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AGE PECULIARITIES OF INTELLECTUAL ABILITIES OF SCHOOLCHILDREN

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Abstract

The age peculiarities dynamics of the intellectual abilities of schoolchildren *(IAS)* in solving problems of various difficulties is studied, as well as the analysis of a computer database is provided, which allows obtaining information on various *IAS* indicators, both at the student's level (individual student's characteristics) and at the level of other parties concerned. Only those *IAS* indicators, the development level of which adequately reflects the whole picture of the student's intellectual development, have been highlighted. The indicators are conditionally divided into two groups: (I) indicators of mental development, which the school education is focused on and (II) indicators characterizing the students' ability to solve heuristic challenging tasks. A qualitative distinction between the intellectual development of two students' groups – 6-9 and 10-11 grades, has been determined, as well as a quantitative difference in *IAS* indicators between all the surveyed schoolchildren age groups. The difference in the effectiveness of solving problems of different difficulty has been revealed. The problems for the solution of which it is required to "go beyond" the initial level of mental support of educational activities, to involve new intellectual "layers", "plans" and a special mental subject organization, i. e. everything which is defined in the study as untapped intellectual potential, are, in general, solved worse. The study demonstrates the importance of knowing the *IAS* indicators age dynamics for the learning management individualization.

Keywords: Age-related characteristics, age-related characteristics dynamics, intellectual abilities of schoolchildren, research technique, untapped intellectual potential

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1. Introduction

Studying the intellectual abilities of schoolchildren *(IAS)* at different education levels is relevant for school education, since it is closely related to the "eternal" problem of pedagogy and psychology – the problem of school poor progress. We believe that one of the factors which determine school poor progress is the students' insufficient ability to optimally use their personal intellectual potential in the learning process. It can be stated with confidence that many students do not even realize the level of their true intellectual abilities and potentialities (the so-called "unmanifested potentialities"). For example, it is known that mastering technologies for solving intellectual problems increases IQ by 20% (Eysenck, 2016). In this case, it is necessary to understand that we are not referring to changing the person's intellectual abilities given by nature, but to forming the skills to use their already existing intellectual potential, which, before solving problems requiring a new creative approach, was in an "unmanifested" state.

In practical terms, studying the *IAS* is of great importance due to the fact that at present, scientific and technological progress significantly increases the weight of intellectual components in human production activities (Bates, 2017; Lehrer, 1983; Sejnovski, 2018). In the modern world of digital technologies, irreversible changes in the employment structure are taking place, in which more and more jobs are "shifted" to higher intellectual "floors", where higher intellectual and moral requirements are imposed on workers (Lehrer, 1983; Shapovalov, 2014). Many researchers generally recognize the importance of intelligence, but few of them have any idea how necessary it is for a student's life success (Macnamara, 2017; Meldrum, 2019; Naghib et al., 2021; Saß et al., 2021; Wai & Worrell, 2021; Yang & Zhao, 2021).

The accumulated experience of numerous scientific works indicates that the intellectual development characteristics affect both the education success, the knowledge accumulation, and the determination of future professional interests and the success of the professional activity itself (Abdubakova & Abieva, 2020; Gorbunova & Minkin, 2016; Savina & Bulatova, 2020; Suvorova, 2020; Van Vo & Csapó, 2020). This necessitates determining the content and structure of intellectual development, the development of scientifically based methods for identifying and assessing its various aspects for a more efficient and purposeful organization of the student's intellectual activity in the learning process. The education optimization, its differentiation and scientifically based work on students' vocational guidance largely depend on the correct solution of these problems. School urgently needs psychological diagnostics, allowing to systematically monitor the course and pace of each student's intellectual development, to reveal the reserves of his/her cognitive abilities. The active introduction of computer technologies into the education system significantly helps to implement the task of the *IAS* complex diagnostics and monitoring (Demetriou et al., 2021; Wang et al., 2020).

