ABSTRACT

of the dissertation by Lyubov Karassyova titled «The development of the algorithmic competence of students in the study of mathematics through information and communication technologies», submitted for the degree of Doctor of Philosophy (PhD) in the educational program 8D01502 – «Teaching mathematics in STEM».

Relevance of the Research. In the Address to the Nation titled "National Unity and Systemic Reforms Are the Foundation of Prosperity" (September 1, 2021), the President of the Republic of Kazakhstan, Kassym-Jomart Tokayev, emphasized the importance of digitalization and innovation in the field of education. This focus aligns fully with the country's strategic goal of transforming Kazakhstan into a hub of information technology. The President stated: "We must accelerate the digitalization of all areas of life, including education. It is digitalization and innovation that determine a nation's competitiveness in the 21st century." The successful development of the information and communication technologies (ICT) sector requires not only high-quality education but also the integration of modern instructional approaches within the educational system.

In the speech at the meeting of the National Council for Science and Technology under the President of the Republic of Kazakhstan on April 12, 2024, Kassym-Jomart Tokayev further emphasized: "It is essential that the younger generation becomes proficient in all emerging digital technologies. To this end, the content of secondary and higher education curricula must be revised, with a strong focus on exploring the full potential of artificial intelligence".

The Education Development Concept for 2023–2029, approved by Resolution No. 249 of the Government of the Republic of Kazakhstan dated March 28, 2023, underscores the necessity of revising curriculum content to equip students for the challenges of the digital era. In the context of modern realities, digitalization and artificial intelligence technologies play a pivotal role in driving economic development. The preparation of highly qualified professionals demands the cultivation of critical thinking, teamwork, and independent decision-making skills. To achieve these objectives, it is essential to prioritize the development of students' algorithmic competence as a fundamental component of their professional and social adaptation.

In this context, algorithmic competence becomes an integral component of education, fostering in students the ability to analyze, synthesize, and evaluate information-skills that are essential for successful adaptation to the rapidly changing conditions of the modern world. Consequently, amid the accelerated development of digital technologies and the growing need to prepare students for emerging challenges, one of the key objectives of education is not only the development of algorithmic competence, but also the active

integration of information and communication technologies (ICT) into the teaching and learning process.

Currently, information and communication technologies (ICT) permeate all spheres of society, including the education system, where they have become an essential component. The relevance of employing ICT in mathematics teaching within the contemporary educational process is underpinned by several critical factors. Its integration into mathematics education facilitates:

– visualization of abstract mathematical concepts;

– development of algorithms;

– solving problems of varying complexity;

– collaboration in problem-solving.

Therefore, the integration of ICT in mathematics education fosters not only the development of algorithmic competence but also cultivates essential skills such as critical thinking, creativity, information literacy, and collaborative abilities. These competencies significantly enhance graduates' competitiveness in the modern labor market and promotes the socio-economic development of the country.

Amid the evolving demands on education, new values are being integrated, fostering the development of a national educational model. This necessitates a reevaluation of the content of quality education and upbringing, aimed at cultivating individuals equipped to engage effectively in a globalized environment. Consequently, enhancing the overall quality of education has become a vital societal priority.

At the heart of these new educational trajectories is a model of pedagogical support in which the teacher acts as a mentor, guiding students in independently exploring the world, unlocking their potential, and nurturing their abilities. This approach enables the provision of education that aligns with students' individual interests and needs, with algorithmic thinking occupying a central role in the learning process.

A substantial body of research within the scientific and pedagogical community has addressed various facets of this issue. The pedagogical and psychological foundations of algorithmic thinking have been examined by prominent scholars and educators, including V.V. Davydov, Yu.K. Babansky, G.I. Sarantsev, V.A. Gusev, V.A. Dalinger, A.A. Temerbekova, and others.

Various aspects of the use of information and communication technologies in education have been explored by scholars such as B.S. Gershunsky, Ya.A. Vagramenko, A.P. Ershov, M.P. Lapchik, E.I. Mashbits, I.V. Robert, Chetin Güler, Takachi, and others.

