ANNOTATION

dissertation work of Yesseikyzy Aiym on the topic “The impact of digital educational technologies on the development of logical thinking of future mathematics teachers”, submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D01501 “Mathematics”.

Relevance of Research. Quality education is one of the main requirements for the modern education system. It is mentioned in several normative documents of the country, as well as in the annual addresses of the head of state. In particular, the Law of the Republic of Kazakhstan No. 319 of July 27, 2007, on Education states that the main principles of state policy in the field of education are "the equality of the rights of all to receive quality education, the priority of the development of the education system, and the intellectual development of each person...".

In the Concept of Development of Preschool, Secondary, Technical, and Professional Education in the Republic of Kazakhstan for 2023-2029, it is stated that "...systematic improvement of teachers' qualifications ensures the quality level of educational services."

In addition, the country's strategic development plan until 2025 states that "Necessary conditions for the development of human capital are education with high quality and necessary skills. For this purpose, the general level of the education system will be improved."

Moreover, in the September 2024 address to the people of Kazakhstan entitled "Just Kazakhstan: Law and Order, Economic Growth, Public Optimism," the head of state, Kassym-Jomart Kemeluly Tokayev, emphasized that "Teachers are the intellectual power of the nation. They pave the way for the prosperity of our country by raising an educated generation. Even if there is an excellent curriculum, modern schools, and an advanced management system, if the teacher is not qualified, it is all in vain." This statement underscores the need to train qualified specialists in the field of education.

The preparation of future specialists for self-educational activities within the framework of the continuous education paradigm of "lifelong learning" ensures rapid adaptation to socio-economic changes, as well as the assimilation of new technologies and new economic behaviors.

According to the country's strategic development plan until 2025, the new model of economic growth will be based on five principles. One of these principles is: "...education is based on the methodology of memorization and the use of technologies in specific areas to develop creative and cognitive skills at all stages of life, along with the mass introduction of technologies and universal digitization..."

In this context, training future teachers who are not only equipped with the latest achievements of science and technology but also possess the ability to think logically, which is a core component of cognitive skills, remains an urgent issue for modern society. These teachers should be proactive in their field and skilled in utilizing digital technologies in education.

At birth, individuals do not inherently possess thinking skills; the ability to think logically develops only through experience over time. Therefore, it is crucial to create special conditions that promote full cognitive development.

Research on the development of logical thinking in middle and high school settings has been ongoing for many years. In the second half of the 20th century, the following pedagogues and psychologists made significant contributions: M. N. Alekseev, J.Piaget, A.Moroz, Y.K.Babansky, D.Rakhimbek, N.B.Berezanskaya, L.Emri, K.Fourier, N.D.Bogoyavlensky, M.I.Makhmutov, G.I.Ibragimov, B.I.Korotyaev, N.A.Menchinskaya, V.V.Nurkova, L.F.Obukhova, V.F.Palamarchuk, N.A.Podgoretskaya, N.N.Redko, Y.V.Slavskaya, E.E.Sokhoru, A.A.Talyzina, A.Ya.Bolokbaev, M.A.Aitkhozhin, among others.

Formal-logical thinking has been studied by researchers like R. Kegan, J.Piaget, L.Kohlberg, V.P.Belous, N.B.Berezanskaya, A.D.Getmanova, T.V.Kosma, and others.

Dialectical thinking was explored by M. Bowen, K.Marx, G.W.F.Hegel, A.V. Brushlinsky, V.V.Davydov, G.I.Zhelezovskaya, M.M.Kashapov, A.E.Nikolaeva, V.S.Shubinsky, I.S.Yakimanskaya, J.M.Abduldin, N.N.Imankul, and others.

Researchers such as Gardner, J.Bruner, Edward de Bono, B. F.Skinner, E.N.Kabanova-Meller, N.A.Polovnikova, N.N.Pospelov, R.M.Bigazieva, A.K.Sagatbekov, G.U.Kulbaeva, and A.K.Bekbolganova focused on logical thinking skills across various age groups.

Most of these studies were related to children of preschool and primary school age. The theoretical foundation of these works is scientifically comprehensive and promising, and in-depth analysis of certain elements can prove useful for enhancing students' logical thinking skills. In many cases, students are assumed to have developed logical thinking abilities and techniques.