2. Problem Statement

The learning process optimization inevitably leads to its differentiation. When mastering a unified educational program, students with a reduced and increased rate of mastering the educational material content are distinguished. As psychological studies show, these individual differences are based on the

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qualitative uniqueness of the mental activity structure. The analysis of this structure, timely correction of underdeveloped components, comparison and selection of various educational programs are impossible without creating and applying psychodiagnostic techniques.

Education and upbringing at all stages and levels of education (from schools to universities) require taking the patterns of intellectual development, fixing their qualitative stages and individual characteristics into account.

Information about the intellectual development characteristics is very important both for the subjects being examined themself and for their teachers and parents. It has not only a differentiating effect on the individual's self-determination, but also serves as its decisive factor. For education providers, knowing about the individual identity of a student's intelligence is the most important factor in organizing and implementing the student-centered education.

3. Research Questions

3.1. What are the age-related characteristics dynamics of the *IAS* when solving problems of different difficulty?

3.2. What are the qualitative differences in the intellectual development of the two combined groups of students – 6-9 and 10-11 grades?

4. Purpose of the Study

To study the age-related characteristics dynamics of the intellectual abilities of a schoolchild in solving problems of different difficulty, as well as to analyze the computer database which allows to obtain information on various *IAS* indicators according to a large sample of students, both at the student level (individual student's characteristics) and at the level of other parties concerned.

5. Research Methods

To study the *IAS* as a person's general ability, a method which includes subtests and tasks of well-known and well-proven tests, such as Amthauer and Eysenck tests, has been selected in the study (Davydov & Chmykhova, 2016; Eliseev, 2018; Eysenck, 2016; Tunik, 2009).

This study did not aim to extract all the possible *IAS* components, but to highlight only those of them, the development level of which, in the most authors' opinion, can adequately reflect the whole picture of the intellectual development (Hegelund et al., 2020). The highlighted *IAS* indicators are conventionally divided into two groups. The first group of indicators has been selected considering the mental development level which the school education is focused on. The second group of indicators characterizes the students' ability to apply existing knowledge to solve heuristic challenging tasks (Breit et al., 2021; Gorbunova & Minkin, 2016; Gunawardena & Wilson, 2021).

In general, the structure of intellectual potential includes seven indicators: 1 – general erudition, 2 – the ability to find logical connections, 3 – the ability to classify concrete concepts, 4 – the ability to classify abstract concepts, 5 – visual-spatial orientation; 6 – the ability to solve mathematical puzzles, 7 – the ability to solve verbal tasks. Four of them (general erudition, the ability to find logical connections,

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classify abstract and concrete concepts) are aimed at identifying intellectual abilities in areas related to the school curricula. Considering that the selection of test material for measuring these indicators corresponded to the concepts, terminology and knowledge within the school subjects (Russian language, mathematics, physics, history, biology and geography), the test results also characterize, first of all, the predictive efficiency in the listed school subjects, as well as a student's professional orientation in a particular field of knowledge – technical, humanitarian and natural.

The next three indicators, included in the intellectual potential structure (visual-spatial orientation, the ability to solve mathematical puzzles and verbal tasks), are aimed at measuring practical productive intellectual abilities, which are no longer associated with handling familiar knowledge and terminology, but with the creative process of solving new for students tasks which require active perception, information development and involvement of heuristic solution methods. Tasks measuring these indicators, in their psychological meaning, require different efforts depending on the level of available unmanifested potential of mental capabilities. Some tasks are introduced in a student's life for the first time and cannot be solved in a traditional way. Therefore, the correct solution of such tasks is the result of a non-traditional, non-standard, that is, a creative approach, where a students have to discover a specific way to solve a heuristic task.

To obtain a reliable picture of the empirical study results, mathematical and statistical processing of the "raw" scores obtained in the survey has been carried out. For this purpose, a program for inputting "raw" data, their computer processing and analysis has been developed. "Raw" students' marks have been subjected to preprocessing, which consisted of checking the questionnaires for accuracy, completeness and quality of filling according to certain criteria.

