European Journal of Contemporary Education
E-ISSN 2305-6746
2023. 12(4): 1212-1222
DOI: 10.13187/ejced.2023.4.1212
https://ejce.cherkasgu.press

Intellectual Support of the Students' ResearchActivities in Mathematics: Experimental Verification of Effectiveness A Hybrid Learning System

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Abstract

The research is devoted to the study of the phenomenon of research activity, as well as the search for effective didactic mechanisms for its development. The most promising direction of activating the research activities of trainees is proposed – the development of learning systems based on artificial intelligence methods. This tool is notable for its flexible interface, the ability to adapt to the unique characteristics of each user and focus on their cognitive capabilities. In addition, it makes it possible to create parametric models of students, taking into account their individual level of cognitive development, as well as to differentiate educational material. The authors developed a hybrid intelligent learning system to support students' research activities and introduced it into the practice of teaching mathematics. In this regard, the problem of verifying the effectiveness of the functioning of this system with innovative organizational and methodological support has been updated. The effectiveness was tested on the basis of the developed parameters of scientific potential, reflecting the specifics of research activities in the field of mathematics (personal, activity, communicative, effective), using the module of a hybrid intelligent learning system. The audit established statistically significant dynamics for all the studied indicators.

Keywords: methods of mathematics, research activities, intellectual management, educational system, criteria system.

1. Introduction

In the context of a large-scale transformation of the socio-economic and cultural spheres of public life, the role of education as a purposeful process of intellectual, spiritual, moral, creative and professional development of an individual is significantly increasing, the generally recognized result of which is the formation of a highly developed, competitive personality. Modern research in the field of psychology and pedagogy confirms that universal skills (such as creativity, the ability to actively learn,

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creativity) are manifested most effectively in the process of independent search and formulation of problems, generation of original ideas and solutions, as well as the application of knowledge in new situations, especially in the framework of educational activities with a research focus.

The actualization of the problem of introducing a research approach to teaching is determined by the implementation of international scientific and educational projects aimed at developing models of research training in the field of mathematical education (InnoMathEd, Fibonacci, KeyCoMath, Scientix2, etc.). The rich potential of mathematical disciplines in the development of students' research skills is due to the uniqueness of the mathematical method based on the application of basic intellectual operations (analysis and synthesis, analogy, generalization and concretization), as well as universal abilities to prove, model, plan, and design.

This article highlights the issues of studying research activities as an important contribution to the development of the theory and methodology of teaching and upbringing in general and for a deeper understanding of the contribution of various disciplines, in particular mathematics, to the development of this phenomenon. A review of the scientific literature devoted to conceptual, theoretical, methodological, procedural and technological issues of the development of research activities (Kleshcheva, 2015; Savenkov, 2013), allowed to formulate a definition reflecting the essence of this phenomenon: "research activity is an active, creative process carried out in a state of uncertainty, aimed at obtaining subjectively new knowledge about the world around students through the application of the scientific method, as well as the formation of new personal structures (scientific thinking, scientific worldview, research experience)" (Dvoryatkina i dr., 2021). We consider research activity as a unique form of education, where participants in the educational process actively master theoretical and empirical methods of scientific knowledge, form research skills and interact with each other.

Most of the educational projects currently being implemented are aimed at using computer and network technologies that stimulate the rapid development of the digital educational environment, the constant updating of organizational forms and teaching methods, and the development of a methodology for managing research activities in automated learning systems (Guryanov, 2015; Kureichik, Bova, 2014; Lavrov, Barchenko, 2005; Cheng et al., 2020; Holmes et al., 2019; Klašnja-Milićević et al., 2017; Kozlov, Kozlova, 2012; Maaliw, 2020; Sinatra et al., 2020; Van der Linden, 2010). The most promising developments in this area include learning systems based on artificial intelligence methods, characterized by a flexible interface and a high degree of adaptability. Widespread foreign intelligent learning systems are Century Tech, Math-u-See, MATHia by Carnegie Learning, Education Perfect, Yixue Education, Wayang Outpost.