However, other opinions exist. For instance, N.N. Pospelov and I.N.Pospelov, based on many years of research, concluded that the majority of teenage boys and girls tend to engage in irrational thinking, speculative reasoning, and work with abstract concepts without adequate evidence or logical reasoning, leading to unsubstantiated opinions. They observed that "adolescents often use acquired knowledge improperly in real-life situations and demonstrate a lack of critical thinking when gaining new knowledge."

During the Soviet era, researchers like P.Ya.Halperin and V.V.Davydov reported that almost half of adults were unable to perform tasks that would demonstrate the existence of formal-operational thinking skills.

According to psychologists, independent thinking, along with the ability to consciously master techniques and methods of mental activity, is insufficiently developed among high school students. As a result of their study, Neubert and Binko discovered that only 39% of 17-year-olds were capable of finding necessary information, organizing it, and interpreting it correctly.

In 2018, based on the results of the PISA (Programme for International Student Assessment) study organized by the OECD, approximately 51% of school graduates in Kazakhstan demonstrated a mathematical proficiency of level 2 or

lower. In 2022, there was no significant improvement, with the average mathematics score being 425, which is considerably below the OECD average of 472. Only 50% of students in Kazakhstan achieved level 2 and above, while the corresponding figure for OECD countries was 69%. Furthermore, only 2% of Kazakhstani students demonstrated advanced proficiency (levels 5 or 6), indicating weak skills in mathematical modeling and strategic problem-solving. In comparison, an average of 9% of students in OECD countries achieved this level.

These findings indicate that while students can explain and understand how to mathematically visualize a simple scenario without direct instruction, they struggle with more complex tasks that require independent reading, comprehension of scientific context, and logical analysis of texts. This reflects a decline in their ability to draw sophisticated conclusions and engage in analytical thinking.

These facts can be explained by the insufficient formation of logical thinking skills in both middle and high school settings under traditional teaching practices. This results in students in higher educational institutions being inadequately versed in the rules of defining concepts and applying methods of scientific inquiry, lacking knowledge on how to prove true ideas and refute false beliefs. Consequently, students who have not acquired logical thinking techniques are likely to have deficiencies in logical reasoning skills. As a result, young professionals often struggle to make correct decisions, including non-standard decisions in complex situations, and fail to creatively apply the professional knowledge gained in higher education. The ability to effectively solve practical problems that arise in daily life is often directly linked to the level of logical thinking developed in these specialists.

In the works of D.Halpern, it was pointed out that higher educational institutions require students to memorize and analyze facts while completing tasks, but they do not teach how to correctly perform these tasks or apply the necessary skills effectively.

Upon studying and analyzing the works of various researchers, we observed that logical thinking is a continuous process. It begins to develop during preschool, progresses throughout school years, extends through higher educational institutions, and continues into young adulthood, effectively persisting throughout one's lifetime. Therefore, in the current context, it is necessary to utilize modern technologies to foster logical thinking as a specific competence, which forms part of an individual's broader personal abilities.

The importance of using modern technologies is highlighted in the Concept for the Development of Preschool, Secondary, Technical, and Vocational Education of the Republic of Kazakhstan for 2023-2029. The competency-based approach includes the fundamental concept of the action approach—"learning by doing"—and is reinforced by the requirement that learners must be able to apply their acquired knowledge in practical situations. The principle of integration of subjects, chapters, and topics within educational programs has been strengthened. Integration at all levels is carried out based on STEAM approaches.

This indicates that one of the key tasks for our country in training future educators is to ensure that they are highly qualified professionals capable of establishing equitable relations with other countries, thereby positioning Kazakhstan

on the global stage. These future educators must be equipped with modern scientific knowledge and provided with digital competencies.

The literature on digital competence and educational technologies is widely addressed by various authors. Ferrari presented a model of digital competence that includes information literacy, communication, and problem-solving in a digital environment. Redecker and Punie explored ways to assess and develop digital competencies in education and proposed a framework for their integration into curricula. Mishra and Koehler developed the concept of TPACK (Technological, Pedagogical, and Content Knowledge), emphasizing the importance of balancing these elements when incorporating digital technologies into education. Voogt and Pareja Roblin pointed to the 21st century as an era that requires a rethinking of educational approaches, with a focus on the use of digital technologies. Binkley et al. highlighted key skills, including collaboration and critical thinking, emphasizing the role of ICT in their development. Selwyn analyzed the challenges and opportunities presented by digital technologies in educational institutions, while Erstad examined changes in digital literacy within school environments. Martin and Grudziecki proposed a hierarchical model of digital literacy, outlining its evolutionary stages. Law, Pelgrum, and Plomp conducted a comparative analysis of the implementation of digital literacy initiatives across different countries, studying their impact on educational outcomes. Aviram and Eshet-Alkalai introduced a new concept of digital literacy that incorporates not only technical skills but also cognitive, emotional, and ethical aspects.

