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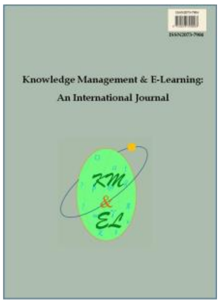

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Development of logical thinking of future doctors with the application of logical tasks

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Abstract: This article presents the outcomes of a pedagogical experiment conducted to assess the efficacy of incorporating experimental logical tasks and exercises within the curriculum of the discipline “Medical Informatics” as a means to foster the development of logical thinking among future medical professionals. The study emerged from the observation of deficient logical reasoning skills among medical students, prompting an investigation into the role of logical thinking in the diagnostic process of physicians. The research involved diverse groups, including medical students, experienced doctors, and educators. The following methods of research were used to achieve the goal of the experiment: Theoretical, in particular, modeling method to identify pedagogical conditions and develop the technology of forming logical thinking of future doctors; empirical, in particular, pedagogical experiment, which allowed to check the effectiveness of technology and developed methodological support of the formation of logical thinking of future doctors and statistical methods of research for quantitative processing of research results and confirmation of their authenticity. The analysis of the results of the pedagogical experiment revealed a decrease in the number of students at a low level and an increase in the number of students at satisfactory and high levels of logical thinking development. The results of statistical data confirm the effectiveness of pedagogical technology in introducing a system of tasks aimed at the development of logical thinking in future doctors.

Keywords: Clinical thinking; Logical thinking; Future doctor; Medical informatics

Biographical notes: Dr. Natalia Lobach serves as an Associate Professor in the Department of Physics at the Medical University. Her research focuses on the formation of information and analytical competence of future doctors in the educational environment of higher medical educational establishments. Dr. Lobach dedicates her research efforts to scrutinizing the integration of information technologies within the realm of medical education, with a keen focus on assessing the efficacy of diverse instructional approaches aimed at augmenting learning outcomes.

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1. Introduction

The dynamic landscape of social and cultural developments, the evolving labor market and professions, and the technological underpinnings of professional activities collectively compel the education system to mold individuals who are not only qualified specialists but also independent, creatively developed personalities capable of critical and logical thinking (Bazmi, 2022; Canas et al., 2017; Shubina et al., 2021). The thinking skills among future medical professionals play a key role in the ability to make informed decisions, and it is crucial to make teaching these skills to future generations a major goal in the education system (Jeong & Kim, 2022; Macri, 2019).

However, the development of critical thinking is inseparable from the cultivation of logical thinking. The ability to logically analyze information, identify connections, and follow a sequence of thoughts forms the foundation for the development of critical skills. (Janveau-Brennan & Markovits, 1999). Logical thinking provides the basis for assessing situations, making informed decisions, and constructing arguments during the process of critical analysis.

We analyzed various approaches and pedagogical methods for developing students' logical thinking, including:

Solving problems and puzzles: This method engages students in analytical thinking and problem-solving skills. Chakraborty and Paul investigated the effect of using electrical engineering puzzles on the formation of recognition and problem-solving skills (Chakraborty, 2018).

Discussions and debates: The discussion method involves a collective exchange of opinions on a topic or problem, fostering the development of critical thinking. According to Wilkinson, this method cultivates students' courage to express opinions and criticize others' viewpoints in a forum (Murphy et al., 2009). Students are required to logically present their points of view and analyze the arguments of their opponents (Budiyono et al., 2021). Yamamoto et al. (2013) also keep the idea that higher education should focus on developing students' logical thinking or reasoning skills through debate.

Project and case method: Engaging students in projects that require problem-solving enhances their ability to apply logic in practical scenarios. Existing studies have demonstrated the positive impact of the Mind Mapping method on the development of logical thinking (Canas et al., 2017; Swestyani et al., 2018). Creating specific cases necessitates the analysis of particular situations, argumentation, and decision-making, contributing to the overall development of logical thinking.

Interactive methods, such as role-playing games, simulations, and group exercises: These activities help students apply logical thinking in diverse situations. For instance, Heliawati et al., (2022) investigated the positive effectiveness of Articulate Storyline 3, a multimedia tool incorporating gamification, on students' critical thinking skills and self-regulated learning in a science course.