At the next stage, a multilevel processing of the data array has been carried out, on the basis of which scales have been formed and a qualitative assessment of the *IAS* indicators development level for different age students' groups has been carried out.

As the criteria for the *IAS* indicators development (manifestation), we have used the average values of the scores separately for each students' age group and their range, which was calculated as the scores mean square deviation. This approach is quite widespread in psychological research and does not contradict the accepted analysis technique. On the basis of this criterion, a student could get into one of three possible "zones" for the intellectual abilities development: Zone I – students with indicators above the value ($X_{av.} + \sigma$) get into this zone, their *IAS* level is characterized as high; Zone II is a zone where get the students who have indicators within the limits ($X_{av.} - \sigma < X_i < X_{av.} + \sigma$), their level is characterized as average; III zone – students whose indicators are less than the value ($X_{av.} - \sigma$) get into this zone, such students have intellectual abilities developed at a below average level, where: $X_{av.}$ – the *IAS* indicator average value for the age sample; σ – mean square deviation; X_i – the *IAS* indicator required level.

The given procedure makes it possible to carry out a complex analysis of the intellectual abilities development level, both of an individual student and a comparative analysis of students among themselves, according to grades, schools and age group.

The study involved 6-11 grades students from 15 schools, a total of about two thousand people. The computer program for processing the experimental research data, analyzing the results obtained and forming the students' individual characteristics has a hierarchical structure for issuing the results

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obtained. That is, information on *IAS* indicators is presented first at the student's level (in the form of an individual characteristic), then at the class, school and district level. This arrangement of information allows us to make the most of the research results for corrective, counseling, vocational guidance and other work at each of the levels presented.

6. Findings

6.1. Development of productive and unproductive thinking of schoolchildren in grades 6-11

The figure (see Fig. 1) shows the general dynamics of intellectual abilities indicators depending on the age levels of the students who have taken part in the experiment. For all age levels, there is a clear difference in the effectiveness of solving tasks which require using the heuristic (productive) methods of solving (we will call them tasks of type I) and tasks, the solution of which required the intellectual skills of handling the information within school knowledge (tasks of type II).

In general, tasks requiring productive thinking have been solved 2.4 times worse than tasks the solution of which was based on logically handling the familiar concepts and terminology, that is, mainly on unproductive thinking. A similar trend, with small deviations up or down, continues for all schools.

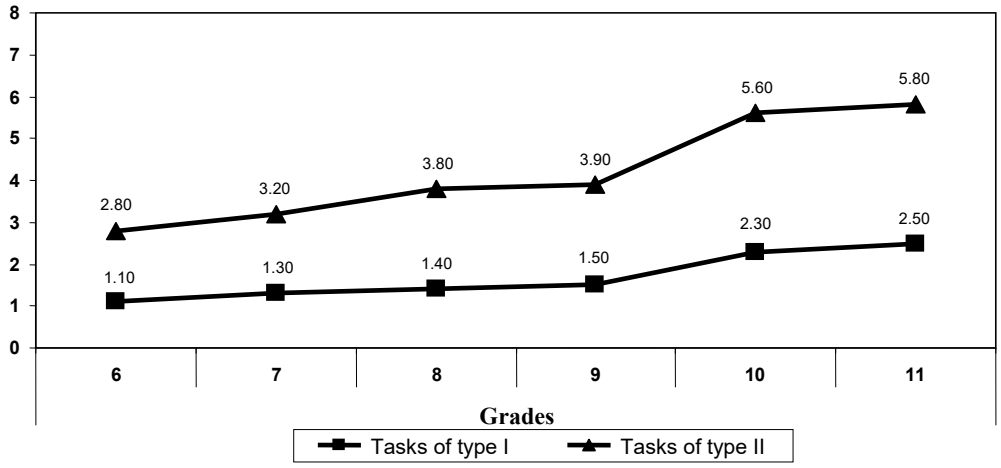

Figure 1. Graph of comparative analysis of solving two types of problems by different age groups *(indicators values in relative units)*