However, in Russia, learning systems based on an intellectual approach are rarely used in school education. Despite the large number of scientific papers devoted to intellectual support of educational research, including the creation and application of adaptive educational materials (Nirmalakhandan, 2007), the development of methodological tools that realize the possibility of solving problems based on the initiation of dialogue (Jonassen, 2000), many experts consider research activities to be too complex, inaccessible to modeling as a type of intellectual and creative activity and they assess its management as a very difficult task, within the framework of which the teacher cannot always control the process of achieving learning outcomes and adapt teaching methods to the individual characteristics of the student (Poddyakov, 2015; Savenkov, 2013).

As part of the implementation of the scientific project "Organization of a hybrid intellectual learning environment in the context of digitalization of general education (using the example of mathematics)", the authors created a hybrid intelligent learning system (HILS) based on artificial intelligence methods for the effective organization and support of students' research activities in the field of mathematics. This system has been implemented in the process of teaching mathematics at school.

When teaching mathematics at HILS, the research activity of students is realized in the process of solving an integral system of non-standard tasks of a motivational and applied nature, which are characterized by the lack of algorithmization, the multivariance of hypotheses and solutions, the need to establish diverse connections and relationships experimentally or theoretically. As a result of such activities, students discover new knowledge, master the methods of scientific knowledge that allow them to delve deeper into the essence of mathematical theories.

The purpose of the study is to develop diagnostic tools for assessing the formation of research activities of trainees and on the basis of statistical methods for verifying the effectiveness of the functioning of an intelligent learning system with innovative organizational and methodological support that supports research activities.

2. Methodology

Within the framework of the study, in order to assess the effectiveness of the functioning of a hybrid intelligent mathematics teaching system, the procedural side of research activity was taken into account when developing a system of criteria, which made it possible to consider it in line with a system-activity approach and assess the formation of such structural components as motive, purpose, conditions, actions, operations. From these positions, the main criteria for assessing the formation of research activities of high school students in teaching mathematics are: motivational and value-based (motivation and value orientation to research activities), cognitive (understanding the structure and methods of solving research problems), operational and activity-based (planning, hypotheses and their justification, rational use of time and resources, as well as teamwork in a group, mutual control), creative (creative attitude to educational and cognitive tasks), communicative (using communication as the main means of interaction and cooperation), reflexive-evaluative (analysis and evaluation of one's activities) (Smirnov et al., 2023). Table 1 presents the characteristics of the listed block of criteria, as well as a set of indicators reflecting the individual characteristics of each criterion. The indicators under consideration act as specific measures of criteria, opening up the possibility for their observation and measurement.

Table 1. A system of criteria and indicators for assessing the formation of students' research activities in teaching mathematics

Criteria	Indicators
Value-motivational: awareness of the importance of research activity as a component of a subjective position	-the presence of a cognitive need, -acceptance of the importance of mastering research skills, -conviction of the personal and social significance of the research being conducted
Cognitive: knowledge of the essence of research activity, availability of a system of special (mathematical) and methodological knowledge	-proficiency in various methods and techniques of research activity, skills for solving atypical cognitive problems, -formation of instructional-theoretical, technological and axiological components of research skills
Operational-activity: possession of key research skills	- ability to plan, organize, regulate and control research activities, - analytical and synthetic skills, skills of formulating hypotheses, defining a generic concept, as well as constructing proofs and refutations
Creative: the ability to think creatively and find non-standard solutions to problems	-independence of the idea and originality of problem solving, -the ability to transfer knowledge and methods of activity to a new situation, - independent search for sources of new knowledge, creative approach to the development of a new product
Communicative: the ability to build relationships between subjects of research activity	-communication and cooperation with research subjects, -readiness to overcome conflict situations, -the ability to defend one's own position using various types of speech activity
Reflexive-evaluative: self-criticism and objective self-assessment in research activities	-argumentation of the reasons for the failure to achieve the planned result, -detecting your own mistakes in your activities and determining ways to eliminate them, -the adequacy of the assessment of their capabilities.

In order to identify the effectiveness of the impact of the intellectual learning system on the level of development of students' research activities, preliminary and final monitoring of individual psychological characteristics was carried out on the basis of the developed set of criteria. At the same time, the quality of achievement of each of the criteria was assessed by a set of personalized parameters of scientific potential, the actualization of which is designed to ensure the adaptability of the hybrid intellectual system to the level of development of the motivational-need, emotional-volitional and cognitive spheres of each student. In general, research potential is understood as a set of unique personal aspects of the student, which affect his willingness and ability to intellectual research activities.