Soufan et al. (2006) suggest developing college courses and materials to enhance students' logical thinking abilities for their importance in clinical careers. Also, they developed a modified version of the Test of Logical Reasoning (TOLT) developed by Frank Etzler and Michael Madden, especially for medical students (Etzler et al., 2014).

Even though these approaches to the formation of logical thinking have proven their effectiveness in various fields, it is important to note that there is a lack of sufficient methods and resources specifically designed to develop the logical thinking of future health professionals. This gap was the catalyst for further study and consideration of this issue in our research.

Crucially, the professional success of a doctor is contingent upon various factors, with the quality of their thinking being paramount. This involves the conscious application of logical operations, including analysis, synthesis, comparison, generalization, abstraction, concretization, systematization, and classification. Additionally, logical forms of thinking, such as concepts, judgments, and inferences, play a pivotal role. The intricate interplay of these logical elements is indispensable in the construction of mental actions, aligning with the demands of the profession (Baserer, 2020).

A cornerstone of a doctor's practical skillset lies in the development of clinical thinking, which is a continuous process evolving through learning and professional experiences (Faucher, 2011; Kaiukova, 2015; Oliveira et al., 2023; Simmons, 2010). We echo the sentiments of Zhao et al. (2020) that correct diagnostic formulation is a multifaceted process relying on logical operations. The careful construction of conclusions, judgments, and concepts necessitates adherence to the laws of logic, underscoring our belief that logical thinking forms the bedrock of clinical thinking (Machin et al., 2022).

This conviction is further substantiated by the resemblance between clinical and logical thinking. Both are rooted in operations such as feature identification, analysis and synthesis, comparison, abstraction, generalization, logical deductions, induction and deduction, as well as drawing upon knowledge, experience, and various other elements (Locke et al., 2020).

The challenge of instilling clinical thinking skills typically emerges during senior courses when nosology is studied, and direct practical interaction with patients occurs. However, the groundwork for this complex task begins in junior courses, where the focus is on preparing students for the responsibility ahead by fostering the development of their logical thinking. This emphasis aligns with the competency model essential for the training of future doctors.

Negreiros et al. (2022) argue that logical thinking is a tool for clinical care, and the exercise of effective clinical care necessitates logical thinking. Hunink (2014), Schleifer and Vannatta (2006), and Stanley and Campos (2013) emphasize the need to develop tools to help foster logical thinking among future doctors, which also facilitates understanding of the diagnostic process.

To systematically enhance the logical thinking of future doctors, purposeful efforts should be integrated into the study of various disciplines. Mathematics and natural sciences, given their inherent logical structures, are often prioritized for this purpose. According to the educational professional programs "*Medicine*", "*Dentistry*" and "*Pediatrics*" the general competencies that should be formed in future doctors include the ability to think abstractly, analyze and synthesize information, learn and master modern knowledge, and search, study, and analyze information from various sources.

The study represents a significant advancement in medical education by introducing an innovative pedagogical approach focused on integrating logical tasks into the curriculum of "*Medical Informatics*". It not only identifies a deficiency in the logical reasoning skills of medical students but goes further to address this gap by developing a systematic framework for the purposeful development of logical thinking skills. The study's emphasis on the link between logical and clinical thinking adds depth to the understanding of cognitive processes crucial for medical professionals.

Furthermore, the findings of the study extend beyond the medical field, suggesting that the proposed pedagogical approach and framework have broader implications for educational practices in various disciplines. The study advocates for a transformative pedagogical approach, recognizing the inadequacy of traditional teaching methods and emphasizing the need for purposeful, systematic efforts in logical skill development. It aligns with evolving paradigms in education by emphasizing the importance of cognitive skills alongside domain-specific knowledge, reflecting a contemporary understanding of education that prioritizes critical and logical thinking skills.

With this in mind, the aim of the article is to present carrying out the pedagogical experiment and its results. The main goal of the pedagogical experiment is to investigate the influence of the experimental logical tasks and exercise system on the development of logical thinking of future doctors during the study of the discipline of "*Medical Informatics*".

The objectives of the research were: 1) to introduce a system of logical tasks and exercises into the "*Medical Informatics*" training course; 2) to find out whether this system can improve the logical thinking skills of future doctors, their ability to analyze information, build logical chains and produce persuasive arguments.

