Early Engagement of Schoolchildren in Research Activities: The Human Factor

Alexander O. Karpov(✉)

Bauman Moscow State Technical University, 2nd Baumanskaya Street, 105005 Moscow, Russia
a.o.karpov@gmail.com

Abstract. Objectives of the study are generalization of best practices of schoolchildren early engagement in scientific-research activities, development of new theoretical visions conceptualizing early research-cognitive activities of learners-researchers. As a result of many years' study the practice in the "Step into the Future" programme, two types of motivations for early scientific-research activity of schoolchildren are identified - social and formal educational. The epistemic-didactic analysis of experimental data shows a key role of the social motivation and a supporting role of the formal-educational motivation. New theoretical concepts are developed: scientific-type research behavior, epistemic (research cognitive) imprinting, scientific-research-type socialization. Attitude to the truth in educational work with schoolchildren-researchers is analyzed; micropedagogic roles of a scientific tutor are identified. It is concluded that research-cognitive self-making of a person is not governed by the formal system of teaching and learning relations but the human factor playing a key social role.

Keywords: Human factor · Education · Engagement · Research · Science · Schoolchildren · Motivation · Imprinting · Socialization · Tutor

1 Introduction

At the end of the 1950s, the US government began to pay peculiar attention to scientific-research training of schoolchildren, which was caused by Soviet achievements in the development of military and space technologies [1]. On October 4, 1957 – the day, when the Soviet Union placed the first artificial satellite on orbit - President David Eisenhower and Congressman John Kennedy in their speeches talked about a decisive role of school classes in the military, social, and economic leadership of the country. In the same 1957, P. Drucker formulated the idea of *proactive* training and came close to the idea of continuing (lifelong) education for people engaged in productive work with knowledge [2]. J. Bruner noted that this was the time that put the challenging question of training at school to the American society [3]. He introduced the "soft technology" concept, which was focused on the *process* of solving scientific problems in natural science education [4].

In Europe, the first Contest for young scientists with participation of upperclassmen was held at the international level in 1989. With the advent of the European Union (1992)

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scientific-research work with schoolchildren became an integral part of a human potential development policy. In 2002, the study of "education through scientific-research" problem completed by the European Strata-Etan expert group showed that generation of research competences required a long time period and should begin at school or initial stages of higher education [5]. Specialized demands were placed on the school - it should bring up propensities for critical assessments, respond to new situations, and train skills of collective and individual work [6].

In the late 1990s - early 2000s, the western education attracted to learning objectives institutions specialized in functions which were executed by knowledge in the post-industrial culture [7, 8]. Scientific researches were defined as an effective tool for solution of education problems, and in this connection, teachers and tutors should catch hold of the latest achievements in the field of epistemology (cognitive theory) [9]. A sector of research education was developing for schoolchildren and students engaged in research activities, i.e. for learners-researches [10].

At the beginning of the 2000s, scientific-research activity of schoolchildren and students was associated with a creative learning concept. So, in 2006, the "Cultivation of creativity among young people" report submitted to the UK government focused on discovery the creative resources of an individual and drawing up an individual educational roadmap [11]. In 2007, the report of the European University Association (EUA) stated that creativity cultivated by education was a key factor for solution of complex socio-economic problems [12]. In 2008, the UN "Creative Economy" report stated an emergence of a new development paradigm, holistically binding the material and spiritual systems of the society [13]. Modern education became at the center of the relation between economy and creativity [14]. It turned out that creativity involved tacit knowledge which pre-determined the ability to create knowledge and success of company's innovation activities [15]; creativity as such was a genetic feature of the research education, where researches were used as teaching methods [16]. Experts pointed out the lack of researches in the field of theoretical understanding of creativity in education [17]; a mismatch between intellectual needs of learners and educational environment [18].

While models of creative and research training were developing in the western system of education in the second half of the XXth century, Russia was remaining a follower of traditions of adaptive learning. Attempts made in the 1970–1980s to reform the Russian mass education in the direction of cognitive independence of learners failed completely [19]. In 1979, in the "No limits for learning" report submitted to the Club of Rome a political position was substantiated, according to which the hope for adaptive learning in present conditions was a recipe for disaster [20]. And this disaster has happened. At the end of 1980s, the study of situation in the general education system completed by the Academy of Pedagogical Sciences of the USSR showed that "one third of children at schools experienced difficulties in self-dependant mastering even *elementary* brainwork. Due to an unsatisfactory improvement of semantic and imaginative memory learners often resorted to mechanical memorizing. They did not know how *concretely define* theoretical principles, *summarize*, *compare*, make *their own* conclusions [21].

