ANNOTATION
of the dissertation work of Altynbek Sansyzbayev,
submitted for the degree of Doctor of Philosophy (PhD)
in the educational program 8D01501 – Mathematics Teacher Training

Research topic: «Technology of using gamification elements in the formation of concepts and their systems in school mathematics».

Relevance of the research. At present, large-scale reforms are taking place in the educational space of our country. The core of these changes is the transformation of the education system in accordance with the requirements of the digital environment. In this regard, the Concept for the Development of Preschool, Secondary, Technical and Vocational Education in the Republic of Kazakhstan for 2023–2029 emphasizes that innovative approach to teaching subjects will be implemented through electronic platforms designed for teachers and learners, thereby enabling comprehensive digitalization of the educational process.

The document identifies, as an important direction of the educational trajectory, the need to move beyond traditional content-oriented instruction toward education aimed at preparing learners for future life conditions. This objective is achieved by strengthening the value-oriented dimension of educational content, directing curricula toward the development of global competencies, emotional intelligence, critical thinking, entrepreneurship, and financial literacy skills, as well as through the differentiation and individualization of instruction and providing learners with broad and flexible opportunities to choose their learning pathways.

In addition, improving the quality of education and increasing the competitiveness of the national education system are highlighted in the national project “Educated Nation” aimed at ensuring high-quality education. Furthermore, the integration of approaches to managing science, education, and innovation was clearly emphasized by the Head of State, Kassym-Jomart Tokayev, in his Address to the People of Kazakhstan entitled “Kazakhstan in the Era of Artificial Intelligence: Current Issues and Their Solution through Fundamental Digital Transformation.”

These provisions are aligned with the objectives defined in the state educational standard, including the development of learners’ values, enhancement of their abilities, adaptation to the dynamic demands of society, and the organization of research activities. Therefore, improving the content of mathematical education and enhancing the quality of students’ mathematical knowledge in accordance with these requirements have become particularly relevant issues today.

From this perspective, the modernization of the education system, the rapid development of digital technologies, and the increasing demands for mastering modern competencies and enhancing learning motivation require a new approach to organizing the content of the school mathematics course. In particular, the issue of forming mathematical concepts and their systems during the teaching of mathematics is recognized as a key mechanism for developing learners' logical thinking, abstract reasoning abilities, and functional literacy.

Generally, mastering and consciously forming concepts is considered one of the most complex issues in pedagogy and psychology. In particular, the acquisition of mathematical concepts is a complex pedagogical process based on the learner's active cognitive activity and the development of thinking operations such as analysis, comparison, generalization, and modeling. Such a process is not limited to the simple perception of ready-made information by the learner; rather, it is characterized by understanding semantic relationships, identifying patterns, and being able to apply knowledge in new situations.

The formation of concepts is closely related to the cognitive development level of learners. This is because cognitive development enhances thinking, memory, perception, attention, and logical reasoning abilities. As these mental processes gradually develop, learners consciously perceive new information, connect it with prior knowledge, compare, analyze, and generalize it. On this basis, scientific concepts are systematically acquired. Therefore, it is impossible to consider the psychological prerequisites of concept formation separately from cognitive development. This issue has been comprehensively examined in the works of many psychologists.

A number of scholars have made significant contributions to the study of learners' cognitive development. Jean Piaget divided children's intellectual development into stages and identified the characteristics of thinking specific to each age level. Jerome Bruner substantiated that cognitive development is carried out through enactive, iconic, and symbolic modes. Lev Vygotsky demonstrated the interrelation between learning and development through the theory of the "zone of proximal development." Sergey Rubinstein proved the unity of consciousness and activity. Vasily Davydov proposed the theory of developmental learning. Pyotr Galperin developed the concept of the step-by-step formation of mental actions. Daniil Elkonin studied the influence of learning activity on child development. Viktor Krutetsky analyzed the psychological characteristics of mathematical abilities.

The scientific conclusions of these scholars make it possible to gain a deeper understanding of the essence of cognitive development and to identify the psychological foundations for the effective formation of concepts among learners.