The theoretical foundations for the integration of information and communication technologies in education are thoroughly examined in the works of researchers such as Yu.S. Branovsky, R.B. Bekmoldayev, S.V. Kurzenko, N.G. Kormushina, A.V. Penkov, V.M. Monakhov, V.V. Kalitina, S.S. Dayyrbekov, A.O. Baidybekova, and others.

Improvement of mathematics education content in secondary schools, along with the development of comprehensive instructional and methodological support, has been the focus of numerous Kazakhstani scholars, including A.Ye.Abylkassymova, B. Baymukhanov, T.A. Aldamuratova, I. Bekboyev, D.R. Rakhymbek, A.M. Mubarakov, O. Satybaldiyev, S.M. Seitova, E.Zh. Smagulov, A. Abdiyev, Zh. Kaidassov, and others.

The use of electronic textbooks by teachers in the educational process has been examined in the works of T.K. Nurgaliyev, S.I. Verkho, A.K. Dayrabaeva, and others.

The literature review demonstrates that the enhancement of the student learning process through algorithmization has been extensively explored by researchers such as P.P. Blonsky, L.V. Zankov, I.N. Antipov, A.A. Shriner, V.S. Ablova, T.I. Kuznetsova, V.P.Bespalko, N.F. Talyzina, L.L. Bosova, as well as Kazakhstani scholars E.Y. Bidaibekov, K.G. Kozhabayev, A.K.Akhmetov, S.S. Satybaldin, G. B. Kamalova, and others. These studies focus on the development of students' algorithmic and logical thinking and the implementation of algorithmization technologies within the educational process.

L.N. Landa was the first to introduce the concept of the algorithmic approach in education.

The issues related to the formation of the foundations of algorithmic culture have been extensively studied by international educators such as A.Turing, J. Bruner, T. Cormen, N. Penrose, J. Piaget, H. Heckhausen, and others. These researchers have explored the educational potential of various disciplines, including mathematics, physics, chemistry, geography, cultural studies, pedagogy, and psychology.

Numerous doctoral dissertations have been devoted to the development of algorithmic thinking, authored by researchers such as V.V. Kalitina, V.V. Popova, O.N. Yarygin, M.V. Kondurar, T.P. Telepova, A.A. Shrainer, T.N. Lebedeva, and others.

For instance, V.V. Popova's doctoral dissertation explores the theoretical justification and practical development of methodologies for integrating ICT to enhance the algorithmic focus of the mathematics curriculum, emphasizing the role and functions of algorithmic tasks in mathematics teaching within the system of secondary vocational education.

In recent years, there has been a growing interest in integrating algorithmic approaches into the educational process. Educators increasingly acknowledge the importance of cultivating students' algorithmic competence as a key factor for effective mastery of mathematics. This has led to a reassessment of traditional teaching methods, placing greater emphasis on algorithmic-focused instruction. The increased attention to the algorithmic component of mathematics education for Kazakhstani students is also evident in the content of assessment tools and the Unified National Testing (UNT) tasks for the subject of Mathematical Literacy.

Current realities in school education reveal that students face significant challenges in grasping algorithmic principles and applying them effectively in mathematical activities. This is evidenced by the low performance results in international assessments such as PISA and TIMSS.

It is also undeniable that pedagogical universities devote insufficient attention to the development and application of algorithmic tasks as a tool for the professional training of future teachers, who serve as transmitters of experience in their subsequent work and are responsible for fostering algorithmic competence. This creates a vicious cycle, whereby inadequate preparation of future teachers results in the persistent neglect of algorithmic competence in school education.

One of the most effective ways to overcome these challenges is the use of ICT, which enables students to visualize algorithmic processes, interact directly with dynamic models, and apply mathematical concepts in practice. Integrating ICT into the learning process not only facilitates the mastery of algorithms but also contributes to enhancing students' mathematical literacy and engagement.