The results obtained cannot be satisfactory for secondary education, especially today, when the school faces the challenge of preparing students who are able to quickly adapt and make decisions in changing environmental conditions. However, such results are quite understandable, and they are embedded in the specifics of designing the tasks of the second type, which are actually created to assess intellectual skills and knowledge within the educational material. Neisser called this intelligence "academic intelligence" (Neisser, 1976). The results obtained for "academic intelligence" have significantly higher indicators than indicators for "practical intelligence", which have been obtained when solving problems which require new, unusual ways of solving. It is assumed that students have the

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necessary knowledge to solve problems, which includes three aspects: the problem statement; searching for relevant skills and abilities; assessing the solution option and a new problem statement.

In our study, the results obtained when solving tasks of the second type are important in that they allow indirectly (i.e., outside the connection with school marks (academic performance)) to analyze intellectual skills and abilities by age groups and to study the real dynamics of general intellectual abilities during the transition from one age group to another.

As the study has shown, significantly worse results have been obtained when solving problems of the first type, requiring developed practical intelligence. The procedure for successfully solving tasks which are new to a student includes the use of unmanifested intellectual capacities, which, in particular, include: the ability to quickly analyze and test the obtained intermediate results of the problem solving; the ability to create a plan for solving a problem in new environmental conditions; the ability to make decisions quickly when there is a lack of time; intuition to find the right solution and other abilities.

In general, tasks of type I for their solution require students to "go beyond" the initial level of mental support of educational activity, transform the situation, to involve (or specially form) new intellectual "layers", "plans" and a special mental subject organization, i. e. everything which is defined in the study as untapped intellectual potential. The research data show that these are the abilities which students have to a lesser extent.

It should be mentioned that practical thinking is an important component of a student's intellectual competence, which can and should be developed at school. The development of practical thinking undoubtedly depends on the success of schooling in mastering traditional knowledge, but most importantly, practical thinking skills allow today's students to have advantages in the competitive struggle for the right to engage in prestigious professional activities in the future.

Although identifying the ways to increase the level of practical intellectual abilities is beyond the scope of our study, it should be noted that, as Eysenck (2016) shows, the very participation of schoolchildren in the procedure for measuring the intelligence level, and, therefore, their familiarity with the tasks of type I, increases their practical intellectual abilities. Indeed, the solving the tasks of type I (the so-called challenging tasks) acts as a means whereby the subject is transferred from incomplete knowledge to a more perfect and comprehensive knowledge and, most importantly, there is an intensive formation of new intellectual activity techniques, his/her personal development, the formation of intellectual competence, in general.

6.2. Age dynamics of the level of intellectual potential

Analysis of the intellectual potential indicators depending on age levels suggests that two curves corresponding to the indicators dynamics of 10 and 11 grades significantly differ (at the level of $p=0.01$) from the indicators dynamics of other age levels (see Fig. 1). Therefore, the results of the experiment testify to the qualitative difference in *IAS*, first of all, in 10-11 grades when solving both tasks of types I and II.

This does not mean that there is no dynamics in the students' development in 6-9 grades. Figure 01 shows that such a dynamic exists. It is most clearly manifested in the change of the "general erudition" and "finding logical connections" indexes between the *IAS* indicators of the of the 6th and 9th grades (by

