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Manifestations of Technical Giftedness in Senior High School Students

Aleksey Panfilov, Valentina Panfilova and Olga Shterts

Abstract---

Background: The socio-economic realia of Russian development require efficient professional selection and consideration of a person's individual psychological traits during training that provide for successful human–technology interaction. This makes topical studying a special ability – technical giftedness and its manifestations during school education. The paper describes the concept of "giftedness", reveals the structural components of technical giftedness, and gives the analysis of Russian and foreign research findings on developing a person's technical giftedness.

Methods: *For identifying gifted senior high school students, an integrated approach was used which includes a wide variety of methods: observation in various situations; psycho-diagnostic trainings and studies using psychometric diagnostics.*

Results: *The signs of technical giftedness were identified as follows: instrumental signs – mechanical comprehension, spatial imagination, analytical and synthetic skills, intellectual lability; motivational signs – interest in technology, inclination to technical activities, inventing, design, individual professional preferences.*

Conclusions: *During the empirical study, the experimental and control samples were divided by gender. Analyzing the empirical study findings leads to the following conclusion: the motivational component of technical giftedness in senior high school students has to be actualized; technical giftedness is directly related to the development of spatial imagination and synthetic skills. Socio-pedagogical stereotypes associated with boys having better technical thinking than girls and boys with high technical giftedness scores being oriented to engineering professions have to be overcome.*

Keywords--- *Technical Giftedness, Abilities, Spatial Imagination.*

I. INTRODUCTION

In recent years, Russian society has seen a trend towards growth in the prestige of engineering professions. This is beneficial for the revival and development of industrial production, development of high technologies crucial for sustainable economic growth. The Russian Government approved the plan of implementing the Strategy of Innovative Development in 2015-2016. It provides tools for improving the system of education, popularizing the scientific, research, engineering and innovation activities, developing the system of state support for scientific and technical creativity of children and adolescents. From this standpoint, the development and support of students' technical creativity play an important role in creating a new engineering and technical personnel reserve for the industrial sector of the country.

Aleksey Panfilov, Kazan Federal University, 89 Kazanskaya Str, Elabuga, Russia. E-mail: panfiloval@mail.ru
Valentina Panfilova, Kazan Federal University, 89 Kazanskaya Str, Elabuga, Russia. E-mail: v.panfilova2010@yandex.ru
Olga Shterts, Kazan Federal University, 89 Kazanskaya Str, Elabuga, Russia. E-mail: olgashterz@mail.ru

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The quality of technical specialist training is to a large extent associated with the efficiency of professional selection and consideration of a person's individual psychological traits during training which provide for successful human–technology interaction, i.e. technical giftedness. The analysis of job profile diagrams of engineering specialists (design engineer, technical engineer, electrical engineer, civil engineer, project engineer) has demonstrated that the professionally important traits for all above mentioned specialists are: mechanical comprehension; good spatial thinking and imagination; a high level of distribution, concentration and switching of attention; flexible thinking, and a keen eye for distances. Therefore, if senior high school students develop a high level of skills listed above, we can speak about potential opportunity to develop technical giftedness by organizing the appropriate educational activities.

II. BACKGROUND

Giftedness is a trait of an individual that involves the best fulfillment of skills of natural and social genesis in various activities, which allows singling out two major components of giftedness: the motivational and instrumental ones.

K.A. Heller describes giftedness as individual (cognitive and motivational) personal prerequisites for high achievements in one or more spheres (Heller and Schofield 2000).

Yu.D. Babayeva treats giftedness not as a constant personal potential but as a constantly evolving potential existing only in dynamics, in perpetual motion, developing, and therefore almost continuously changing (Babayeva 2008). The giftedness evolution factors according to J. Renzulli are: creativity, intelligence, motivation (Renzulli and Reis 1994).

Giftedness is manifested in the "man vs. environment" context, and this may fail to occur due to the absence of a relevant element in the environment. Therefore, it is crucially important to create a diverse, multifunctional educational environment in which giftedness may emerge and develop and which provides for the development control.

The studies of M.U.M. Gross are devoted to features of psychosocial development in intellectually gifted children in the process of social adaptation. When comparing moderately and highly mathematically gifted children, M. Gross has found that moderately gifted children better adapt to the environment (Gross 2002).

A.N. Panfilov has developed a multifactor pedagogical model of environment for the development of gifted children and young people, which is experimentally implemented at Elabuga Institute of Kazan Federal University. The first stage of the model includes studying the efficiency of children's giftedness development in conditions of "vertical enrichment". The second and third stages provide for preliminary specialization within a field of interests, abilities of gifted children for teaching them at network laboratories. The third stage of giftedness development involves further differentiation of senior high school students according to their personal inclinations and abilities. The fourth stage of the pedagogical multifactor model of the environment for the giftedness development includes readiness for personal and professional self-identity. The fifth stage of giftedness development is professional and personal self-fulfillment (Merzon et al. 2013).