However, an analysis of existing scientific, pedagogical, and methodological literature reveals that the development of algorithmic competence through ICT in the context of mathematics education is primarily addressed at a theoretical level. Practical studies focusing on specific methods and tools for fostering algorithmic competence in students remain insufficiently explored, leading to the following **contradictions**:

– *At the socio-pedagogical level*, a discrepancy exists between society's demand for specialists with high algorithmic competence and the actual insufficient development of this competence among school students;

– *At the scientific and pedagogical level*, there is a gap between the recognized importance of fostering algorithmic competence and the lack of comprehensive theoretical frameworks for its development within a digital learning environment;

– *At the scientific and methodological level*, a contradiction arises between the need for effective methodologies and digital tools to develop algorithmic competence through ICT and the inadequate development and implementation of these tools in educational practice.

The pursuit of effective approaches to fostering students' algorithmic competence through the integration of ICT constitutes a significant scientific and pedagogical challenge. This formed the basis for selecting the research topic: «**The development of the algorithmic competence of students in the study of mathematics through information and communication technologies».**

Research Aim: To theoretically justify, design, and experimentally validate a methodology for developing students' algorithmic competence in mathematics learning through ICT integration.

Research Object: The mathematics learning process in secondary schools.

Research Subject: The development of students' algorithmic competence in mathematics lessons utilizing ICT.

Research Hypothesis: The implementation of the developed methodology for cultivating students' algorithmic competence through information and communication technologies in mathematics learning will lead to a more effective development of their algorithmic skills and enhance the overall quality of mathematical training.

Research Objectives:

1) To investigate psychological and pedagogical aspects of developing students' algorithmic competence within a digital educational environment;
2) To identify effective methods and tools for fostering students' algorithmic competence in mathematics learning in a digital learning context;
3) To design a model and develop a methodology for enhancing students' algorithmic competence in school mathematics learning using ICT;
4) To experimentally evaluate the effectiveness of the proposed methodology for developing students' algorithmic competence in mathematics learning using ICT;
5) To develop methodological guidelines for teachers on promoting students' algorithmic competence in mathematics learning through ICT integration.

To achieve the research aim and address the set objectives, the following **research methods** were employed:

- *General scientific methods of theoretical research*: study and analysis of domestic and international scientific-theoretical, educational-methodological, psychological-pedagogical, and methodological literature on the research topic, as well as previously conducted dissertations focused on the development of algorithmic competence, the use of information and communication technologies, and the specifics of mathematics teaching in educational institutions;
- *Social research methods*: conducting observations, exchanging views with students and teachers, organizing surveys, and analyzing their results;
- *Empirical research methods*: carrying out a pedagogical experiment and performing statistical analysis of the experimental data to validate the research hypothesis.

Research Sources: The Law of the Republic of Kazakhstan «On Education»; the Address of Kassym-Jomart Tokayev to the people of Kazakhstan dated September 1, 2023; the National Project "Educated Nation,"aimed at ensuring quality education; the Concept of the Education

Development Program for 2023–2029; scientific research by educators and psychologists; scholarly works; the author's personal teaching experience; and educational-methodological resources.

Scientific Novelty of the Research:

1. The psychological and pedagogical foundations for applying information and communication technologies to develop students' algorithmic competence in mathematics have been identified and theoretically substantiated.
2. Effective methods and tools for fostering algorithmic competence among students within a digital learning environment have been established.
3. A conceptual model and a comprehensive methodology for enhancing students' algorithmic competence in mathematics through the integration of ICT have been developed.
4. The proposed methodology has been experimentally validated and successfully implemented in the educational process.
5. Practical methodological guidelines for teachers on promoting algorithmic competence in mathematics learning using ICT have been formulated.

Theoretical Significance of the Research:

1) Psychological and pedagogical foundations for the use of information and communication technologies in developing students' algorithmic competence in mathematics learning have been identified and substantiated;
2) Effective methods and tools for fostering algorithmic competence in students within a digital learning environment have been established;
3) A comprehensive model and methodology aimed at promoting students' algorithmic competence in mathematics learning through ICT have been designed and developed.