In addition, pedagogical and didactic scholars such as A. V. Usova, N. M. Verzilin, and M. N. Skatkin studied the didactic foundations and methods of mastering scientific concepts. At the same time, mathematics educators and researchers including George Pólya, Zoltán Dienes, Nina Talyzina, Yury Kolyagin, A. A. Stolyar, J. Ikramov, I. B. Bekboev, S. S. Salykov, A. V. Muzhikova, G. E. Chekmarev, V. A. Lyubetsky and others comprehensively investigated problem-solving methods in teaching mathematical concepts, as well as ways of forming these concepts while taking into account learners' age characteristics.

Alongside the above-mentioned foreign scholars from both distant and neighboring countries, Kazakhstani researchers such as A. E. Abilkassymova, V. P. Dobritsa, D. Rakhymbek, A. K. Kobesov, M. Zh. Akhmetov, S. Elubaev, B. S. Zhanbyrbaev, A. S. Keneshev, and S. M. Seitova, among others, have examined various approaches to the formation of mathematical concepts in their works. In addition, there are domestic dissertation studies devoted to the problem of forming mathematical concepts.

Research studies consider the formation and systematization of concepts among learners as one of the leading tasks of school education. In this regard, the process of concept formation is emphasized as a complex and multifaceted cognitive activity, and its decisive role in the development of learners' thinking abilities is substantiated.

In particular, according to the viewpoint of D. Rakhymbek, concept formation is characterized, first, by mastering a system of actions aimed at identifying the essential, necessary, and sufficient features of specific objects and phenomena, and second, by organizing these actions into a certain logical structure and consciously understanding the relationships between them.

Furthermore, a number of studies emphasize that the formation of mathematical concepts is achieved through the integration of activities such as spatial representations, verbal descriptions, algebraic expressions, and symbolic models. Such multifaceted representations make it possible to achieve a deeper understanding of mathematical content and its conscious assimilation. In this regard, J. Ikramov substantiates that, in the formation of concepts, a significant role is played not only by external and objective visual characteristics, but also by sensory and non-sensory perceptions reflecting activity schemes, that is, by internal cognitive structures formed during the process of activity.

The mastery of concepts is not limited merely to memorizing their definitions; rather, it is achieved through understanding them, identifying their interconnections, and applying them in various situations. However, as observed in traditional teaching practice, the process of forming mathematical concepts often

remains formal in nature, which leads to a decline in learners' interest in the subject and results in passive learning activity.

Therefore, despite the theoretical significance of studies devoted to the problem of concept formation, it can be noted that, taking into account the requirements imposed on the modern education system, the methodological aspects of forming the fundamental concepts of mathematics and their systems on the basis of modern technologies have not yet been sufficiently explored.

Learning effectiveness depends on the learner's activity in the educational process and their conscious engagement in cognitive activity. Therefore, it is important that learners show intrinsic motivation not only toward the final result but also toward the learning activity itself. In this regard, the use of game elements as a driving force for increasing intrinsic motivation becomes necessary.

In pedagogical practice, the use of game-based technologies has been known since ancient times. Today, the application of game technologies in education has become an object of research within the teaching and upbringing process. At the same time, modern children are highly attracted to the opportunities offered by the Internet: there is a significant dependence on digital technologies, and online communication predominates. In the digital environment, multimedia, interactivity, and the accessibility of information attract learners' attention.

Numerous studies show that games and game applications play a special role in shaping adolescents' interest in the virtual environment. In this context, one of the most effective approaches of game-based technologies that allows us to consider the needs and interests of today's learners and, based on this, develop their cognitive motivation is gamification.

The term gamification was first used in 2002 by American programmer Nick Pelling, and by around 2010 it had gained popularity as a concept referring to the use of game design elements in non-game contexts.

Analysis of the scientific works of foreign scholars related to the integration of gamification into the education system shows that their research is mainly aimed at increasing learners' learning motivation, enhancing cognitive activity, and optimizing the process of mastering complex concepts. These studies can be conventionally grouped into three main categories: works defining the theoretical and methodological foundations of gamification (Sebastian Deterding, Dan Dixon, Rilla Khaled, and Lennart Nacke); studies examining mechanisms for applying gamification in the learning process (Karl M. Kapp, Kevin Werbach, and Dan Hunter); and empirical research proving the effectiveness of gamification (Juho Hamari, Jonna Koivisto, Harri Sarsa, and Yu-kai Chou).