In Russia, the emergence of the scientific-research activity among schoolchildren was a result of implementation the "Step into the Future" program – the non-governmental and non-commercial initiative of scientists, teachers and educational professionals [22]. Generative didactics cultivated by the programme provides a problem-cognitive movement of a learner with a school teacher in conditions of professional research environment [23]. And thereby comprehensive and joint development of basic and special competences is implemented on the basis of cognitive mobility in educational research-type networks [24]. In this context, *early* engagement of promising schoolchildren at the age of 11–13 in scientific-research activity plays a key role. Experience in implementation of the "Step into the Future" program is taken as the basis for this article.

2 Objectives, Methodology and Research Design

Objectives of the study: (1) generalization of experience in early engagement of schoolchildren in scientific-research activities, (2) development of new theoretical models conceptualizing early research-cognitive activity of learners- researchers, where the human factor plays a decisive role.

The research methodology includes an episteme-didactic analysis of experimental material accumulated in practices of early engagement in scientific-research activities; theoretical definition of the fundamental system of socio-pedagogical relations forming early research-cognitive activities. Methods of comparative analysis and generalization of socio-pedagogical work with creatively active schoolchildren and students are used in the experimental part of the study; methods of cognitive psychology, structural and functional analysis of a social action, philosophical ontology – in the theoretical part.

The research design defines the structure of the article. General analysis of research environment is provided at the first stage from the perspective of a key human factor role. Next, we review and analyze two types of engagement in early scientific-research activity: (a) on the basis of social motivation, (b) on the basis of formal-educational motivation. Finally, the experimental and analytical material is transformed into the system of theoretical concepts.

3 Results of the Experimental Study

3.1 Research Environment: "Step into the Future" Programme as Social Effectiveness of the Human Factor

The research cognitive space of the "Step into the Future" programme - one of the most powerful systems of research education in present-day Russia - is taken as an environment for the experimental study. The programme is an authoritative nation-wide movement uniting scientists and teachers, tutors and professionals, parents and far-sighted politicians. It focuses on cultivation of talented young people who are able to create scientific innovations, advanced engineering and high technologies. As of today, the "Step into the Future" programme involves more than 150 000 young researchers –

schoolchildren and students. In the field of research training of youth the "Step into the Future" programme is in cooperation with the European Commission and partners from 39 countries, which makes possible to accumulate the most advanced educational experience in its activity.

The "Step into the Future" programme was founded in 1991 at the peak of socio-economic reforms, when the majority of people in Russia were only interested in problems of survival and sustenance. A small group of enthusiasts were wondering about the role to be played by "children of reforms" in future of national development. Creators of the Programme set at the focus of the programme a goal to bring up young researchers from schoolchildren who will be able to transform the society in future. I, as the founder of the Programme, have succeeded in convincement my colleagues of an importance and prospects of a new initiative, and then thinking over the system of works under the program, developing its regional architecture and a concept of the research training method.

By 2005, an educational research-type network, created by the program covered all nine time zones of the country - from the Pacific coast in the east to the Karelia in the west, from Murmansk in the north to Dagestan in the south. At the World Innovation Summit for Education (WISE, Doha, 2011), the "Step into the Future" programme was recognized by the international community as one of the two major innovative projects in Russia. As a result of independent monitoring and expertise, only two projects were invited to the summit from Russia – the "Step into the Future" programme and "Skolkovo" center. Thus, the initiative social project has got in a row with a financial empire with the amount of investments being a noticeable part of the country's budget.

3.2 Engagement Through Social Motivation

Based on the practice of the "Step into the Future" programme, I distinguish two types of motivations for *early* scientific-research activities: social and formal educational.

Under the *social motivation* for scientific-research activity, I understand the learner's desire to solve research-type problems (scientific and technical), which is determined by external factors in relation to the formal education and is based on a conscious or unconscious perception of their extra-curricular importance. These external factors in relation to formal education are stimulating effects of social and cultural groups, street and family environments, but most of all, internal and own irresistible desire for knowledge creativity, unfortunately not typical for all persons.

Engagement in research activities relying on social motivation is based on the basic system of initial cognitive practices.