Practical Significance of the Study:

1) The methodology for enhancement students' algorithmic competence in mathematics learning using ICT has been experimentally tested and integrated into the educational process. It includes the following educational and methodological support:

- A teaching manual titled "Elective course of teaching mathematics in schools using digital resources GeoGebra and Desmos" (recommended for publication by the Academic and Methodological Council of the NPJSC "Sh. Ualikhanov Kokshetau University", protocol No. 9 dated June 20, 2023);
- Educational websites: algorithmic-lab.kz – designed for students, aimed at organizing their independent work and developing algorithmic competence; algorithmic-learning-lab.kz – a methodological support site for teachers to assist in lesson planning and implementation using ICT;
- An original elective course program titled "Designing activities to

enhance students' algorithmic competence in mathematics lessons using ICT" (Certificate of the National Institute of Intellectual Property on inclusion in the state register of copyright-protected objects, No. 31566 dated January 5, 2023);

2) A methodological guide has been prepared (methodological recommendations) for teachers titled "Developing students' algorithmic competence in mathematics learning using information and communication technologies" have been prepared (recommended by the Methodological Council of the Department of Education of Kokshetau, Order No. 1 dated March 17–18, 2025).

The reliability and validity of the research results are ensured by:

1) The theoretical foundation based on fundamental studies in the fields of pedagogy, educational psychology, the theory of algorithmic thinking, and the use of information and communication technologies in education;
2) The use of scientifically grounded research methods, including theoretical analysis, pedagogical experimentation, surveys, observation, and statistical data processing, which provide an objective evaluation of the effectiveness of the developed methodology for enhancing students' algorithmic competence;
3) Empirical validation of the methodology's effectiveness, conducted within real educational conditions in schools, confirming its impact on the development of algorithmic competence, ICT skills, and the improvement of students' mathematical performance;
4) Statistical analysis of the results of the pedagogical experiment, ensuring the reliability of conclusions based on both quantitative and qualitative analysis of the obtained data.

Provisions submitted for defense:

1. The psychological and pedagogical aspects of developing students' algorithmic competence, taking into account the age-related and cognitive features of middle school students, as well as the capability of using information and communication technologies (ICT), constitute the theoretical foundation of the study.

2. The developed model and methodology for evolvement students' algorithmic competence through ICT means, which includes a set of teaching techniques and tasks adapted to the specific features of "Mathematics" subject", serves as the methodological basis of this research.

3. The methodological recommendations that ensure the effective integration of ICT means in fostering students' algorithmic competence in the process of learning mathematics align with the key requirements of contemporary pedagogical education.

The research base: The experimental part of the study was conducted at the following institutions: Municipal State Institution "School-Gymnasium No. 1" in Kokshetau, Municipal State Institution "General Secondary School No. 4"

in Kokshetau, Novoselskaya Secondary School in the North Kazakhstan Region, Secondary School No. 15 in Taldykorgan, and Secondary School No. 8 with a preschool mini-center in Tekeli.

States of the research. In accordance with the research objectives and tasks, the experimental work was carried out from 2021 to 2024 in natural conditions of educational process and included three main stages.

First stage (2021–2022) This stage involved an analysis of scientific, educational, and instructional-methodological literature related to evolvement of algorithmic competence, the use of information and communication technologies in education, and the characteristics of formation of school students' algorithmic thinking. Psychological and pedagogical approaches to the development of algorithmic thinking were identified, and modern digital resources used in teaching mathematics were examined. The theoretical literature review and data from the ascertaining experiment built the basis for refining the research objectives and tasks, and advancement the working hypothesis.

Second stage (2022–2023) During this stage, the model and methodology for evolvement students' algorithmic competence through information and communication technologies were designed. Two educational websites such as *algorithmic-lab.kz* and *algorithmic-learning-lab.kz* were created, along with an extracurricular course program on development algorithmic competence utilizing GeoGebra and Desmos. Additionally, methodological guidelines were prepared to ensure the effective implementation of these resources and techniques in the educational process.