In addition, it has been demonstrated that gamification can enhance learners' learning motivation and strengthen cognitive engagement through the purposeful

integration of elements such as point scoring, competition, and game rules into the educational process. By incorporating gamification elements into instruction, teachers can transform the learning environment into a more dynamic and interactive space, thereby motivating learners to engage in deeper acquisition of mathematical concepts. Moreover, gamification elements may be particularly effective in individualized learning, as they enable the design of personalized learning trajectories adapted to different learning speeds and styles.

Alongside the above-mentioned foreign scholars, there are also researchers from neighboring countries and Kazakhstan who are engaged in studying the integration of gamification into the education system. In particular, A. Z. Alekseeva, G. S. Solomonova, R. A. Aetdinova, L. P. Varenina, A. V. Polyakova, Zh. Kuanbayeva, G. K. Kassymova, M. A. Yermaganbetova, A. S. Karmanova, A. N. Tokzhigitova, A. O. Aldabergenova, U. Esseykzy, and G. T. Kydyrbaeva, among others.

At present, it is encouraging that there are young domestic researchers actively engaged in issues of gamification. However, the application of gamification technology in teaching core subjects that directly influence learners' academic achievement has not yet been fully implemented. Domestic scientific publications and methodological materials on this issue remain insufficient. The main difficulty arises from the challenge of integrating game mechanics and dynamics with the content of learning topics, despite the availability of experience in their design. The development or effective selection of such content is often assigned to a qualified specialist in this field, in our case, the mathematics teacher.
Thus, although both foreign and domestic studies have confirmed the positive impact of gamification on learning motivation, academic achievement, and learner activity, the theoretical and methodological foundations for applying gamification elements in the process of forming mathematical concepts and their systems in school mathematics have not been sufficiently defined.

This situation makes it possible to identify the following contradictions in the issue of integrating gamification into the education system:

- between the importance of the conscious and systematic formation of mathematical concepts and the predominance of their formal acquisition by learners in educational practice;
- between the need to enhance learners' cognitive activity and learning motivation and the insufficient ability of traditional teaching methods to stimulate active engagement in school mathematics;
- between the high potential of digital technologies and gamification elements in education and the insufficient scientific and methodological justification

for their purposeful and systematic integration into the process of forming mathematical concepts.

In this regard, the problem of effectively using modern technologies, including gamification elements, in the formation of concepts and their systems in school mathematics has emerged. The need to resolve the identified contradictions determines the relevance of the research and provides the basis for selecting the dissertation topic: **"Technology of Using Gamification Elements in the Formation of Concepts and Their Systems in School Mathematics."**

Aim of the research – to determine the theoretical and methodological foundations of the technology of using gamification elements in the formation of mathematical concepts and their systems in the school mathematics course, to develop its structural-content model, and to prove the effectiveness of the methodology for its implementation.

Object of the research – the process of teaching mathematics in general secondary education institutions.

Subject of the research – the process of using gamification elements aimed at the formation of mathematical concepts and their systems in school mathematics instruction.

Scientific hypothesis of the research. If a methodology based on the use of gamification elements aimed at the formation of mathematical concepts and their systems in school mathematics is developed and systematically implemented in the learning process, then the level of learners' mastery of mathematical concepts, their cognitive activity, and learning motivation will increase, because gamification enables the organization of the learning process in an active, engaging, and outcome-oriented manner.

In accordance with the aim and hypothesis of the research, the following main objectives were identified:

1. To analyze the level of study of the problem of forming mathematical concepts and their systems in school mathematics as presented in psychological, pedagogical, and methodological literature.
2. To define the essence and significance of the concept of gamification and determine the didactic conditions for the effective use of its elements in the formation of mathematical concepts and their systems in school mathematics.
3. To develop a structural-content model of the technology for using gamification elements in the formation of mathematical concepts and their systems, and to design the methodology for its implementation.
4. To test the effectiveness of the proposed methodology through pedagogical experimental work and draw scientific and methodological conclusions.