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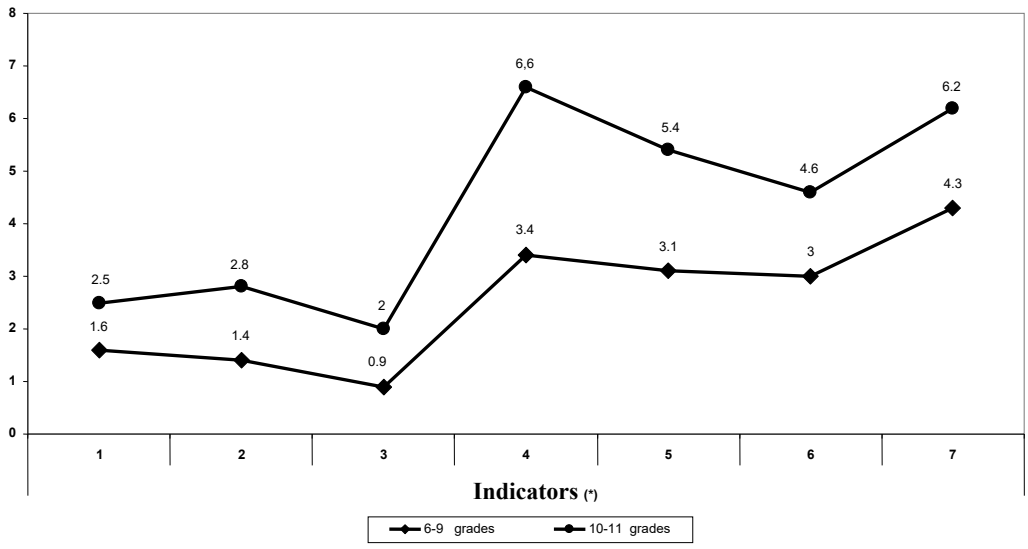
1.4 times). However, these changes are slow, and practically invisible for the tasks of type II. It can be assumed that at the level of 6-9 grades the internal processes, which improve the cognitive mechanisms necessary for the full disclosure of the existing hidden *IAS*, "work". These changes, as it were, prepare the *IAS* of 6-9 grades for a qualitative "jump", which takes place at the level of 10-11 grades (for example, the change in the average value of the "general erudition" index between grades 9 and 10 is 1.65 times, and the "ability to solve verbal tasks" index – 1.9 times) (see Table 1).

Table 1. Age dynamics of the intellectual potential level

Grades	1	2	3	4	5	6	7
	Visual-logical orientation	Solving mathematical puzzles	Solving verbal tasks	General erudition	Finding logical connections	Classification of abstract concepts	Classification of concrete concepts
6	1.4	1.1	0.8	2.7	2.6	2.4	3.6
7	1.5	1.4	0.9	3.2	2.9	3	4
8	1.8	1.5	1	3.6	3.4	3.2	4.8
9	1.8	1.6	1	3.9	3.6	3.3	4.9
10	2.2	2.7	1.9	6.4	5.3	4.5	6.1
11	2.7	2.8	2	6.7	5.5	4.7	6.3

The results obtained allow us to combine the examined age groups, depending on the qualitative differences which they undergo in terms of intellectual potential when transferring from one age level to another, into two generalized groups: the first group – 6-9 grades, the second group – 10-11 grades (see Fig. 2).



*1 – visual-logical orientation; 2 – solving mathematical puzzles; 3 – solving verbal tasks; 4 – general erudition; 5 – finding logical connections; 6 – classification of abstract concepts; 7 – classification of concrete concepts

Figure 2. Comparative analysis of the *IAS* indicators of two conditionally identified age levels (6-9 and 10-11 grades)

Therefore, two age periods (6-9 grades and 10-11 grades) have been identified in the study, which are qualitatively different from each other, and which can actually be called periods, in the sense of the word as this term is used in pedagogy for the age periodization of schoolchildren.

7. Conclusion

Data on age differences in intellectual abilities are of great importance for managing the schoolchildren education, for identifying their available intellectual potential, for monitoring the development dynamics and predicting the educational process. Information about the *IAS* can be obtained only through a complex examination of students of all age levels using a common methodological toolkit. This has been done in this research work. The education optimization, its differentiation and scientifically based work on students' vocational guidance largely depend on the correct solution of these problems. School urgently needs psychological diagnostics, allowing to systematically monitor the course and pace of each student's intellectual development, to reveal the reserves of his/her cognitive abilities. The active introduction of computer technologies into the education system significantly helps to implement the task of the *IAS* complex diagnostics and monitoring. The study has shown the importance of knowing the age-related changes in the intellectual abilities of students for the individualization of education management, as well as for monitoring the development level and predicting the competitive personality of a student in general.

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