Third stage (2023–2024) included the experimental validation of the designed methodology and educational resources in schools academic process. Diagnostics of students' algorithmic competence levels were conducted, and a comparative statistical analysis of experimental and control group data was performed, confirming results reliability. During this stage, theoretical and practical findings were summarized, adjustments to the designed methodology were made, key conclusions were formulated, and the final version of the dissertation was prepared.

Approval of the research results:

- The main findings and results of the research were presented and discussed at scientific and methodological seminars of the Department of Physics, Mathematics and Computer Science of Sh. Ualikhanov Kokshetau University, and at the meetings of the Department of Physics and Mathematics at the Faculty of Physics and Mathematics of Zhetysu University named after I. Zhansugurov. The practical results were tested during the experimental work with students at Municipal State Institution "School-Gymnasium No. 1" in Kokshetau, and Municipal State Institution "Secondary School No. 4" in Kokshetau, Novoselskaya Secondary School in the North Kazakhstan Region, Secondary School No. 15 in Taldykorgan, and Secondary School No. 8 with a

preschool mini-center in Tekeli. In addition, the research results were presented during the research internship at the Institute of Physics and Mathematics of Gorno-Altaisk State University of the Russian Federation;

- The results of the research were reported at scientific and practical conferences and seminars, including the 2nd International Scientific and Practical Seminar "Prospects for Teaching Physical and Mathematical Disciplines in Higher Educational Institutions" (Altai Republic, Gorno-Altaisk,2021); International Scientific and Practical Conference on Modern Educational Technologies and Practices EdUCO 23 (Russia, Barnaul, 2023); the 7th International Scientific and Practical Seminar "Prospects for Teaching Physical and Mathematical Disciplines in Higher Educational Institution" (Altai Republic, Gorno-Altaisk, 2023); International Scientific and Practical Conference "11th Nazarov Pedagogical Readings: Integrating Sustainable Development Goals into Mathematics Education" (Kyrgyzstan, Osh, 2023); Kazakhstan–Russia International Seminar (Kazakhstan, Taldykorgan, 2024);

- The main results and provisions of the dissertation were published in various scientific journals and conference proceedings (a total of 17 publications, including 2 articles in journals indexed in the Scopus bibliographic database; 2 publications in journals recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan; 9 publications in proceedings of international scientific and practical conferences in Kazakhstan, Kyrgyzstan, and Russia; 2 publications in other editions; 1 teaching and methodological manual; 1 Author's program of an optional course.

Structure of the dissertation: The dissertation consists of an introduction, two chapters, a conclusion, a list of references, and appendices.

The *Introduction* outlines the relevance of the topic and the scientific framework of the study, including the research aim, object and subject, scientific hypothesis, research tasks, theoretical and methodological foundations, stages and methods of the study, research base, scientific novelty, theoretical and practical significance, and provisions submitted for defense.

Chapter One, titled "Theoretical Foundations for Evolvement of Students' Algorithmic Competence in Mathematics through Information and Communication Technologies", specifies the psychological and pedagogical aspects of developing algorithmic competence, analyzes key factors influencing its formation, and explores the features of applying digital educational technologies in this process. Special attention is given to the issues of organization educational environment conducive to the development of algorithmic competence, as well as methodological approaches for improving it in learning Mathematics using ICT means.

Chapter Two, titled "Methodological Foundations for Developing Students' Algorithmic Competence in Mathematics through Digital

Technologies", presents a teaching model outlining the structure, goals, principles, and pedagogical conditions required for students' algorithmic competence development. It describes the methodology for using digital resources aimed at fostering step-by-step problem-solving skills and students' independent work. This chapter also includes the results of the pedagogical experiment confirming the effectiveness of the proposed methodology, along with practical recommendations for Mathematics teachers on how to develop students' algorithmic competence using ICT means.

The *Conclusion* summarizes the research, presents the main findings, and outlines prospects for future investigations.

The *List of References* includes scientific works, regulatory documents, and other materials directly related to the research topic. A total of 154 sources were analyzed and utilized in the study.

The *Appendices* contain materials developed during the research, as well as documentation of the implementation of the study results into the school academic process.