As a result of the study, four clusters of scientific potential parameters were identified, containing specific characteristics of research activity in the environment of HILS (Figure 1): personal (achievement orientation, stylistic features of thinking, logical component of cognition); activity (cognitive processes, visual and analytical-synthetic thinking, computing and design skills); communicative (empathic abilities, communicative tolerance, verbal intelligence); productive (originality, creative activity) (Dvoryatkina et al., 2021). The experimental verification of the effectiveness of the research activities of schoolchildren based on the intellectual management of mathematics teaching in the HILS was carried out with the participation of 1st and 2nd year students of the Institute of Secondary Vocational Education of I.A. Bunin Yelets State University, as well as high school students of Yelets schools. The experiment was conducted during the 2019–2020, 2020–2021, 2022–2023 academic years. A total of 131 students took part in the experiment.

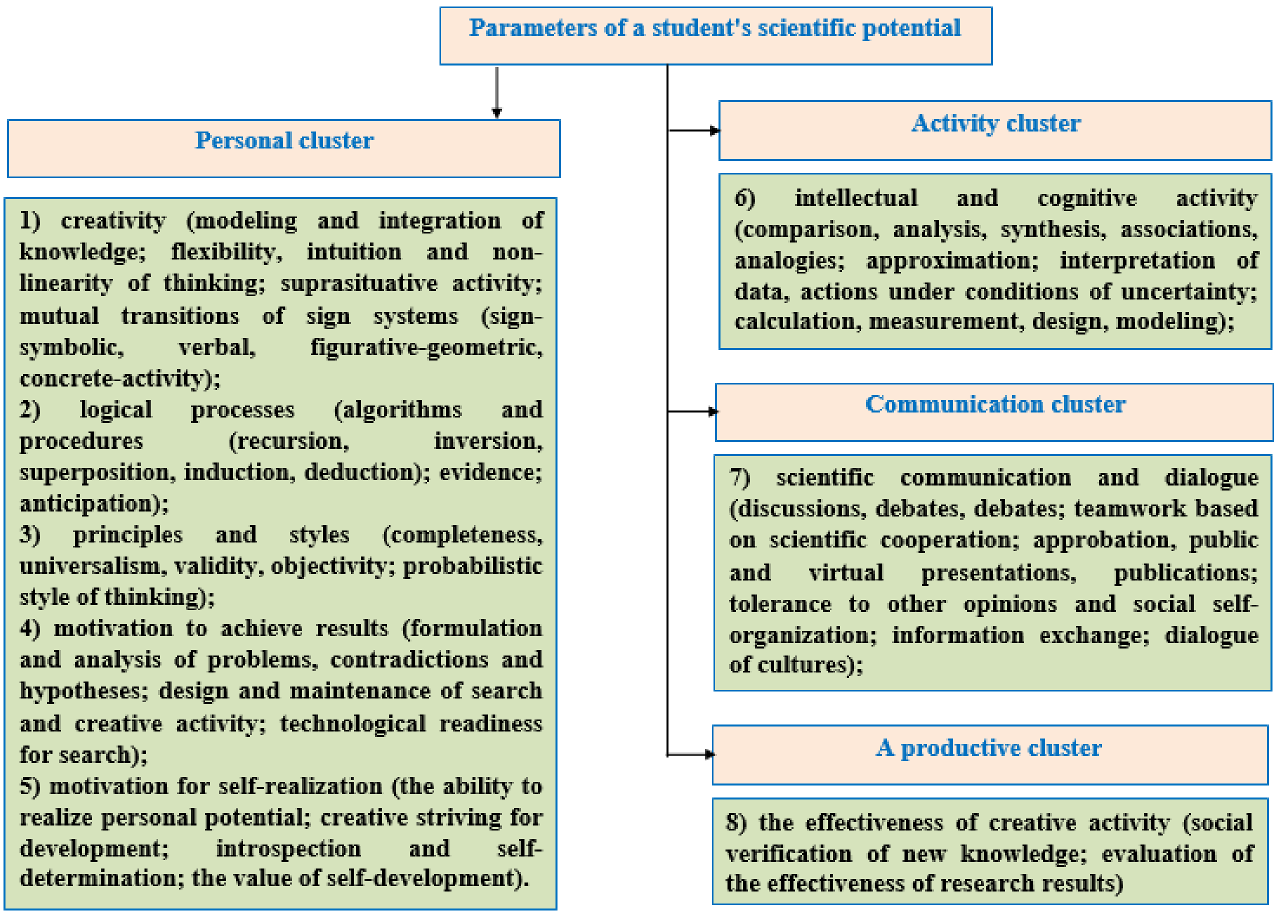

Fig. 1. Distribution of scientific potential parameters by clusters of individual characteristics of research activities in the field of mathematics

The main sampling strategy for statistical verification of the effectiveness of the functioning of an intelligent learning system was the method of forming a simple random sample – a simple non-repetitive sample. The main focus during group creation was on uniformity and representativeness, which is crucial for statistical processing of research results. In particular, an equal number of boys and girls with an average level of academic achievement in mathematics were selected for each age or class. The choice of teachers of these disciplines was carried out according to the principle of the same rating (pedagogical knowledge and skills). Descriptive statistics methods were used to process experimental data, as well as the following statistical criteria – the nonparametric G-criterion of signs, the Wilcoxon T-criterion, the multifunctional φ-criterion, the Piron χ^2-criterion and the parametric Student t-criterion.

To diagnose scientific potential, a set of qualimetric techniques was used, such as testing, psychodiagnostics, and expert assessment. At the same time, the activities of the trainees were monitored, group work, communication situations, discussions and procedures for the protection of research projects were analyzed. The initial, current and final measurements of the parameters of scientific potential were carried out using the module of a hybrid intelligent learning system (Figure 2) (Dvoryatkina, Golovin, 2023).