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During practical implementation of the proposed multifactor model, we achieve the following interrelated objectives: 1) to determine the basic concept of technical giftedness for the subsequent empirical research; 2) to create a psychological and pedagogical technology for diagnostics and forecast of giftedness in children and adolescents; 3) to develop psycho-pedagogical basis and establish a system of development of technically gifted children and adolescents.

The expected results of model implementation are as follows: 1) psychological and pedagogical readiness of higher and secondary professional education specialists for detecting technically gifted adolescents and rendering psycho-pedagogical, methodical support to them; 2) informational and methodological support for controlling the development of giftedness of adolescents: the selection of contents, creation of programs and elective courses; development of practical (methodical, psychological etc.) instructions for training gifted adolescents; creation of a specialized website to disseminate the positive experience of implementing the model of "Cooperation of higher and general education institutions in psychological and pedagogical support of developing the technical giftedness in adolescents", to render psychological and pedagogical support in inaccessible and remote locations; 3) higher figures of detecting the adolescents who have signs of technical giftedness, their development, formation of their inner motivation of activity and their value system, which will provide the basis for their successful socialization and self-fulfillment in the future.

Signs of giftedness are the features of a gifted child that are manifested in his/her real activities and can be evaluated during observation. They cover two aspects of behavior of gifted children: the instrumental and the motivational ones. The instrumental aspect describes the methods of his/her activities. The motivational aspect describes a child's attitudes to various components of activities. In the context of children's upbringing, it is particularly important that many followers have accepted the idea where the key feature of a person's potential is not the outstanding intellect or high creativity, but his/her motivation. Pedagogical practice has learned to identify only three categories of gifted children. The first category includes children with a high level of total giftedness. The second one includes children who make good progress at school ("academic giftedness"). The third category of gifted children includes those who are successful in certain activities. Identification of these categories is based on "ecologically valid" diagnostic techniques and poses no particular difficulties. Gifted young musicians, artists, mathematicians, athletes gained a right to have special education long before. Let us dwell on a group of children with special technical abilities.

Technical skills are the abilities that are manifested in working with equipment or its parts. With regard to this, such work requires special mental abilities, as well as a high level of development of sensory motor skills, mental agility, and physical strength.

Yu.A. Shevchenko has proposed a model of technical giftedness which includes technical intelligence, technical creativity, activity component of technical abilities and specific personal motivation. The characteristics of technical intelligence, according to Yu.A. Shevchenko, are technical comprehension, understanding of mechanics and technical relations, features of reflection of natural phenomena, spatial phenomena and interactions.

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The structure of technical abilities that depend on psychological attributes includes: quick eye for technology; advanced technical thinking; advanced spatial imagination; ability to combine; personal traits (interest in technology, curiosity, persistence, diligence); ability to take into account the properties of materials, parts, forms used.

Unlike the technical intelligence associated with mental structures, activity components of technical abilities are related to particularities of reflecting and processing information. The characteristics of *modus operandi*, process of problem solving are referred to this group. Thus, technical intelligence determines cognitive abilities, potential, and the components of this group are related to the characteristics of an individual (in the field of technology) (Shevchenko 2011).

With technical tasks being able to be subdivided into theoretical and practical, the signs of technical giftedness will therefore also manifest themselves at theoretical and practical levels. In the former case, we associate them with the characteristics of technical thinking while in the latter case – with a specific phenomenon referred to in the literature as "manual skills", "manual dexterity". We believe the latter term to be more appropriate. Theoretical analysis of the term "manual skills" suggests that manual dexterity is a complex phenomenon, not only good coordination of movements (as it is sometimes treated). N.A. Berstein calls this dexterity "motor creativity" and, in this context, we deem it reasonable to treat it simultaneously with technical thinking on different activity levels (Berstein 1991).

T.V. Kudryavtsev suggested that the very unique nature of production and technical labor causes predominant development of certain aspects of thinking (Kudryavtsev 1975).

The following properties of professional thinking are usually listed: goal orientation, lability, circumstantial thinking, fluency and flexibility as indicators of thinking activity, and other properties. Lability is a property of nervous system which characterizes functional mobility of nervous processes, speed of their origin and termination. Consequently, lability is an ability to rapidly fulfill tasks, to abstract, to grasp the essence in the subject of perception. Lability directly affects the attention switch speed. Fluency reflects the ability to generate large numbers of verbally formulated ideas and stimulates creativity in general. Flexibility estimates the ability to generate different ideas, to switch from one point to another, to use various solution strategies. Low flexibility level may indicate rigid thinking, poor awareness, limited intellectual development or low motivation (Kudryavtsev 1975).