In studying the works of various researchers, it became evident that the formation and development of logical thinking among future mathematics teachers have been comprehensively analyzed from different perspectives. However, the development of logical thinking in future mathematics teachers in the context of digital technologies remains an area in need of further research. The following contradictions have been identified:

Between the need to develop logical thinking among future mathematics teachers in line with the demands of modern society and the insufficient level of scientific and theoretical research into their professional development;

Between the significance of the impact of digital educational technologies on the development of logical thinking in future mathematics teachers and the underdeveloped methodological bases for their integration into the teaching process in higher educational institutions.

These contradictions define the research problem: to theoretically justify the development of logical thinking in future mathematics teachers through digital educational technologies and to establish methods for integrating these technologies into the educational process of higher education institutions. This formed the basis for the dissertation titled **"The Influence of Digital Educational Technologies on the Development of Logical Thinking of Future Mathematics Teachers."**

Purpose of the Study: The purpose of the study is to theoretically and methodologically substantiate the impact of digital educational technologies on the development of logical thinking in future mathematics teachers.

Object of Research: The process of training future mathematics teachers.

Subject of Research: Methodology for the development of logical thinking in future mathematics teachers through digital technologies.

Research Hypothesis: If the impact of digital educational technologies on the development of logical thinking in future mathematics teachers is substantiated, and a methodology is developed and implemented in the teaching process, then the educational process will be methodologically ensured, and the level of logical thinking in future mathematics teachers will increase. This is because the visualization and programming capabilities of digital educational technologies used in teaching mathematical subjects contribute to improving the quality of education.

Research Tasks: According to the purpose of the research and based on the proposed hypothesis, the following tasks were determined:

1. Develop the structure of logical thinking based on scientific-theoretical and methodological research, clarifying the concept of developing logical thinking in future mathematics teachers.
2. Justify the need for the development of logical thinking in future mathematics teachers within their professional activities.
3. Create a model for the development of logical thinking in future mathematics teachers through digital educational technologies.
4. Develop a methodology for the development of logical thinking in future mathematics teachers through digital educational technologies and experimentally verify its effectiveness.

Research Methods: In accordance with the goals and objectives of the study, the theoretical and methodological level of research was coordinated with the solution of applied problems, which led to the selection of the following set of methods:

- **General Scientific Methods of Theoretical Research**: Analysis of normative documents, psychological and pedagogical literature, methodological literature, educational and methodological complexes, systematic analysis, classification, and generalization of obtained results to establish the basis.
- **Social Research Methods**: Surveys of future mathematics teachers and university lecturers, observation, interviews, and testing.
- **Empirical Research Methods**: Conducting pedagogical experiments, applying statistical methods, processing, and analyzing results to confirm the scientific predictions of the study.

Theoretical-Methodological Foundations of the Study:

- Works on educational methodology (V.I.Andreev, B.S.Gershunsky, M.A.Danilov, V.I.Zagvyazinsky, I.Ya.Lerner, M.K.Mamardashvili, A.M.Novikov, A.Mukhanbetzhanova, T.A.Aldamuratova, A.Bidosov, M.I.Makhmutov, A.K.Igibaeva).
- Works on modern philosophical theories of knowledge and the logic of scientific research (V.S.Bibler, B.M.Kedrov, V.I.Kurashov, G.I.Ruzavin, A.M.Kenzhebulatova, B.T.Barsai, N.N.Imankul).
- Works devoted to the study of various forms of logical thinking (L.S.Vygotsky, E.I.Gorbacheva, M.Johnson, J.Dewey, G.S.Kostiuk, G.Lakoff,

N.A.Menchinskaya, P.D.Puzikov, O.Ya.Sivkov, M.M.Vakhrushev, M.S.Yeritsyan, E.I.Ivanitsyna, A.Turgynbaev, A.O.Ayashev, S.B.Bulekbaev, S.Elubaev, K.M.Mukhambetaliev).