2. Materials and methods

2.1. Participants

The study involved participants at different stages, including medical students (pilot experiment), experienced doctors (survey), and teachers (survey). The main experimental groups consisted of second-year students from the medical and dental faculties at Poltava State Medical University.

2.2. Research context

The initial pilot experiment with medical students revealed challenges in logical thinking, prompting a broader investigation into the role of logical reasoning in the professional activities of physicians. Subsequently, a survey was conducted among experienced doctors and teachers to gather insights into their perspectives on logical thinking in medical education.

2.3. Research design

The research followed a mixed-methods design, incorporating both qualitative and quantitative elements. The pedagogical experiment was organized in three stages (ascertaining, formative, and control). A comparative approach was employed, with the experimental group receiving systematic and purposeful logical thinking development, while the control group had traditional classes with no specific interventions.

Research Procedure. The study proceeded through the following stages:

1. Surveying experienced doctors and teachers to understand their perspectives on logical thinking in medical education.
2. Conducting a pilot experiment with medical students to identify challenges in logical thinking.
3. Conducting a comprehensive literature review, synthesizing insights from philosophical, psychological-pedagogical, and scientific-technical sources.
4. Identifying pedagogical conditions and developing technology for the formation of logical thinking in future doctors.
5. Determining criteria and indicators for assessing the formation of logical thinking.
6. Organizing a pedagogical experiment.

2.4. Instrument

The use of multiple instruments, including tests and questionnaires tailored for students, teachers, and doctors. These instruments were meticulously crafted to gather information on participants’ perspectives, experiences, and the impact of pedagogical interventions on logical thinking development.

2.5. Data collection

The tests and questionnaires were administered to students, teachers, and doctors to gather both quantitative and qualitative data at different stages of the experiment, including the pilot experiment, the survey, and the three stages of the pedagogical experiment.

2.6. Data analysis

The collected data were analyzed using statistical methods. The analysis included comparing results between the experimental and control groups, identifying existing levels of logical thinking, and validating the effectiveness of pedagogical interventions.

This comprehensive methodological approach aimed to explore the effectiveness of pedagogical interventions in shaping the logical thinking capabilities of future doctors. The results and discussions from the experiment will provide insights into the development of logical thinking in the context of medical education.

2.7. The description of the research

In the context of a scientific study, a pilot experiment involving medical students was conducted to assess their logical thinking. Participants were presented with simple logical tasks in the form of puzzles and logic tests. Despite the expectation that the tasks would be relatively easy, a significant number of students were unable to successfully complete the assigned tasks.

The unsuccessful task performance prompted researchers to delve deeper into understanding the role of logical reasoning in the professional activities of a physician. To achieve this, a survey was conducted among experienced doctors representing various fields of medical practice (34 participants). Respondents were asked questions, revealing that a doctor’s thinking during the diagnostic process should be definite, consistent, and evidence-based. Making a correct diagnosis is a complex process that involves working with conclusions, judgments, and concepts. Each of these forms of thinking requires the obligatory observance of the laws of logic.

Thus, the development of logical thinking in future doctors is an urgent concern for higher medical educational institutions. The results of a survey among teachers (25 participants) revealed a contradiction: all teachers (100%) recognize the need for the development of logical thinking in the process of professional training for future doctors. However, they lack awareness of its essential characteristics, structure, and organizational methods. Almost 17% suggest that the formation of logical thinking, crucial for future doctors, is possible when studying disciplines in the general training cycle, while 83% of respondents claim that only the disciplines in the professional training cycle can fully shape the logical thinking of future doctors.

Regarding the concretization of academic subjects in which clinical thinking is formed to the greatest extent, the teachers emphasized only practical disciplines with direct contact with the patient. From this, it becomes clear that the majority of respondents identify the concept of clinical and logical thinking. They define it as a diagnosis and methods of treatment adequate to its results. At the same time, this is considered the main setting in the educational process of higher medical educational institutions and the main activity of students.

Consider the features of the development of logical thinking in the process of training future doctors, using the example of the discipline “*Medical Informatics*”. The purpose of studying this discipline is to form and develop competencies aimed at the use of modern computer technology in medicine and healthcare, gain knowledge about informatization methods of medical activities, automation of clinical trials, computerization of management in the healthcare system, and the ability to use modern general and special purpose software in the processing of medical and biological data. The teaching content of this discipline is designed based on the specifics of future professional activities of students. We put forward a hypothesis: the development of logical thinking in students in the study of medical informatics will be most productive if specially designed tasks are purposefully used in the classroom. These tasks provide for the necessary minimum of students’ logical skills and are also aimed at acquiring the necessary knowledge in the discipline.