The basic system of initial cognitive practices is the research form of primary self-awareness and self-making, which is realized through mentally-beneficial activities of cognitive-diagnostic type and it relies on a set of scientific-research tasks to choose from or independently formulated by a learner. These search activities allows a novice researcher to choose an initial domain of cognitive interests. Completed cognitive self-diagnosis gives rise to prediction of a social (including professional) career for the future.

Here are some examples. For three years, from the age of 12, Liuba Bysygysova from Olekminsk has been studying commonality in attitude to birds in spiritual culture of the Yakuts and Russians. Environmental problem of microscopic examination of sludge in municipal wastewater treatment plants in Krasnoznamensk allowed Ivan Petushkov (11 years) to find a method of sludge reuse as a biological additive in animal food. Research of meteor showers of Perseids, Cassiopeid and Aquarids completed by Sasha Popov (13 years) from Chelyabinsk was proved to be useful for the study of dust particles spreading in the Earth's atmosphere, which affects the environment and people's lives. Hazrat Bofov (14 years) from Nalchik designed a unique model of an electrically-driven spinning wheel that facilitated the work of his mother.

I carried out a statistical study of the effect of social motivation developed in school years on progress in studies (level of grades) of students at the Bauman Moscow Technical University. Education at this University has a pronounced research nature. Schoolchildren gained experience in research activities under the "Step into the Future" programme ("stepists") and enrolled into the University within five consecutive years were chosen as an experimental team. The number participant in the first team was 40, in the second team – 70, and in subsequent three teams - 150 students each. GPA (gross-point average) and a number of dismissed students per semester within first four years of study at the university were recorded for each of the teams. The majority in these teams was schoolchildren who studied outside of the capital region.

The eight-year study gave the following information. The progress of "stepists" and the number of dismissed students for the first two years of study at the university (where general technical disciplines were studied), were no worse, and at certain faculties were only slightly worse than average indicators (as a consequence of inadequate level of education at regional schools). Starting from the third year, profession-oriented disciplines and scientific-research projects were prevailing at the university. Pass rates of "stepists" in that period were steadily improving relative to statistically average. Eventually, the social motivation for scientific-research activities developed in school years allowed the participants in the experimental teams to overcome difficulties of first two years of education and reach positions of unquestionable leadership.

Due to losses suffered by the experimental teams during the initial period of education, the question of a role of formal-educational motivation played in early engagement in scientific-research activities was raised. An answer to this question can be given by a study of a team of schoolchildren which, first, is formed on the basis of formal school indicators and, secondly, takes a long research training course, where the scope of disciplinary knowledge competes with research.

3.3 Engagement on the Basis of Educational Motivation

Educational motivation for early scientific-research activities was studied on basis of experience accumulated by Distance (part-time) and Research (full-time) Schools working at the Bauman University as an integral part of a *supplementary* education system. The first school was established by me in 2010 for schoolchildren living outside of the Moscow Region, the second school - in 2014 for Moscow schoolchildren. As a rule, schoolchildren from the age of 13 were admitted to the schools. The purpose was cultivation a future researcher in the field of science and technology. A disciplinary component prevailed in early engagement in scientific-research activities, i.e. the engagement was based on the formal educational motivation.

By the formal educational motivation for scientific-research activities I mean an incentive of a learner for solution research-type (scientific and engineering) problems, which is driven by internal regulated factors of formal education, backed and supported by them. They include: (a) imperative status of knowledge and cognitive abilities specified by teacher's evaluation procedures; (b) directive learning environment, including teacher's control, requirements for a content and structure of cognitive procedures; (c) access to additional and specialized sources of knowledge; (d) social (including parent's) evaluation built in motivating formal education schemes.

Learners at the University's Schools in classes received a large content of additional and specialized knowledge in "physics" and "mathematics" disciplines they studied also at the primary school. Initial entry into research activities permitted to "alive" this knowledge, i.e. use them in the context of real life, which was simulated by science. In this way, research training boosted academic success at the primary school. Projects carried out in research training, even at a very early stage, completely satisfied the requirements for activity under the project, which were set by directive conditions of learning at the basic school. Learners had access to additional sources of knowledge - scientific libraries, engineering designs, scientific research practices and technical developments, equipment, documentation of research laboratories, specialized virtual scientific resources.

Qualitative feature of access to additional sources of knowledge was a contribution of scientific tutor who guided the learning process and selected knowledge resources. Study at the University's schools, participation in works of a high-status scientific group, engagement in professional rather than learning work provided the learners a high-level social evaluation in the system of formal education as such in eyes of peers and parents. It was important for parents to reduce the impact of accidental and adverse factors (and, first of all, "street") on personality development of young people. All these generated a powerful formal-educational motivation for early scientific-research activities. However as the experience showed, this motivation has not justified the hopes pinned on it by parents, schoolchildren, and researchers, who launched this project. However, at each of the schools, it proved to be different.