A.A. Loseva points out the following indicators of successful personal fulfillment in the technical field depending on manifestations of abilities in a particular life sphere: interest in mechanisms and machines, design, ability to perform manual tasks, art activities, creativity and flexible thinking (Loseva et al. 2004).

M.G. Davletshin has found that for performing professional tasks an engineer perceptive faculties, keen eye for distances, spatial imagination, advanced technical thinking, rational approach to problem solving, manual devolution (Davletshin 1971).

During longitudinal studies, K.A. Heller came to the conclusion that teachers believe girls, in teachers' opinion, less often belong to a group of intellectually gifted children. However, girls have better academic results in school

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subjects than boys, except mathematics and physics (Heller 1992). However, proceeding from empirical studies (sample of adolescents including 45 girls and 45 boys), we have come to preliminary conclusions that socio-pedagogical stereotypes associated with boys having better technical thinking than girls have to be overcome. In particular, the components of technical giftedness are better developed in adolescent girls than boys.

III. METHODS

When detecting gifted children, it is advisable to use an integrated approach including a wide variety of methods: observance over children in various situations; psycho-diagnostic trainings and psycho-diagnostic studies using psychometric diagnostics (Anastasi and Urbina 1997). In studying technical giftedness, we relied on the following aspects: integrated assessment; principle of sustainability; the principle of using training methods; recording the potential capacities of a child; principle of reliance on valid diagnostic methods; principle of participation of different specialists; participation of children in assessing their own giftedness. The latter is the key principle because gifted children often evaluate themselves, their abilities and possibilities very critically, comparing their "real" and "ideal" selves and being the most objective experts of their own giftedness.

IV. EMPIRICAL METHODS

This study uses the following methods: Bennett Mechanical Comprehension Test, Amthauer Intelligence Structure Test (subtest No. 7 Spatial imagination, subtest No. 8 Spatial generalization), and differential-diagnostic questionnaire by E.A. Klimov (DDQ). During the study of technical giftedness signs, 240 senior year students of secondary schools (grades 10-11) were tested in the period from February 2015 to April 2015. Students with a high level of mechanical comprehension were selected from this sample. The total experimental sample included 85 senior high school students. The control sample included students with low mechanical comprehension level. This sample included a total of 73 senior high school students. To determine the accuracy of the study results for the control and experimental samples, we performed the comparative analysis of the findings according to Bennett Mechanical Comprehension Test. The results of comparative analysis according to the statistic test (Student's t-test) have shown that in mechanical comprehension development level both samples vary significantly ($p \leq 0.001$ ($t = 12.94$)). That is, children with a high level of technical comprehension have higher scores than senior high school students with low level of technical comprehension. For the statistical analysis of the empirical research results, the Statistical Package for Social Sciences (SPSS) software was used. The SPSS software is a very powerful and widespread tool for computer data analysis in psychology and social sciences.

V. RESULTS AND DISCUSSION

During the empirical research, the experimental and control samples were divided by gender, as the Bennett test involves different gradations of levels of mechanical comprehension development for boys and girls. Signs of giftedness cover two aspects of a gifted child's behavior: instrumental and motivational. The detection of instrumental signs of technical giftedness was aimed at determining the level of mechanical comprehension development, spatial imagination, spatial generalization and intellectual lability. Lability is a property of nervous system that characterizes functional mobility of nervous processes, speed of their origin and termination; an ability

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to rapidly fulfill tasks, to abstract, to grasp the essence in the subject of perception; direct influence on the attention switch speed. In this study, the scope of motivation is associated with such characteristics as interest in technology, technical activity, invention activity, design. The motivational signs of technical giftedness were investigated using DDQ by E.A. Klimova that allows to determine individual professional preferences.

Table 1: Indicators of Technical Giftedness Signs in Senior High School Students with High Mechanical Comprehension

	Intellectual lability			Spatial imagination			Spatial generalization		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
Boys	47%	47%	6%	60%	33%	7%	53%	40%	7%
Girls	38%	50%	12%	58%	38%	4%	34%	66%	0%
Total	41%	49%	10%	59%	36%	5%	41%	56%	3%

Table 2: Indicators of Technical Giftedness Signs in Senior High School Students with Low Mechanical Comprehension

	Intellectual lability			Spatial imagination			Spatial generalization		
	High	Medium	Low	High	Medium	Low	High	Medium	Low
Boys	8%	52%	40%	12%	40%	48%	7%	48%	45%
Girls	12%	52%	36%	12%	60%	28%	8%	60%	32%
Total	9%	52%	39%	12%	48%	40%	8%	52%	40%

The diagnostics results show (Table 1 and Table 2) that the level of intellectual lability, spatial imagination and spatial generalization in boys and girls with high technical comprehension is above average. In the control sample (students with low level of technical comprehension), the indicators of spatial imagination, intellectual lability and spatial generalization development are below average.