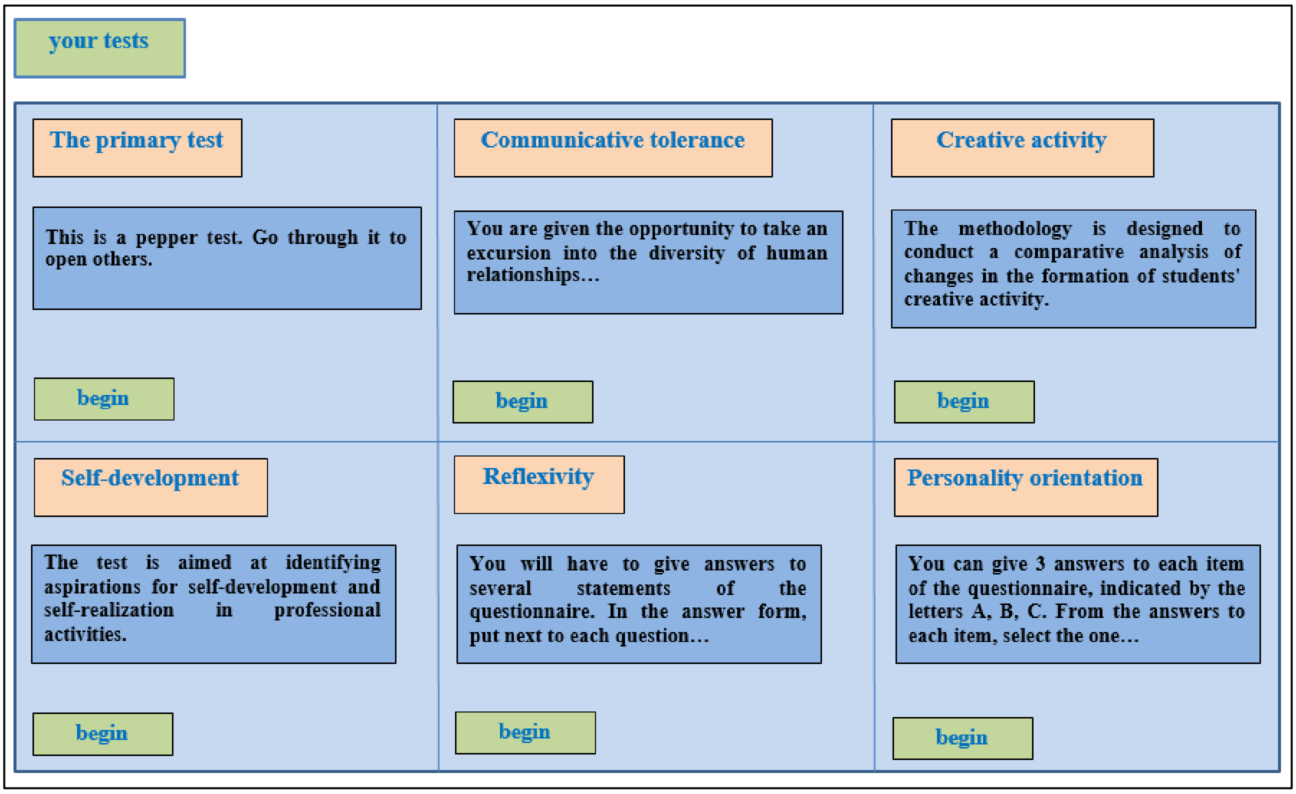

Fig. 2. A diagnostic testing environment for evaluating the effectiveness of the functioning of the HILS, accompanied by the research activities of schoolchildren in mathematics

In particular, the Amthauer intelligence structure test was used to evaluate such parameters as "Mastery of logical operations", "Intellectual and cognitive activity". The study and evaluation of the "Creativity" parameter was carried out using the D. Creativity questionnaire. Johnson. Diagnostics of the parameters "Motivation to achieve the goal" and "Motivation for self-realization" was performed by conducting a questionnaire test by A. Mehrabian and a test "Reflection on self-development" by L.N. Berezhnova, respectively. A questionnaire developed on the basis of theoretical assumptions about the structure of human values (M. Rokich) was used to study the parameter "Value orientations and the significance of research activities". The parameter "Thinking styles" was evaluated by means of the A. Alekseev, L. Gromova "Individual thinking styles" test. Despite the difficult diagnosability of the parameter "Scientific communication", the authors justified and considered the method of diagnosing the orientation of the personality of B. Bass for its assessment.

Empirically obtained weight values of the parameters of scientific potential made it possible to establish threshold values of diagnostic criteria for assessing the quality of research activities of high school students in teaching mathematics in a hybrid intellectual environment and to assess the level of manifestation of each of the criteria in 3 positions – low, medium, high. For example, the levels of development of the motivational and value component are presented as follows: low is a manifestation of situational passivity in relation