- Works on the theory of thinking of future specialists (B.F.Lomov, V.D.Shadrikov, S.R.Kydyrova, N.Sh.Almetov, A.S.Shayakhmetova, B.T.Kalymbetov, A.K.Bekbolganova, N.N.Imankul).
- Works on methodological directions of higher professional education in the current context (V.I.Zagvyazinsky, S.Ya.Kazantsev, V.V.Kondratiev, V.Kraevsky, A.M.Novikov, B.Zh.Zhientaeva, G.B.Abdramanova, A.D.Tolegenova).

Research Sources: Law of the Republic of Kazakhstan "On Education"; Concept of the Development of Higher Education and Science in the Republic of Kazakhstan for 2023-2029; Concept of the Development of Preschool, Secondary, Technical, and Professional Education in the Republic of Kazakhstan for 2023-2029; Address of the President to the People of Kazakhstan; Strategic Development Plan of the Government of Kazakhstan until 2025; philosophical, psychological, and pedagogical scientific works; educational and methodological literature; textbooks; educational and methodological complexes; encyclopedic handbooks and dictionaries on logical thinking, digital technologies, and educational issues; and the personal pedagogical and research experience of the author.

Scientific Novelty of the Study:

1. Based on scientific-theoretical and methodological research, a structure of logical thinking was created, and the concept of developing logical thinking in future mathematics teachers was clarified.
2. The necessity for developing logical thinking in future mathematics teachers during professional activities was substantiated.
3. A model for developing logical thinking in future mathematics teachers was created using digital educational technologies.
4. A methodology for developing logical thinking in future mathematics teachers through digital educational technologies was created.

Theoretical Significance of Research Results: Psychological and pedagogical aspects of logical thinking; studies on the development of logical thinking; classification of digital technologies in mathematics education; and the potential of digital educational technologies to enhance the logical thinking of future mathematics teachers.

Practical Significance of the Dissertation Research: The model for the development of logical thinking in future mathematics teachers using digital educational technologies proposed in this study will serve as a methodological aid for developing logical thinking during the training of students in the educational programs 6B01501 "Mathematics" and 6B01502 "Mathematics and Informatics." As part of developing logical thinking in students of these educational programs, they may use the course **"Elementary Mathematics"**, developed to incorporate programming language features on the Stepik.org educational platform, as well as the monograph **"Methodology for Developing Logical Thinking of Future Mathematics Teachers with the Aim of Nurturing Mathematical Thinking in**

Prospective Students" and the educational tool **"Features of Formation and Development of Logical Thinking in Future Mathematics Teachers."**

Validity of Scientific Results: The validity of the results is based on a consistent reliance on modern scientific knowledge methodologies, the use of complementary research methods aligned with the goals and objectives of the study, and the characteristics of the phenomenon being studied. The reliability of the research results and the representativeness of the experimental data are ensured through quantitative and qualitative analysis, the use of modeling methods, conducting pedagogical experiments, and applying mathematical statistics to process the experimental data.

The following provisions are submitted for defense:

1. The structure of logical thinking developed based on scientific-theoretical and methodological research, as well as the clarified concept of logical thinking development in future mathematics teachers, will serve as additions to the existing structure and concept of logical thinking.
2. The justification for the need to develop logical thinking in future mathematics teachers in their professional activities will be the theoretical foundation of the research.
3. The model for developing logical thinking in future mathematics teachers through digital educational technologies will be the methodological foundation of the research.
4. The developed methodology for enhancing logical thinking in future mathematics teachers using digital educational technologies has a positive effect on their logical thinking development.

Experimental Base of Research: The main experimental work was conducted with second to fourth-year students at "I. Zhansugirov University" (ZhU JSC). More than 50 students participated in the research.

Main Stages of the Research: In line with the defined goals and objectives of the scientific research, experimental work was conducted over three phases from 2019 to 2023.

• **The first stage (Defining experiment) is 2019-2020.** At this stage, analytical work was carried out with domestic and foreign literature on logic, pedagogy, psychology and digital educational technologies. Based on the studied material, the purpose, objectives and hypothesis of the study were formulated. The psychological and pedagogical aspects of logical thinking, its importance in mathematical education and professional activity of future teachers of mathematics are determined.