Leading idea of the research. The systematic and purposeful use of gamification elements in the process of forming mathematical concepts and their systems in school mathematics contributes to learners' conscious mastery of mathematical concepts and their systems, increases their cognitive activity, and strengthens their learning motivation. A gamification-based teaching technology transforms the acquisition of mathematical knowledge into an engaging, accessible, and outcome-oriented process.

Sources of the research. The research is based on the Concept for the Development of Preschool, Secondary, Technical and Vocational Education for 2023–2029, the Addresses of the President of the Republic of Kazakhstan to the People of Kazakhstan, state mandatory educational standards for all levels of education, curricula and syllabi for school mathematics, scientific studies by domestic and foreign scholars on the formation of mathematical concepts, gamification and game-based technologies, digital education and innovative teaching methods, textbooks on methods of teaching school mathematics, best practices of pedagogical scientists, gamified digital platforms, electronic databases, scientific articles, and online resources.

Research methods. The study employed theoretical methods such as analysis of psychological, pedagogical, and scientific-methodological literature on the research topic, examination of state educational standards, curricula and regulatory documents, as well as comparative analysis, systematization, generalization, and modeling. Empirical methods included analysis and synthesis of pedagogical experience, observation, diagnostics, pedagogical experiment, questionnaires, interviews, and mathematical-statistical methods. The integrated use of these methods ensured the scientific validity, reliability, and practical significance of the research results.

Methodological and theoretical foundations of the research. The methodological and theoretical basis of the study consists of philosophical concepts and principles; the Law on Education of the Republic of Kazakhstan, its concepts and programs; principles of scientific systematization; epistemology and its principles; developmental learning theory; competence-based and personality-oriented approaches; theories of mathematical concept formation; as well as concepts of gamification and game-based learning.

Scientific novelty of the research:

1. The theoretical foundations of the technology for using gamification elements in the formation of mathematical concepts and their systems in school mathematics were clarified, and its scientific and methodological prerequisites were defined.

2. The role and pedagogical significance of gamification in mathematics education were specified, and the didactic conditions for the effective use of gamification elements in the formation of mathematical concepts and their systems were determined.
3. A structural-content model of the technology for using gamification elements aimed at forming mathematical concepts and their systems was developed, and a methodology for its implementation was designed.
4. The effectiveness of the proposed methodology was validated through pedagogical experimentation, and its efficiency was confirmed based on both quantitative and qualitative analysis.

The theoretical significance of the study is determined by the improvement of the theory of mathematical concept formation in school mathematics methodology based on the didactic potential of gamification. In the course of the research, the theoretical and methodological foundations of using gamification elements were clarified, and the scientific and pedagogical prerequisites for integrating them into the process of forming mathematical concepts and their systems were identified. Furthermore, the proposed findings make it possible to consider the problem of mathematical concept formation in a comprehensive manner through personality-oriented, cognitive, systemic, activity-based, and competence-based approaches.

The practical significance of the study is defined by the possibility of applying the proposed methodology in mathematics lessons in general secondary schools. The developed structural-content model can be used in organizing mathematics lessons, designing learning tasks, and enhancing learners' cognitive activity. The methodological solutions proposed in the study enable teachers to: design gamification-based tasks for the systematic formation of mathematical concepts; effectively integrate gamification elements into instruction; increase learners' learning motivation; and improve the assessment of learning outcomes.

Main provisions submitted for defense:

1. The technology for using gamification elements in the process of forming mathematical concepts and their systems is scientifically and methodologically substantiated, and its content and structure are implemented in accordance with the didactic objectives of instruction.
2. The pedagogical justification and purposeful application of gamification enhance the effectiveness of mastering mathematical concepts and their systems in school mathematics, and strengthen learners' learning motivation and cognitive activity.
3. Gamification tasks and the didactic conditions for their effective use contribute to learners' deeper understanding of mathematical concepts, their

comprehension of logical relationships between them, and the development of skills for applying knowledge in practice.

4. Taking into account learners' age characteristics, the structural-content model of using gamification elements in the formation of mathematical concepts and their systems enables the systematic organization of the learning process, and its implementation methodology increases learners' mathematical preparedness and learning motivation.