The tasks that were solved during the ascertaining experiment were as follows:

- To study the state of the development of logical thinking of future doctors;
- To develop a technology for the formation of logical thinking in future doctors;
- To determine the criteria and indicators for assessing the formation of logical thinking;
- To identify and justify statistical methods for evaluating the results of experimental work;
- To identify the existing level of formation of students' logical thinking;
- To prepare teachers for the formation of logical thinking in future doctors.

The ascertaining experiment aimed to check the formation of logical thinking in future doctors according to all indicators and criteria.

There are three forms of logical thinking: concept, judgment, and conclusion. A concept is a form of thinking that reflects the general, essential, and distinctive features of objects and phenomena. A form of thinking that reflects the connections between objects and phenomena, their properties and characteristics, is called judgment. A conclusion is a form of thinking in which a person, comparing and analyzing different considerations, derives a new judgment from them (Luna-Guevara et al., 2021; Shuib et al., 2021). Therefore, we have identified the following skills that are necessary for the development of clinical thinking:

- To operate with concepts, establish connections between them, and correctly formulate definitions of concepts;
- To express judgments, to prove their truth, using correct and convincing arguments, expressing opinions clearly, consistently, and reasonably;
- To establish inferences, verify the accuracy of conclusions, rebut false conclusions, and identify logical errors in reasoning.

Thus, to determine the level of formation of logical thinking of future doctors at the ascertaining stage of the experiment, the following techniques were used:

- The short indicative test (SIT) by Buzin and Vanderlik is designed to diagnose the general level of intellectual abilities, which allows for determining the ability of students for further study and cognitive activity.
- Raven's progressive matrices test is used to test the level of development of attention, perception, and figurative thinking, such as establishing relationships, finding analogies, progressive changes, the principle of regrouping, analysis, and synthesis.
- Rudolf Amthauer subtests, including the 1st "*Logical selection*", 3rd "*Analogy*", 4th "*Classification*", and 6th "*Series of numbers*", assess numerical and spatial thinking, logical abilities, attention, and memory. They also evaluate the classification of concepts, establishment of analogies, bringing two concepts under the general category (generalization), and the ability to find numerical patterns.

The scientific validity and reliability of these methods have been corroborated by numerous studies, rendering them pertinent tools for the meticulous assessment of various cognitive abilities in the context of our research. This introduction sets the stage for a comprehensive exploration of the results obtained during the ascertaining experiment, shedding light on the efficacy of the pedagogical interventions in shaping the logical thinking capabilities of future doctors.

3. Results and discussion

Experimental verification of the development of logical thinking of future doctors was organized and conducted in three stages (ascertaining, formative, and control) during 2020 – 2022 at Poltava State Medical University. The experiment involved second-year students of medical faculties №1, №2, and dental faculties majoring in "*Medicine*", "*Pediatrics*" and "*Dentistry*". The general model of the pedagogical experiment was based on the comparison of control and experimental groups. The experimental group (EG) included 127 students, and the control group (CG) had 134 students. In the control group, no additional conditions were created for the development of logical thinking, and classes were held traditionally, while in the experimental group, the development of logical thinking was carried out systematically and purposefully using the technology developed by us. The results of solving the problems of each method described above are presented in Table 1.

Table 1
Indicators of experimental groups and controls at the stage of experimentation determination

Method	Groups	The level of formation					
		low		sufficient		high	
		N	%	*N*	%	*N*	%
SIT	CG	10	7.46	104	77.61	20	14.93
	EG	9	7.09	103	81.10	15	11.81
Raven's progressive matrices	CG	39	29.10	87	64.93	8	5.97
	EG	40	31.50	80	62.99	7	5.51
R. Amthauer's 1st subtest "*Logical selection*"	CG	14	10.45	108	80.60	12	8.96
	EG	16	12.60	101	79.53	10	7.87
R. Amthauer's 3rd subtest "*Analogies*"	CG	16	11.94	102	76.12	16	11.94
	EG	12	9.45	94	74.02	21	16.54
R. Amthauer's 4th subtest "*Classification*"	CG	20	14.93	101	75.37	13	9.70
	EG	25	19.69	86	67.72	16	12.60
R. Amthauer's 6th subtest "*Series of Numbers*"	CG	32	23.88	96	71.64	6	4.48
	EG	33	25.98	91	71.65	3	2.36

Verification of group homogeneity was carried out using the criterion of homogeneity χ^2 – criteria, the results of which are presented in Table 2.