• **The second stage (Search experiment) – 2020-2022.** During this period, the role of digital educational technologies and their impact on the development of logical thinking of students was studied. Based on the data obtained, a model and methodology for the development of logical thinking of future mathematics teachers using digital educational technologies were developed and presented.

• **The third stage (Formative experiment) – 2022-2023.** At this stage, the model and methodology developed during the study were tested in the learning process. Their effectiveness has been verified, as well as the analysis and

generalization of experimental and theoretical results. Based on the data obtained, conclusions were formulated, methodological recommendations were developed, and the results of the study were presented in the form of a dissertation.

Approbation and Implementation of Research Results: The conclusions and findings of the research were presented and discussed at the scientific-methodological seminar of the Faculty of Physics and Mathematics named after I. Zhansugirov, as well as in the monograph "Methodology for Developing Logical Thinking of Future Mathematics Teachers with the Aim of Nurturing Mathematical Thinking in Prospective Students" and the educational tool "Features of Formation and Development of Logical Thinking of Future Mathematics Teachers." Additionally, the research findings were considered and discussed during a scientific internship at the Institute of Mathematics and Mathematical Modeling.

- From September 10, 2020, to January 10, 2021, within the framework of the "ZhasProject" competition on the topic "Information Technologies in Education," an online professional development course for teachers in Taldykorgan was conducted.
- In 2021-2022, within the framework of the "Young Scientist" competition at Zhetisu University named after I. Zhansugirov, the online learning platform "Digital Educational Resources" for teachers was developed.
- From February 22, 2022, to March 16, 2022, and from October 23, 2023, to November 18, 2023, professional development courses on "Information Technologies in Education" were conducted for teachers of the Faculty of Physics and Mathematics at Zhetisu University named after I. Zhansugirov.
- In 2022-2023, professional development courses were conducted for mathematics and computer science teachers in the Zhetysu region at the Pedagogical Excellence Center of "Nazarbayev Intellectual Schools" JSC.

The research findings were disseminated through scientific and methodological publications and presentations at conferences and seminars.

Publications: The main content of the dissertation was presented in journals of the Science and Higher Education Quality Assurance Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan, as well as at international scientific and practical conferences with domestic and foreign scientific advisors. A total of 20 scientific works were published based on the dissertation:

1. Scientific works published in the Scopus database – 1 (percentile - 36, Quartile - Q3);
2. Scientific works published in journals recommended by the Science and Higher Education Quality Assurance Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan – 4;
3. Scientific works presented at international scientific and practical conferences – 10;
4. Articles published in other scientific journals – 3;
5. Educational tool – 1;
6. Monograph – 1.

Dissertation Structure: The dissertation consists of an introduction, three main parts, a conclusion, a bibliography, and appendices. The text of the dissertation comprises 140 pages, with a total of 150 sources, including 14 sources from foreign authors, 17 appendices, 42 tables, and 41 illustrations.

"Theoretical Foundations of the Development of Logical Thinking in Future Mathematics Teachers" focuses on analyzing the main theoretical aspects related to the formation of logical thinking in future mathematics teachers. Psychological-pedagogical characteristics of logical thinking, its impact on cognitive functions, and its significance in the professional activities of teachers are considered. The importance of developing logical thinking in mathematical education, its role in teaching, lesson planning, and solving pedagogical challenges is described. Additionally, the role of logical thinking in the proper mastery of mathematical subjects and the quality of professional training for future teachers is examined.

"Methodological foundations for the development of logical thinking of future mathematics teachers using digital educational technologies" is devoted to methodological aspects of the development of logical thinking using digital technologies. The methods and forms of organizing the educational process are described, including the student's independent work (SIW) and the student's independent work with the teacher (SIWT), aimed at solving mathematical problems using programming, visualization and modeling tools. This chapter also presents a model for the development of logical thinking using digital technologies and discusses the importance of their application in the training of future teachers.

"Pedagogical Experiment and Its Results" describes the pedagogical experiment aimed at determining the effectiveness of using digital educational technologies for developing logical thinking in students. The methodology of the experiment is comprehensively presented, including the use of digital tools in the learning process and descriptions of control and experimental groups. The quantitative and qualitative results of the experiment are presented and analyzed in terms of the impact of digital technologies on logical thinking development. At the end of the chapter, conclusions are drawn about the effectiveness of using digital technologies, and recommendations for further implementation in educational practice are provided.

Conclusion: The general conclusions, recommendations and prospects for future work are analyzed in the conclusion.