The basic course of study at the University's schools was organized in the form of three verticals of training: research cycle, disciplinary cycle and analytic cycle. The scope of training in the research cycle at an early stage was noticeably inferior to the disciplinary cycle; but by the middle of the second year of the basic course, the situation was changed for reverse.

Despite the fact that comfortable cognitive and organizational conditions were created for applicants throughout the qualification phase of training in the Distance School, all types of tasks were completed only by 25% (not successfully completed, but just completed!) out of 150 schoolchildren admitted to the qualification-based selection. The high attrition rate showed that formal educational motivation played a minor role in distance research training.

The organization of full-time study at the Research School, which began four years later, I anticipated about the same attrition rate at the stage of qualification-based selection. However, dynamics of losses was another. 89 students out of the 152 candidates (at the age of 13) who participated in the qualification were enrolled for the first research training course, i.e. nearly 60%. Considerable changes took place at the beginning of the second year, when the research component began to play a dominant role. Only 29 schoolchildren (at the age of 14–15) took a decision to continue education or about 20 percents of admitted to the qualification phase.

Thus, formal-educational motivation plays a very limited role compared to social motivation in early engagement in scientific-research activities.

4 Theoretical Vision Conceptualizing Early Research-Cognitive Activity

This section summarizes new theoretical vision which were developed by me for conceptual understanding of early research-cognitive activities of a specific category of learners - those who show potentials and willingness to research works and technical developments.

4.1 Attitude to the Truth in Research Education

What is the aim of scientific-research activities in the research education? Learner's goals may include self-making, a set of competencies, intellectual "muscles", etc. However, the main goal leading a learner to scientific-research activity is a search for the truth, which is embodied in a new knowledge. For education as a system the purpose can consist in mental training, education, etc. At the same time the research education has its own special task in the attitude to the truth. The attitude to the truth in the research education is determined not only by ethos and practices of everyday life, but it becomes a professional component in scientific work with knowledge that indentifies the foundation of cognitive behavior.

Research interpreted *a search for the truth* is as important for organization of the teaching and learning process as an educational emphasis in *upbringing* a researcher. Moreover, the latter is impossible without the first, because education dead to the learner's truth losses also *upbringing*. It should be able to feel and perceive the truth clear, look for and recognize the truth, and be able to detect and distinguish it as the truth.

Consequently, the attitude to the truth in a research education is an ontological foundation of training and the basis of scientific-type research behavior.

4.2 Scientific-Type Research Behavior

The scientific-type research behavior is fundamentally different from innate psychobiotic "curiosity" rooted in a primitive struggle for survive. This "curiosity" appears intuitively, irrespective of a profession and social role of an individual. The scientific-type research behavior is driven by a conscious search for the truth, which is embodied in scientific discoveries, engineering inventions, and social innovations.

a.o.karpov@gmail.com

The scientific-type research behavior has distinctive features in the cognitive, emotive-suggestive and values spheres. In the *cognitive* dimension it is based on the scientific methodicalness of thinking, critical rationalism, logic (including logic of contradictions); in *the emotive-suggestive* dimension it is characterized by persistence in cognition, resistance to uncertainties, scientific interest; in *the values* dimension it strives for allegiance to the truth, cognitive reliability (empirical and logical verifiability of knowledge), traditions of the scientific community.

The scientific-type research behavior arises not as a result of discursive study of one or another discipline, i.e. in the subject field of a classroom. It is not an implementation of a canonical set of cognitive actions and motives. Moreover, it destroys the subject field both in terms of disciplinary isolation and in relation to subject-lesson organization of knowledge. The scientific-type research behavior stakes its origin in the problematic situations that internally and originally motivate the mind to research-type cognitive acts. It is driven by deep and strategic personal interests and not by external and private teacher's evaluation (grades).

A person develops values of a research attitude towards life by own efforts by overcoming obstacles on the way to the truth and defending the truth.