to research activities; medium – active and conscious application of the research approach; high – clear internal motivation and a high degree of activity in research behavior. The gradation of the levels of formation of the creative component has the following characteristics: low – performing research tasks based on trivial representations; medium – the presence of individual elements of creativity in research procedures; high – the use of a creative search approach in solving mathematical problems.

3. Results

The study used several quantitative indicators of scientific potential to assess the effectiveness of the intellectual system. During experimental work, a cluster of individual characteristics of research activity was formed, which established statistically significant differences in the parameter "Logical processes". The sample consisted of 16 randomly selected trainees. Measurements were made before and after the experimental training. Prior to experimental training, the sample mean and standard deviations were $\bar{x}$ = 35,56; σ=6,87, after the experimental – $\bar{x}$ = 43,75; "σ = 4,47. Verification using the Student's t-test for dependent samples revealed that t_{emp}=2,49 > t_{kr}(0,05; 15)=1,75.

According to the parameter "Motivation for self-realization" of the personality cluster, an experimental check revealed significant differences in the level of self-development before and after working in a hybrid intellectual learning system. The distribution of the total number of points by levels obtained as a result of testing of trainees is shown in Table 2. As a result of data clustering, three groups of trainees with different levels of self-realization were identified: an insufficient level of self-realization, with an average level of self-realization and a high level of self-realization.