Thus, the experimental and control groups of students can be considered to have the same level of development of logical skills being diagnosed. All of this allowed us to conclude that the formative stage of the experimental work was successful.

In the experimental groups during the two semesters of 2020-2021, each lesson in medical informatics used exercises and tasks aimed at developing various components of logical thinking. Practical classes in medical informatics enabled students to master the technology of processing medical and biological information, study the principles of intelligent information systems, and grasp the basics of mathematical logic. Occasionally, this posed challenges in mastering the study material; however, the tasks offered to students in the formative stage of the experiment were designed to pique the interest of future physicians.

Table 2
The value of criterion χ^2 at the ascertaining stage of the experiment

Indicators	The value of χcriterion 2	
	CG / EG	Tabular value
SIT	0.58	5.99
Raven's progressive matrices	0.19	
R. Amthauer's 1st subtest "*Logical selection*"	0.36	
R. Amthauer's 3rd subtest "*Analogies*"	1.39	
R. Amthauer's 4th subtest "*Classification*"	1.88	
R. Amthauer's 6th subtest "*Series of Numbers*"	0.96	

The main methods used during the explanation of the material included game methods, the method of creating a problem-searching situation, the method of "brainstorming" the case method, and discussion. Additionally, other methods were employed to develop basic mental operations such as analysis, synthesis, comparison, generalization, abstraction, classification, regularity, and exercises to build a conclusion based on the comparison of judgments and their proof.

For instance, the game method was implemented at the beginning of the lesson to spark students' interest and motivation when introducing a new topic. Tasks included puzzles, riddles, anagrams, and cryptograms. After capturing students' interest, the teacher explained the meaning and relevance of the new concept, involving students in the self-assembly of puzzles, anagrams, or cryptograms.

An example of the case method used in the lesson is the work on the topic "Health System Information Resources." The purpose of the case was to determine the criteria for assessing the reliability of information sources. The situational task for the lesson is framed as follows: "*Mobile phones are detrimental to human health. Based on information analysis, students are given the task of finding confirmation or refutation of this statement, compiling a bibliographic list of used literature, and determining the criteria of reliability and importance by which to evaluate information sources.*"

The teacher shared the task with students a few days before the lesson to allow time for information gathering. Students were divided into three subgroups: the first searched for information using only library collection catalogs; the second used internet resources; the third used all sources without restrictions.

During the first stage of the lesson, each subgroup presented a report on the given topic, either refuting or confirming the allegations about the harm of mobile communications, supported by facts from scientific literature in the medical field. At the conclusion, the sources used were indicated, and criteria were defined to assess the reliability and importance of the information found in solving the task.

The second stage of the lesson involved determining general criteria for establishing the reliability of information sources. It was concluded that these criteria would help verify information in terms of reliability and increase confidence in information security.

The case method aimed to resolve the problem by generating new ideas. Students learned to analyze information, synthesize information, formulate conclusions, and prove the truth from their perspective.

In agreement with Shafina et al. (2020) and Belousova and Belousova (2020), we acknowledge that problem-solving is one of the most important tools for developing logical thinking. A task is considered a complex information system about a phenomenon, object, or process, where only a portion of the information is clearly defined, and the remainder is unknown. The solution can be obtained by analyzing information formulated in a way that introduces inconsistencies and contradictions between individual concepts and provisions, necessitating the search for new knowledge, evidence, transformations, agreements, etc.

In the example of the topic "*Formal logic in solving problems of diagnosis, treatment, and prevention of diseases*", students mastered the basic concepts of the algebra of logic and developed skills to apply them to classical logic problems and problems of medical content. For instance, given that blood group IV occurs in children if their parents have the following groups: II and III, II and IV, III and IV, or IV and IV, if a child has blood group IV and the mother has group II, can a man with blood type II be the father of the child? The method of solving such a problem can be tabular, using the truth table; analytical thinking; using spreadsheets; or using the logical operators "*if*", "*or*", "*and*". In any case, the student should apply logical thinking skills.

