Qualitative (experimental and theoretical) study of productive thinking (solving of comprehensible problems)', *Journal of Genetic Psychology* (1926), pp. 642–708, cited in Landa, op. cit. (50), p. 118. The reader should note that this example is premised on views deeply at odds with the idea of gender as a social construct.

57 Landa, op. cit. (50), p. 119.

58 Landa, op. cit. (50), p. 120.

59 Landa, op. cit. (50), p. 147.

60 Landa, op. cit. (50), p. 147.

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In Landa's typology, algorithmic prescriptions fully controlled the mind's actions, while heuristic prescriptions only offered a beaconing light on one's path to solving a problem. Landa developed a list of heuristic rules to aid the process of solving creative problems. The following are three examples of the rules written for middle-school students doing geometry proofs:

1 Think over, to yourself, all the sufficient attributes of the figure to be proved that you know; compare some or even each of them with the given information and with the diagram, and then decide which of them seems to be best for proving what you need to prove. Then search among the sufficient attributes for the chosen attribute; and so on. If one attribute does not work, or seems not to be promising, try another one.
2 If the diagram contains none of the figures or elements which are necessary in order to use the attributes which you thought of above, then construct the ones you need.
3 If the question: 'What else could these elements be?' leads you to see certain elements as elements of a geometrical figure which is not in the given diagram, but the properties of which could be useful in your proof, then construct this figure.[61]

Essentially, these rules taught students to assess whether they needed to go beyond the conceptual field of a given problem. The first rule prompted the search for a solution within the given problem field. The second and third explained how, sometimes, one needs to search for a new conceptual field to solve a problem. While Landa successfully wrote his algorithmic prescriptions in the notation of mathematical logic, his heuristic rules existed only in verbal form, similar to Polya's heuristics in *How to Solve It* and consistent with Pushkin. Since his prescriptions were written for humans, translating them into logical notation was unnecessary.[62] Landa's AHT aimed to demystify the process of creative thinking, making it explicit and accessible to any mind.

Conclusion

In the 1960s, creativity became an educational goal and an object of cognitive studies in the Soviet Union. The urgent need for automation allowed creativity to crystallize into an essential category for the Soviet state. Defined in purely instrumental terms, creativity became an umbrella term for problem solving for technoscientific innovation. At the same time, the rise of cybernetics and its spread across human and social sciences, including psychology, allowed for the development of a quantitative approach to human cognition. Soviet scholars drew on methods from information theory and artificial-intelligence research to measure and model how human minds make decisions and solve problems. These social, political and cultural shifts paved the way for the development of Lev Landa's theory and methodology of problem solving, which strived to demystify creative thinking and make it accessible to every mind.

While the purpose of the AHT was to fulfil the Soviet state's dream of cultivating creative thinking on a mass level, it found its practical application only on the other side of the Iron Curtain. In 1975, Landa's son Boris, a Soviet dissident, married an American woman and left the Soviet Union for the United States, where he became a citizen. With this, Landa's reputation as a trustworthy Soviet citizen was at risk. A year later, he followed his son and settled in New York City. This geographical transition was

61 Landa, op. cit. (50), pp. 246–7.

62 Lev Landa, 'The creation of expert performers without years of conventional experience: the landamatic method', *Journal of Management Development* (1987) 4, pp. 40–52.

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accompanied by a remarkable shift in Landa's career. As a newly minted New Yorker, he now used his AHT to develop training materials for bank and insurance companies' clerks. His exclusive offer was that his algorithmic and heuristic prescriptions could improve a company's productivity by 75–90 percent.[63]

This final episode from the history of the AHT bolsters the claim that Landa's methodology was an instrument of cultivating rule-bound creativity, first in Soviet and then in US citizens. Far from being challenging, nonconformist, or groundbreaking, this type of creativity served (and continues to serve) corporate and state goals. No historical record indicates that the AHT has ever been used in teaching advanced science or engineering. In other words, it never aided in training new Marxes, Watsons and Einsteins; rather, the AHT cultivated semi-autonomous problem solving within well-defined limits of corporate and industry settings.

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63 Otis Port, 'Lev Landa's worker miracles', *Businessweek*, 21 September 1992, p. 72.

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