Author's personal contribution is expressed in defining the theoretical and methodological foundations of the technology for using gamification elements in the formation of mathematical concepts and their systems among learners of general secondary schools, in its practical implementation, as well as in conducting experimental work and proving the validity of the scientific hypothesis through the analysis of the obtained results.

The reliability and validity of the research results are ensured by the clarity of its methodological foundations and the comprehensive application of methods selected in accordance with the aim and objectives of the study. In particular, during the research, the interconnection between theoretical analysis and empirical data collection was maintained, and the pedagogical experiment was conducted systematically through ascertaining, formative, and control stages.

The authenticity of the obtained results is confirmed by the content validity and consistency of the diagnostic tools used, as well as by the processing of data through mathematical and statistical methods. The validity of the research conclusions is further supported by comparing the obtained results with data from domestic and international studies, repeated verification during pedagogical practice, and their applicability in educational practice. This, in turn, ensured the scientific credibility and practical significance of the proposed conclusions and findings.

Publications based on the research results. The total number of publications reflecting the content of the dissertation is 11, including: 1 article in a peer-reviewed international journal indexed in the Scopus database (65th percentile), 2 articles in scientific journals recommended by the Committee for Quality Assurance in the Sphere of Science and Higher Education of the Republic of Kazakhstan, 1 article in a foreign scientific journal, 4 papers in materials of international scientific-practical conferences held in the Republic of Kazakhstan, 1 textbook, 1 methodological guide, and 1 copyright certificate.

In an international journal indexed in Scopus:

1. Sansyzbayev, A., Kadirbayeva, R., Daiyrbekov, S., Zhetpisbayeva, G. "Applying Gamification Technology to Enhance Student Engagement in High School Mathematics." International Journal of Information and

Education Technology, 2025, 15(7), pp. 1398–1409. https://doi.org/10.18178/ijiet.2025.15.7.2341 (65th percentile).

In domestic journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Republic of Kazakhstan:

2. Kadirbayeva R. I., Sansyzbayev A. S. "The impact of using gamification elements on learning effectiveness in teaching school mathematics." Bulletin of Abylai Khan KazUIR&WL, Pedagogical Sciences Series, Almaty, 2024, No. 1(72), pp. 491–511. https://doi.org/10.48371/PEDS.2024.72.1.034

3. Kadirbayeva R. I., Sansyzbayev A. S., Daiyrbekov S. S. "The essence and stages of forming concepts and their systems in the school mathematics course." Bulletin of Khoja Akhmet Yassawi University, 2025, No. 4(138), pp. 274–286. https://doi.org/10.47526/2025-4/2664-0686.292

In a foreign scientific journal:

4. Kadirbayeva R., Sansyzbayev A. S., Saduakasova Zh., Aimashova Zh. "The possibilities of using gamification elements in teaching mathematics." Eurasian Journal of Researches in Social and Economics (EJRSE), Vol. 10, Special issue 1, 2023, pp. 157–170. https://dergipark.org.tr/tr/download/article-file/3104664

In international conference proceedings (Kazakhstan):

5. Sansyzbayev A. S., Aimashova Zh. T. "Gamification and its application possibilities in teaching mathematics." Proceedings of the 10th Republican Student Scientific-Practical Conference dedicated to Science Workers' Day, Shymkent, 2023, pp. 419–424.

6. Kadirbayeva R. I., Sansyzbayev A. S. "Methods and forms of organizing gamification elements in teaching school mathematics." Proceedings of the International Scientific-Practical Conference "Digitalization of Education: Artificial Intelligence and Development of Science," Zhetysu University, Taldykorgan, 2025, pp. 153–157.

7. Kadirbayeva R. I., Sansyzbayev A. S. "Stages of developing gamified tasks aimed at forming mathematical concepts and their systems." Proceedings of the X International Scientific-Methodological Conference "Mathematical Modeling and Information Technologies in Education and Science," Almaty, 2025, pp. 906–910.

8. Sansyzbayev A. S. "Structural-content model of using gamification elements in the formation of mathematical concepts and their systems." Proceedings of the International Scientific-Theoretical Conference "Zhanibekov Readings–3," Shymkent, 2026, pp. 95–99.