After mastering the theoretical material and completing the practical task, students had the opportunity to test their acquired knowledge through computer-based test control. The compiled tests included the following types of questions: single-choice, multiple-choice, open question, compliance question, and orderly list. Through these question types, future doctors learned to analyze information, compare facts, concepts, and definitions, build a logical chain, etc. Analysis of the experimental exercises carried out by the students revealed that the students showed interest in achieving success, positively impacting the emotional background of the lesson and the overall motivation of future doctors. The students' answers became more convincing and persuasive.

To determine the dynamics of the development of logical thinking, the final stage of the experiment was carried out using the same methods as the ascertaining stage. A comparative analysis was conducted to establish the differences between the results obtained during the initial measurement between the experimental and control groups (see Table 3).

Table 3
Indicators of the experimental and control groups at the control stage of the experiment

Method	Groups	The level of formation					
		low		sufficient		high	
		N	%	*N*	%	*N*	%
SIT	CG	9	6.72	106	79.10	19	14.18
	EG	2	1.57	100	78.74	25	19.69
Raven's progressive	CG	38	28.36	88	65.67	8	5.97
matrices	EG	20	15.75	95	74.80	12	9.45
R. Amthauer's 1st subtest	CG	14	10.45	107	79.85	13	9.70
"*Logical selection*"	EG	5	3.94	101	79.53	21	16.54
R. Amthauer's 3rd subtest	CG	11	8.21	108	80.60	15	11.19
"*Analogies*"	EG	5	3.94	95	74.80	27	21.26
R. Amthauer's 4th subtest	CG	18	13.43	103	76.87	13	9.70
"*Classification*"	EG	11	8.66	87	68.50	29	22.83
R. Amthauer's 6th subtest	CG	33	24.63	95	70.90	6	4.48
"*Series of numbers*"	EG	15	11.81	103	81.10	9	7.09

The reliability of the obtained results was checked by us using the χ^2 – criterion. Measurement data of the χ^2 – criterion of changes between EG and CG at the end of the molding experiment are presented in Table 4.

Table 4
The value of the χ^2 – criterion of the control experiment

Indicators	The value of χ^2 - criterion	
	CG / EG	Tabular value
SIT	5.26	5.99
Raven's progressive matrices	6.47	
R. Amthauer's 1st subtest "*Logical selection*"	6.14	
R. Amthauer's 3rd subtest "*Analogies*"	6.33	
R. Amthauer's 4th subtest "*Classification*"	8.95	
R. Amthauer's 6th subtest "*Series of Numbers*"	7.49	

According to the results of this table, it can be argued that EG and CG have values of the χ^2 – criterion much more than the table, which indicates significant changes. Thus, we prove the hypothesis that spontaneous full-fledged development of logical thinking does not occur. It is necessary to carry out purposeful, systematic, specially organized work on the formation of logical skills on the material of various disciplines. In the process of studying medical informatics, it is possible and necessary to create favorable conditions for the development of logical thinking of students. One of the ways to develop logical thinking is to include in the educational process a variety of exercises and tasks with logical operations, concepts, judgments, and conclusions.

The dynamics of the level of logical thinking among future doctors and the effectiveness of experimental logical tasks and exercises in the study of "*Medical Informatics*" were determined based on the results of selected methods, as shown by the calculations of growth of relevant indicators (see Table 5).

The visual representation of the dynamics of logical thinking efficiency indicators in future doctors is presented in Fig. 1.

A comparative analysis of the results obtained during the ascertaining and control stages of our experimental work unveils noteworthy insights into the impact of our pedagogical interventions on the logical thinking abilities of future doctors.

The "*Short Approximate Test*" by Buzin and Vanderlik demonstrated a remarkable improvement in the experimental group, with a 7.89% increase at the high level compared to the beginning of the experiment. This surge underscores the heightened proficiency of future doctors in verbal, logical, numerical, and spatial capabilities. The ability to comprehend causation, discern patterns, draw accurate conclusions, and manipulate spatial representations also witnessed notable advancements.