Pearson's correlation analysis in the results obtained (students with high levels of technical comprehension development) shows that there is no statistically significant relationship between the level of technical comprehension and intellectual lability in boys and girls ($r = 0.19$ and $r = 0.17$). This is associated with the fact that high attention switch speed is not the main indicator of achieving high results in technical creativity. Intellectual lability is a property of nervous system that generally affects the efficiency of an individual's activity and does not dominate in creation of new technological models. The results of correlation analysis between the level of technical comprehension and spatial imagination in both samples (girls and boys with high levels of technical comprehension) show statistically significant relations at the level of $r = 0.23$ at $p \leq 0.05$ and $r = 0.24$ at $p \leq 0.05$. These results indicate that there is a trend towards direct interrelation between the levels of technical comprehension and spatial imagination. Therefore, the better spatial imagination, the better the ability to understand technical models. Spatial imagination is the ability of mental simulation and "imagination" of various projects or constructions, seeing them with the inner eye in color and details, which is a particularly important aspect of creating new high-tech models.

As for the experimental sample, Pearson's correlation analysis of the index of technical comprehension and spatial generalization also indicates mild interrelation at levels of $r = 0.25$ at $p \leq 0.05$ in girls and $r = 0.23$ at $p \leq 0.05$ in boys. Therefore, if senior high school students have advanced constructive practical skills and are able not only to use spatial patterns, but to synthesize their relationship, they are also good at understanding various technical mechanisms and devices.

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Thus it may be assumed that the development of spatial imagination and generalization promotes the development of technical giftedness.

Moderate correlation dependencies between technical comprehension and spatial imagination and generalization, in our view, are associated with the unstable motivational component in the sample of testees. For example, among boys and girls with a high level of technical comprehension, there is a trend to mastering not only the professions of "human–technology" (29%) and "human – sign system" (17%) types, but also a number of other professions, which are not associated with the development of technical giftedness (Table 3). It should be also pointed out that in the sample of students with a high level of technical comprehension there is an influence of gender stereotype on the professional preferences, thus, the "human–technology" type profession was chosen by 60% of boys, and only by 10% of the total number of girls interviewed, despite high levels of technical comprehension. In the control sample, in spite of low level of technical comprehension, 35% of boys chose a "human–technology" type profession and 28% of boys – a "human – sign system" profession. If we compare the overall sampling index, 28% of students with low mechanical comprehension chose "man–technology" professions while only 29% of students with a high technical comprehension preferred "man–technology" professions. This points to the fact that when choosing a future profession young men and women are not always guided by their abilities to mastering a particular profession.

Table 3: Indicators of Professional Orientation among Senior High School Students

	DDQ									
	Students with a high level of mechanical comprehension					Students with a low level of mechanical comprehension				
	h-h	h-n	h-s	h-t	h-a	h-h	h-n	h-s	h-t	h-a
Boys	27%	13%	0%	60%	0%	15%	10%	28%	35%	12%
Girls	32%	22%	28%	10%	8%	24%	28%	16%	16%	16%
Total	30%	19%	17%	29%	5%	18%	17%	23%	28%	14%

Legend: h-h stands for human–human, h-n – human–nature, h-s – human – sign system, h-t – human–technology, h-a – human – art image.

The control sample includes students with low development levels of technical comprehension. During the correlation analysis, we obtained no reliable significant relations between the index of development of technical comprehension and intellectual lability, as well as between the index of development of technical comprehension and spatial imagination and generalization.

VI. CONCLUSIONS

Giftedness is a complex mental phenomenon in which cognitive, emotional, volitional, motivational, psychophysical and other mental properties, potential makings and special abilities are interlaced. The development and extinction of these properties are determined by personal, social and pedagogical factors.

One of the main signs of technical giftedness is a high level of development of technical comprehension, spatial imagination and spatial generalization.

Intellectual lability is a property of nervous system and does not substantially influence the development of technical comprehension and is not the main sign of technical giftedness of an individual.

When developing technical giftedness, the motivational component has to be actualized, which would enhance productivity in the field of technical creativity. Therefore, working with children in the direction of professional self-identity has to be started at middle school, with actively involving them in interactive workshops, where they would be able to plunge into the world of professions to the full.

VII. List Of Abbreviations

DDQ = differential-diagnostic questionnaire by E.A. Klimov.

SPSS = Statistical Package for Social Sciences.

VIII. Availability Of Data And Materials

The dataset supporting the conclusions of this article may not be made publically available due to ethical reasons involving impossibility to receive the respondents' or their parents' concent.

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