Table 2. Distribution of the total number of points of the trainees

Levels	Total points	Before, %	After, %
Low	18-29	44	6
Medium	30-39	50	75
High	40-49	6	19

The Pearson χ^2 criterion was used as the main statistical method to identify differences between two empirical distributions (χ^2 = 6,3, p<0,021, df = 2). The motive for self-realization has a positive effect on the ability to develop various ideas, solve various problems, formulate hypotheses, i.e. on the implementation of research activities by students. Motivation to achieve results was measured using questions taken from the A. Mehrabian questionnaire, which has two forms – for boys and girls and includes 32 and 30 questions, respectively. Two types of motives were taken into account: the desire for success and the desire to avoid failure. To select the dominant motive, the scores were summed up and the subjects were divided into two contrasting groups: 165-210 points (motivation to achieve success); 76-164 points (motivation to avoid failure). If empirical data fall within the range of 30-75 points, it is impossible to draw a conclusion about the dominant motive (Table 3).

Table 3. Distribution of respondents by motivation for achieving results

	The dominance of motivation for success	The dominance of the motivation of avoiding failure or there is no dominant motive
Before	12,5 %	87,5 %
After	37,5 %	62,5 %

The angular Fisher transform was used to assess whether the differences in the proportions of the characteristic characteristics between the two samples were reliable. Significant differences between the "before" and "after" indicators were found at a 5 % significance level: (φ^*_{emp} = 1,68 > φ^*_{kr} = 1,64). This allowed us to reject the hypothesis that there were no differences in the manifestation of the studied effect (dominance of motivation for success) in the trainees before and after the experimental exposure. Thus, respondents with a predominant motivation for the result are characterized by a high level of scientific potential.

The conducted experiment allowed us to establish a significant difference in the level of creativity of the trainees before and after the experimental exposure. The innovative approach proposed by the authors contributes not only to a deep understanding of mathematics, but also ensures the development of mathematical creativity. If before experimental training, the values of high and low levels of creativity among schoolchildren were 6 % and 43 %, respectively, then after studying at the HILS, it was possible to observe indicators in 6 % and 62 % of respondents. On the basis of Pearson 's χ2 criterion, significant differences in the level of creativity before and after experimental exposure were established: $\chi^2_{emp} = 7{,}5 \geq \chi^2_{kr}(0{,}05;2) = 5{,}99$.

The results obtained confirm the conclusions of studies that found that the search for solutions to complex problems in a hybrid open environment contributes to the acquisition of creative thinking skills (Waldrop, 2015; Hämäläinen, Vähäsantanen, 2011; Tan, 2009). In turn, Gerald F. Smith notes that the knowledge-intensive nature of innovative tasks creates the possibility of generating productive ideas and developing creativity (Gerald, 2003). Thus, students with a high level of creativity can achieve high results in the scientific field.

The distribution of trainees by levels of development of the parameter "Principles and styles" is shown in Table 4. It is obvious that the entire range of cognitive thinking styles is represented in the studied sample, while the predominant thinking styles of the trainees are idealistic (assessment of problem solving based on intuition, a broad information basis, formal logic, emotional states, subjective assessments and values) and pragmatic (reliance on individual experience in solving problems, focus on fast and the specific result of the activity, the use of widely available materials and information). The preference for practical activities, practice-oriented thinking, and the desire to control ongoing processes have a positive impact on readiness for research activities. At the same time, intuitiveness, increased interest in the goals and motives of research activities, and a tendency to control have a positive impact on the innovative nature of research activities.

Table 4. Distribution of thinking styles before and after experimental learning

Styles	before(%)	after (%)
analytical	13	42
synthetic	23	36
idealistic	45	33
pragmatic	39	29
realistic	33	25

The analysis of the distribution of stylistic features of thinking has established that after experimental training, the predominant analytical style of thinking is characterized by a tendency to systematic and comprehensive consideration of the object under study, a logical way of solving problems, and synthetic, expressed in the ability to combine various methods, conduct thought experiments, generate new ideas. In the course of research activities in a hybrid intellectual environment, such significant features as a tendency to in-depth analysis of issues, comprehensive and systematic consideration of the problem in those aspects that are set by objective criteria were formed. A slight change in the percentage of students with one of the most complex skills and a synthetic style of thinking that is difficult to develop after experimental training is due to a change in the conditions and means of learning. The ability to plan, design a solution to a problem, establish relationships between the elements of problem solving, and find a fundamentally new solution to a problem initiated the intensification of research activities. The combination of analysis and synthesis is a systematic thinking necessary to obtain a comprehensive understanding of a complex situation and problem and is an important element of research activity (Bartlett, 2001).