The outcomes of the visual thinking test, exemplified by Raven's test, showcase a positive trend. There was a 3.94% increase in high-level students and a substantial 15.75% reduction in low-level students. This shift suggests the formation of skills crucial for pattern recognition, analytical thinking, and drawing conclusions by analogy.

Analyzing R. Amthauer's 3rd subtest "*Analogies*", the experimental group exhibited a commendable 4.72% increase in students with a high level of proficiency in drawing conclusions by analogy. Conversely, the control group's results remained relatively unchanged, with a marginal decrease of 3.73% in low-level students.

Table 5
Dynamics of indicators of efficiency of technology of formation of logical thinking at future doctors

Levels	Slices	KG		Increase	EG		Increase
		134	%	%	127	%	%
SIT							
Low	I	10	7.46	- 0.75	9	7.09	- 5.51
	II	9	6.72		2	1.57	
Sufficient	I	104	77.61	1.49	103	81.10	- 2.36
	II	106	79.10		100	78.74	
High	I	20	14.93	- 0.75	15	11.81	+ 7.87
	II	19	14.18		25	19.69	
Raven's progressive matrices							
Low	I	39	29.10	- 0.75	40	31.50	- 15.75
	II	38	28.36		20	15.75	
Sufficient	I	87	64.93	0.75	80	62.99	+ 11.81
	II	88	65.67		95	74.80	
High	I	8	5.97	0.00	7	5.51	+ 3.94
	II	8	5.97		12	9.45	
R. Amthauer's 1st subtest "*Logical selection*"							
Low	I	14	10.45	0.00	16	12.60	- 8.66
	II	14	10.45		5	3.94	
Sufficient	I	108	80.60	- 0.75	101	79.53	0.00
	II	107	79.85		101	79.53	
High	I	12	8.96	0.75	10	7.87	+ 8.66
	II	13	9.70		21	16.54	
R. Amthauer's 3rd subtest "*Analogies*"							
Low	I	16	11.94	- 3.73	12	9.45	- 5.51
	II	11	8.21		5	3.94	
Sufficient	I	102	76.12	4.48	94	74.02	+ 0.79
	II	108	80.60		95	74.80	
High	I	16	11.94	-0.75	21	16.54	+ 4.72
	II	15	11.19		27	21.26	
R. Amthauer's 4th subtest "*Classification*"							
Low	I	20	14.93	- 1.49	25	19.69	- 11.02
	II	18	13.43		11	8.66	
Sufficient	I	101	75.37	1.49	86	67.72	+ 0.79
	II	103	76.87		87	68.50	
High	I	13	9.70	0.00	16	12.60	+ 10.24
	II	13	9.70		29	22.83	
R. Amthauer's 6th subtest "*Series of numbers*"							
Low	I	32	23.88	0.75	33	25.98	- 14.17
	II	33	24.63		15	11.81	
Sufficient	I	96	71.64	- 0.75	91	71.65	+ 9.45
	II	95	70.90		103	81.10	
High	I	6	4.48	0.00	3	2.36	+ 4.72
	II	6	4.48		9	7.09	

The ability to classify demonstrated notable improvements in the experimental group, with a substantial 10.24% increase in high-level students, whereas the control group saw no significant change. Additionally, the experimental group witnessed a 0.79% rise in students with an average level of development, while the control group experienced a 1.49% increase. Notably, there was a significant 11.02% reduction in students with a relatively low level in the experimental group, whereas the control group saw only a 1.49% decrease.