4.3 Epistemic (Research-Cognitive) Imprinting

The basis of research behavior can be formed by a special mechanism of primary socialization, which I call "epistemic imprinting" or "research-cognitive imprinting". The existence of this mechanism is outlined in studies by such authors as M.E. Perelman and M. Ya. Amus'ya and supported by Academician A. Sakharov. They study the problem of influence on the choice of a scientist carrier and show that school children at the age of 11–12 are "to be attracted to science". This age can be deemed as decisive for those who in the future will carry out scientific work with knowledge; it is the age of "imprinting" in minds of external images.

K. Lorenz in his ethological studies considers the imprinting as intermediate behavior by placing it between the instinct and the "clean" learning (without understanding). Imprinting is in close relations with such form of social learning as simple imitation, which unlike vicar learning is a reproduction of actions without understanding their consequences. At the same time, memory in the form of imprinting is very resistant to extinction and has a long-lasting impact on social behavior - its traces in the psyche are detected even after a single experience.

Imprinters are both resonant social events (a human space flight) and deep personal contacts (academic tutoring). The imprinting mechanism socializing a growing person requires an internal response coherent with the stimulus (i.e. consistent with it) coming from the predisposition of deep psychics and cognitive abilities to scientific activity. Internal response to scientific "incentives" at an early age gives signs of a mission by directing intellectual aspirations of a person towards the research type of activities. Here a scientific tutor plays the role of an imprinter who takes the function of social teaching of a specific scientific type.

4.4 Micropedagogy of a Scientific Tutor

In micropedagogy of a scientific tutor I distinguish three main role functions – a perfect image of personality, a knowledge translator, a thoughtful friend.

The scientific tutor as *a perfect image of personality* plays a value-oriented role, which exposes itself in such forms as a professional image, a social image and a moral image. V.N. Druzhinin associated the formation of specialized creativity in teenage years (from 13 to 20 years) with the role of professional image [25]. The tutor having a social status relevant for a learner can make believe that he/her is a desired social and professional image, if the tutor is able to be a moral image for a learner.

The scientific tutor as a *knowledge translator* performs a cognitive stimulating function in the process of "rooting" an educatee into the cognitively specialized system of the society. Along with explicit the tutor transmits tacit knowledge, i.e. mental models and skills that can not be verbalized but gained from own experience and human interactions [26]. Interaction between a scientific tutor and a teacher gives the teacher's subject knowledge a link with real life by providing "a contact between psyche of a child and the nearest spheres of already accumulated social experience" as mentioned by L.S. Vygotsky [27].

In contrast to asymmetrical relationships between a learner and an tutor -ideal or an tutor -translator of knowledge, the role of a thoughtful friend as a peculiar personal role assumes a large extent of equality in relationships. Understanding the World by a learner manifests itself largely through an tutor's worldview, which in turn, is reflected in dynamics of specific interpersonal relationships, where the tutor becomes both a teacher and a friend at the same time.

4.5 Scientific-Research-Type Socialization

Scientific knowledge has become a major force in shaping the cultural, social and economic development of the society [28, 29]. This force creates a special process of engagement an individual in the society, which takes into account a dominant role of scientific knowledge and its productive nature. To describe this process, I coined the term "scientific-research-type socialization" [30].

Scientific-research-type socialization is developing as a total social process transforming the behavior of people of all ages and professions. In the most general terms, it is in progress through a special social teaching involving a person in the culture of work with scientific knowledge and its technical and technological embodiments in professional environment and everyday life. In everyday life, an individual faces with things endued, to a certain degree, with artificial intelligence. The boundaries of new social stratification and professional dispositions are determined by cognitive-role complexes [31], which are generated as a set of related types of work with knowledge.

One of the key problems of the knowledge society establishment is socialization of young people who are able to create new knowledge, its technologization and introduction into socio-economic life. This socialization is viewed by me as the scientific-research-type socialization in the narrow sense of this term. It acts through research education, which is developing today as a part of the formal educational systems and

a.o.karpov@gmail.com

incentive movements of scientists, teachers and professionals, such as the “Step into the Future” programme.

5 Conclusion

The early engagement of schoolchildren in scientific-research activities is a tool for diagnostics of professional vocation in the field of science and technology. The key role in this process is played by social motivation, which is formed as a result of thinking about a social importance of problems solved by learners. As shown by my studies, the formal educational motivation plays a very limited and supportive role in engagement of learners in scientific-research activities.

Research-cognitive self-making of a person in research training is determined not by a formal system of school relations but a human factor, which includes a learner, a teacher, a scientific tutor, a professional team, social environment and plays a key social role. Taken in total, the human factor makes the research-cognitive development of a learner possible, which leads a learner into spheres of professional work with knowledge.

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