At the significance level of 0.05 %, the absence of significant differences in stylistic features among the trainees before and after experimental training was revealed (Table 5). The Student's t-test proved the normality of the trait distribution, and the accuracy of mode, median, and sample average was confirmed by using th 3-sigma rule.

Table 5. Comparison of the average of two samples based on the application of the Student's t-test

Styles	The empirical value of the t-test	The critical value of the t-criterion	$(\bar{x}; \sigma)$, before	$(\bar{x}; \sigma)$, after
analytical	1,8144	2,0211	(50,09; 7,81)	(52,00; 7,36)
synthetic	0,8545	2,0395	(55,86; 12,06)	(53,4; 5,82)
idealistic	1,0712	2,0227	(53,40; 7,81)	(51,09; 7,80)
pragmatic	0,5579	2,0322	(58,20; 9,93)	(56,81; 5,70)
realistic	0,9684	2,0369	(56,13; 11,46)	(53,45; 5,87)

Analyzing the results for the activity cluster (the parameter individual cognitive activity), we can conclude that there are minor differences in the shift of the obtained indicators. Applying the Student's t-test, it was decided to reject the null hypothesis at a 5 % significance level about the equality of the average two samples before and after experimental training $t_{emp} = 2{,}16 < t_{kr}(0{,}05; 15) = 2{,}13$. The "Paired two-sample t-test for averages" mode of the Excel TP was used for verification. Thus, a slight dynamics of intellectual cognitive activity was established due to the provision of a hybrid intellectual system for the regularity of tasks, a high level of independence of trainees, constant monitoring, self-organization of trainees, motivation for a sequence of actions and the need for intellectual activity.

Scientific communication in research activities serves as a presentation and measure of scientific productivity, an effective way to convey complex information, especially to an audience that is outside the field of scientific research, and is also necessary in communication activities with oneself, for example, in order to deal with complex mathematical concepts, focus on determining learning outcomes, etc. However, statistical verification using the G-criterion of signs did not reveal significant differences in the dynamics of scientific communication development at the 5 % significance level: $G_{emp} = 4 > G_{kr} = 2\ (0{,}05; 11 - \text{the number of typical shifts})$. The axes of significance in this criterion are inverted. Therefore, the null hypothesis is accepted: the increase in the level of scientific communication is accidental. This result is quite expected due to the fact that many aspects of the traditional model of scientific communication (scientific discussion of a question or group of questions, communicative interaction, communicative culture) are difficult to form when working in an intellectual learning environment. Verbal scientific communication in the form of an active dialogue or discussion is necessary.

The effectiveness of creative activity was tested on the basis of the Wilcoxon T-test. A significant change in the positive dynamics of this indicator was found at the 1 % significance level: $\mathrm{T}_{emp} = 24 > \mathrm{T}_{kr}(0{,}01; 16 - \text{total number of respondents}) = 23$ (the axes of significance in this criterion are inverted). Therefore, the null hypothesis is rejected: the intensity of shifts in the direction of increasing the level of creative activity does not exceed this indicator in the direction of decreasing. Creative activity is characterized by independent and original solutions to complex problems, the desire to penetrate deeply into the essence of phenomena, the active search for non-standard solutions, the free transfer of knowledge and skills to new situations. Therefore, this personality quality is an effective source of personal development and an important indicator of the level of formation of research activity, and a hybrid intellectual environment creates conditions for its effective development by solving complex, non-standard research tasks.

4. Discussion

The monitoring of the individual psychological characteristics of students made it possible to identify the optimal parameters of the psychological readiness of schoolchildren for research activities in the context of the implementation of a hybrid intellectual learning environment, among which the authors include motivation to achieve goals and motivation for self-realization, value orientations and the importance of research activities, the cognitive component of creativity, mastery of logical operations, thinking styles, skills, skills and experience design and research activities, readiness for scientific communication and dialogue. Thus, personalized parameters of scientific potential, grouped into four clusters (personal, communicative, activity, and productive), were introduced into the scientific field, which determine the content of the structured educational content of the intellectual learning system.

The theoretical value of the results obtained consists in expanding the conceptual understanding of the system of psychodiagnostic research of the quality and success of students' research activities in the context of the implementation of a hybrid intellectual environment. The developed diagnostic complex for assessing the parameters of scientific potential is important both for psychological science and for the theory and practice of introducing intelligent systems into the field of education.