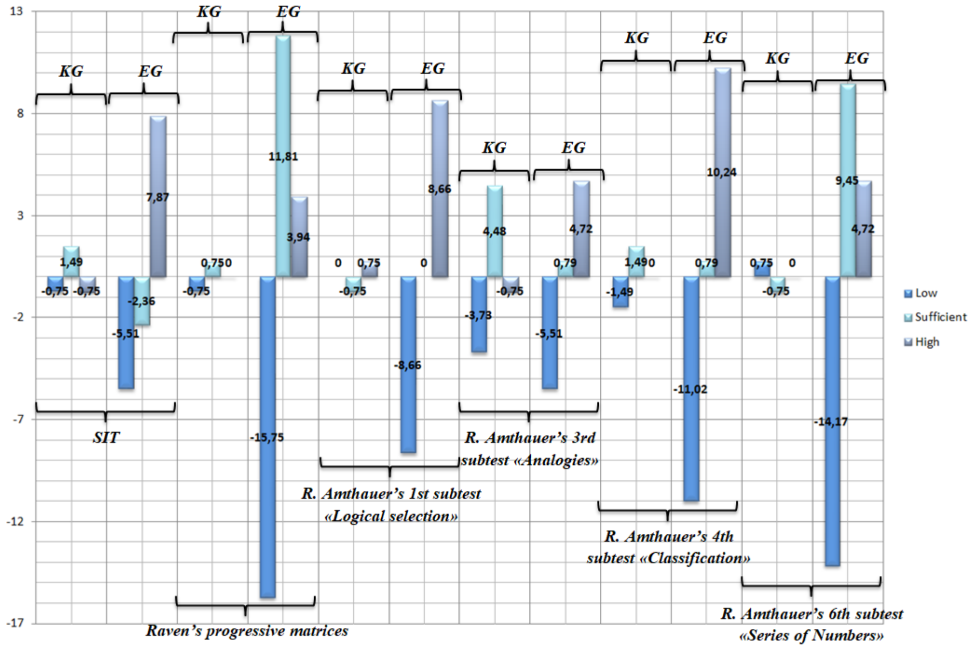

Fig. 1. Dynamics of indicators of efficiency of technology of formation of logical thinking at future doctors

The examination of logical relationships between concepts revealed a positive trajectory in the experimental group, with an 8.66% increase in high-level students. In contrast, the control group exhibited a marginal 0.75% growth. Simultaneously, the experimental group saw an 8.66% reduction in students at low levels, while the control group remained relatively unchanged.

In essence, the observed changes in the development levels of logical thinking predominantly stem from a reduction in the number of students at a low level and a concurrent increase in those at sufficient and high levels. These substantial shifts, particularly the heightened presence of students at sufficient and high levels, affirm the efficacy of our experimental logical tasks and exercises in advancing the logical thinking skills of future doctors.

In summary, our findings underscore the effectiveness of the introduced pedagogical interventions, signaling a positive shift in the logical thinking capabilities of future doctors. These results accentuate the potential for meaningful advancements through the purposeful integration of logical tasks and exercises in medical education.

4. Conclusions

The statistical data obtained from our ascertaining experiment unequivocally affirms the effectiveness and feasibility of the pedagogical technology deployed. This technology, encapsulating a structured system of logical tasks and exercises, emerges as a potent tool for fostering the development of logical thinking among future doctors. Recognizing that the spontaneous, full-fledged development of logical thinking in this cohort is not given, our study advocates for purposeful, systematic, and specially organized efforts to instill and enhance logical skills across various disciplines.

The integration of logical tasks and exercises within the realm of medical informatics proves to be a fertile ground for nurturing logical thinking. Our findings suggest that creating favorable conditions for logical thinking development during the study of medical informatics is not only possible but imperative. Moreover, we contend that the cultivation of logical thinking should extend beyond specialized topics dedicated to thinking as a cognitive process, permeating the entire duration of the discipline's study period.

Central to our study is the notion that the development of clinical thinking, a fusion of professional knowledge and logical thinking is pivotal for the professionalization of individuals in the field of medicine. Our experiment elucidates that acquiring dominant logical operations becomes a prerequisite for logical thinking and, subsequently, the cornerstone for the development of clinical thinking. The symbiotic relationship between logical and clinical thinking is unveiled, emphasizing the interconnectedness of these cognitive processes.

A critical inference drawn from our experiment is the inadequacy of traditional teaching methods in effectively promoting the development of logical thinking in future doctors. In contrast, our systematic and purposeful approach, enriched with tasks integrating elements of logic into the educational process, emerges as a robust method. This approach not only catalyzes the development of logical thinking skills but also serves as a catalyst for activating clinical thinking. The ultimate outcome is the professionalization of future doctors, solidifying the indispensable role of logical thinking in this trajectory.

In conclusion, our study underscores the paramount importance of logical thinking in the cultivation of clinical thinking and, consequently, the professionalization of future doctors. By advocating for a transformative pedagogical approach that places logical tasks at its core, our research contributes to the ongoing discourse on refining medical education to better equip aspiring doctors with the cognitive skills essential for their future roles.

Author Statement

The authors declare no conflict of interest.

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