Textbook and methodological guide:

9. Kadirbayeva R. I., Daiyrbekov S. S., Sansyzbayev A. S. Modern Assessment Technologies. Textbook. Shymkent: Alem Publishing House, 2025, 208 pages.

10. Sansyzbayev A. S. Using the “OIQ Game” Gamification Platform in Mathematics Lessons. Methodological guide, Shymkent, 84 pages.

Copyright certificate:

11. Kadirbayeva R. I., Daiyrbekov S. S., Kadirbayeva R. I., Aryn M. K., Sansyzbaeva A. S. “OIQ Game – Interactive Educational Platform (Computer Program).” Certificate of entry into the State Register of Copyrighted Objects, No. 63105, October 17, 2010.

Research base: the experimental work was carried out at Secondary School No. 59 of the Education Department of Shymkent city and at School-Gymnasium No. 65 named after I. Altynsarin.

Stages of the research. The study was conducted in three stages.

The first stage (2022–2023) – preparatory and analytical stage – involved defining the research topic and analyzing regulatory documents of the Republic of Kazakhstan aimed at the development of education and science. A systematic review of domestic and foreign scientific and methodological literature related to the topic was conducted, the theoretical foundations of forming mathematical concepts and their systems in school mathematics were examined, and the essence of the concept of gamification was defined. The relevance of the research was substantiated, and the scientific apparatus of the study was formulated. A diagnostic (ascertaining) experiment was carried out through questionnaires, and its results were analyzed.

The second stage (2023–2024) – the formative-experimental stage – involved continuing the study, analysis, and systematization of works related to the research topic. The role of gamification in education was clarified, and the possibilities and didactic conditions for effectively organizing the formation of mathematical concepts and their systems through the use of gamification elements were determined. A structural-content model of the proposed technology was developed, along with the methodology for its implementation. In addition, the interactive educational platform OIQ Game was designed, and the methodology was tested in school practice.

The third stage (2024–2026) – the final analytical stage – focused on organizing a pedagogical experiment to determine the effectiveness of the proposed technology. The conditions and stages of the experiment were defined, after which the obtained data were processed and subjected to quantitative and qualitative analysis. The effectiveness of the methodology was evaluated, the research results were systematized, and the main conclusions were formulated. Practical recommendations and directions for future research were developed. In addition, the dissertation was finalized in accordance with academic requirements, and the manuscript version was submitted for discussion.

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

Introduction: the relevance of the research is substantiated, highlighting the effectiveness of using gamification elements in the formation of mathematical concepts and their systems in school mathematics. The aim of the research is formulated, and the object, subject, and objectives of the study are defined. The research hypothesis, scientific novelty, and main provisions submitted for defense are presented. The stages of the research are described, including theoretical analysis, methodology development, experimental verification, and data processing.

The first chapter entitled **"Theoretical Foundations of the Technology for Using Gamification Elements in the Formation of Mathematical Concepts and Their Systems"** analyzes the theoretical bases of forming mathematical concepts and their systems in school mathematics instruction. The essence of the concept of gamification is defined, and its role in education is described. In addition, the methodological approaches to the technology of using gamification elements in the formation of mathematical concepts and their systems are identified, and on this basis, the didactic conditions for implementing the technology are determined.

The second chapter entitled "**Methodological Foundations of the Technology for Using Gamification Elements in the Formation of Mathematical Concepts and Their Systems"** presents the structural-content model of the technology for using gamification elements in the formation of mathematical concepts and their systems in school mathematics. Methods and techniques for designing gamified tasks aimed at mastering mathematical concepts are described, and the methodology for implementing the technology is developed. Furthermore, the organization and results of the pedagogical experiment are analyzed, and the effectiveness of the proposed methodology for forming mathematical concepts and their systems is empirically validated.

Conclusion: the conclusion presents the significance of the scientific and pedagogical results obtained during the research. The main theoretical and practical findings are formulated, and the scientific value of the conducted work as well as its future application prospects are outlined.

The list of references includes scientific works, regulatory documents, and other materials used in the course of the study related to the research topic. A total of 214 sources were used.

Appendices include implementation certificates of the developed methodology, a copyright certificate for the developed interactive educational platform, as well as supplementary materials containing questionnaires and statistical data.