The practical value of the experimental results lies in the fact that they act as the technological basis for the formation of a set of parameters of the integrated model of the learner for setting adaptation algorithms, as well as the preliminary formation of a system of didactic, setting-target, meaningful and logical-structural conditions in order to minimize the imprinting time of a hybrid intelligent system by selecting the topology of a neural network. The diagnostic experiment investigated how the saturation factor of the information environment affects the psychological readiness of students for research activities. A significant positive effect has been established on such indicators as principles and styles, motivation to achieve, and logic processes of early immersion in the academic scientific space.

The results obtained do not contradict the already available data in the field of activating the research potential of trainees through modern methods and tools (Bartlett, 2001; Gerald, 2003; Waldrop, 2015; Hämäläinen, Vähäsantanen, 2011; Tan, 2009). At the same time, the proposed technological solution has a number of advantages over previously developed intelligent learning systems. Utilizing a blend of methodologies in the creation of an advanced system is crucial to mitigate the potential dangers linked to inaccuracies in tracking individual paths. The developed intellectual system is not only focused on teaching subject knowledge and skills, but also contributes to the effective development of the student's personality through involvement in the process of solving non-standard mathematical problems, which generally contributes to the formation of a stable knowledge system, the development of cognitive abilities, motivation, and research thinking. The outcome of research endeavors focused on the advancement of comprehensive constructs of intricate knowledge is the expansion of scientific capacity, ingenuity, and analytical reasoning, consequently leading to an enhancement in the standard of mathematical instruction in educational institutions.

Optimization of algorithms for building a knowledge space; improvement of technologies for storing, processing and presenting the structure of knowledge; detailing the complex of psychological and pedagogical conditions for the use of a hybrid intelligent mathematics teaching system; expansion and enrichment of organizational and methodological support for the functioning of this system can be considered as prospects for further research in the process of testing an intelligent mathematics teaching system. The solution of these large-scale tasks will contribute to the further transformation of the landscape of traditional mathematical education in the direction of creating a high-tech educational space in which artificial intelligence mechanisms act as a means of interactive interaction of all subjects in the context of global scientific discourse.

However, despite the identified positive effects of the introduction of a hybrid intellectual system in the process of teaching mathematics (the possibility of personalizing learning, building an individual educational trajectory, developing important social skills such as creativity, critical thinking, self-regulation of behavior), a number of potential problems and limitations associated with the process of incorporating this technological solution into the educational environment can be indicated schools. In particular, they should include the presence of limiting characteristics of the degree of intellectualization of the system, established by the developers and limiting its capabilities in terms of self-learning, data synthesis and analysis, perception of the full range of the sensory-emotional sphere of subjects of education, as a result of which the system remains only a means of simulating the situation of "live communication". On the other hand, the desire of developers to strengthen the autonomous nature of the functioning of a hybrid intelligent system requires continuous analysis of the dynamics of its operation, assessment of the correlation dependence of the implemented algorithms and learning outcomes, predictive analytics, which significantly complicates the process of integrating such software products with the digital educational environment.

5. Conclusion

During the investigation, the researchers formulated a set of standards for measuring the efficiency of the mixed cognitive system of math instruction, enabling a thorough evaluation of the development of all essential elements of students' academic performance – motivational, cognitive, activity, communicative, reflective. The developed criteria and indicators are able to provide an objective assessment of the dynamics of the development of research activities of high school students in the process of teaching mathematics, which makes a significant contribution to the expansion of organizational and methodological support for the process of teaching mathematics using innovative digital technologies.

Monitoring of the individual psychological characteristics of the formation of the parameters of scientific potential before and after the application of the system of intellectual support of research activities based on a set of qualimetric techniques makes it possible to more accurately select the content of structured educational content, differentiate the levels of success and quality of research activities in the layers of a hybrid neural network.

An analysis of the empirical results of the study using a set of mathematical and statistical methods showed a positive dynamics in the level of development of research skills and abilities in experimental groups of students, ensuring the reliability of previously obtained theoretical conclusions about increasing the level of research potential in the context of the implementation of a hybrid intellectual system of teaching mathematics.

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