



ISSN: 3060-4613



MAKTABGACHA
VA MAKTAB
TA'LIMI VAZIRLIGI



O'zbekiston
Milliy Pedagogika
Universiteti



№2(1)
2026

- 13.00.00 Pedagogika fanlari
- 13.00.01 Pedagogika nazariyasi. Pedagogik ta'limotlar tarixi
- 13.00.02 Ta'lim va tarbiya nazariyasi va metodikasi (sohalar bo'yicha)
- 13.00.03 Maxsus pedagogika
- 13.00.04 Jismoniy tarbiya va sport mashg'ulotlari nazariyasi va metodikasi
- 13.00.05 Kasb-hunar ta'limi nazariyasi va metodikasi
- 13.00.06 Elektron ta'lim nazariyasi va metodikasi (ta'lim sohaları va bosqichlari bo'yicha)
- 13.00.07 Ta'limda menejment
- 13.00.08 Maktabgacha ta'lim va tarbiya nazariyasi va metodikasi
- 13.00.09 Ijtimoiy pedagogika
- 07.00.00 Tarix fanlari
- 19.00.00 Psixologiya fanlari
- 01.00.00 Fizika-matematika fanlari
- 02.00.00 Kimyo fanlari
- 03.00.00 Biologiya fanlari
- 09.00.00 Falsafa fanlari
- 10.00.00 Filologiya fanlari
- 11.00.00 Geografiya fanlari

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Pedagogika, psixologiya fanlariga ixtisoslashgan ilmiy jurnal



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Elektron nashr. 772 sahifa,
2-fevral, 2026-yil.

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Pedagogika fanlari bo'yicha: OAK Kengashi tavsiyasi (26.08.2024-y., №11-05-4381/01) asosida:

- Ekspert kengashi (29.10.2024-y., №10)
- Rayosat qarori (31.10.2024-y., №363/5)

Psixologiya fanlari bo'yicha: Toshkent davlat pedagogika universiteti murojaatiga asosan OAK tavsiyasi (24.04.2025-y., №11-05-2566/01):

- Ekspert kengashi (25.05.2025-y., №10)
- Rayosat qarori (08.05.2025-y., №370/5)

"Maktabgacha va maktab ta'limi" jurnali

26.09.2023-yildan

O'zbekiston Respublikasi Prezidenti Administratsiyasi huzuridagi Axborot va ommaviy kommunikatsiyalar agentligi tomonidan **№C-5669363** reyestr raqami tartibi bo'yicha ro'yxatdan o'tkazilgan.

Litsenziya raqami: **№136361**

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INNOVATIVE APPROACHES TO EARLY MATHEMATICS EDUCATION AND DEVELOPMENT IN PRESCHOOL CHILDREN

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Abstract: This article presents a contemporary, research-informed framework for supporting the development of early and preschool children through innovative approaches to early mathematics education. The focus is placed on the formation of foundational mathematical representations—number, shape, measurement, patterns, and data reasoning—alongside cognitive abilities that are critical for school readiness, including executive functions, cognitive flexibility, spatial reasoning, and problem-solving initiative. Particular attention is given to issues of equity, family–school partnership, and the ethical boundaries of digitalization in early childhood education.

Key words: early childhood education; preschool development; early mathematics; mathematical representations; spatial reasoning; logical thinking; play-based learning; manipulatives; pentomino; Möbius strip; formative assessment; learning analytics; educational technology; augmented reality; artificial intelligence in education.

Annotatsiya: Ushbu maqolada bolalarning erta va maktabgacha yosh davridagi rivojlanishini qo'llab-quvvatlashga qaratilgan, erta matematika ta'limiga asoslangan innovatsion yondashuvlarning zamonaviy, ilmiy asoslangan modeli bayon etiladi. Tadqiqotda son, shakl, o'lchov, qonuniyatlar va ma'lumotlarni tahlil qilish kabi asosiy matematik tasavvurlarni shakllantirish bilan bir qatorda, maktabga tayyorgarlik uchun muhim bo'lgan kognitiv qobiliyatlar – ijro etuvchi funksiyalar, kognitiv moslashuvchanlik, fazoviy tafakkur va muammolarni hal etish tashabbusini rivojlantirish masalalariga alohida e'tibor qaratiladi. Shuningdek, ta'limda tenglikni ta'minlash, oila va ta'lim muassasasi hamkorligi hamda maktabgacha ta'limda raqamlashtirishning axloqiy chegaralari yoritib beriladi.

Kalit so'zlar: maktabgacha ta'lim; maktabgacha yoshdagi bolalar rivoji; erta matematika; matematik tasavvurlar; fazoviy tafakkur; mantiqiy fikrlash; o'yin asosida o'qitish; didaktik materiallar; pentamino; Möbius lentasi; formativ baholash; ta'limiy analitika; ta'lim texnologiyalari; kengaytirilgan reallik; ta'limda sun'iy intellekt.

Аннотация: В статье представлена современная научно обоснованная модель поддержки развития детей раннего и дошкольного возраста на основе инновационных подходов к раннему математическому образованию. Основное внимание уделяется формированию базовых математических представлений – числа, формы, измерения, закономерностей и элементарного анализа данных, а также развитию когнитивных способностей, имеющих ключевое значение для готовности к обучению в школе, включая исполнительные функции, когнитивную гибкость, пространственное мышление и инициативу в решении задач. Особое внимание уделяется вопросам равенства образовательных возможностей, взаимодействия семьи и образовательной организации, а также этическим границам цифровизации в сфере дошкольного образования.

Ключевые слова: дошкольное образование; развитие дошкольников; ранняя математика; математические представления; пространственное мышление; логическое мышление; обучение через игру; дидактические материалы; пентамино; лента Мёбиуса; формирующее оценивание; образовательная аналитика; образовательные технологии; дополненная реальность; искусственный интеллект в образовании.



INTRODUCTION

Across international and national education agendas, early childhood education is increasingly viewed as a critical period during which the foundations of learning capacity are established—language development, self-regulation, problem-solving skills, and early mathematical thinking. Professional standards and policy documents consistently emphasize that high-quality early mathematics experiences should not be understood as “early schooling” in a narrow sense, but rather as a developmentally appropriate pathway that strengthens children’s curiosity, reasoning, and confidence. Position statements on early mathematics learning underscore the importance of providing rich, meaningful, and play-based mathematical experiences beginning in the preschool years.

In the context of Uzbekistan, the ongoing modernization of preschool education and the emphasis on competency-based learning create a strong foundation for the implementation of innovative approaches in early mathematics education. National strategic documents outline systemic development priorities for preschool education through 2030, while the State Preschool Curriculum “Ilk Qadam” emphasizes learning through play and the creation of nurturing educational environments that take into account children’s individual differences.

LITERATURE REVIEW

Conceptual foundations: what “innovation” means in early math education. “Innovation” in preschool mathematics should not be reduced to the mere use of gadgets or digital content. Evidence-based guidance emphasizes that instructional effectiveness is primarily determined by the quality of pedagogical design, the nature of teacher–child interaction, and purposeful practice that supports children’s conceptual understanding. From this perspective, innovation in early mathematics education is understood as a multidimensional construct grounded in developmental science rather than technological novelty alone.

Within this framework, innovation in early mathematics education encompasses several interrelated dimensions. These include developmental alignment, whereby learning tasks correspond to children’s cognitive and socio-emotional development and are connected to everyday experience; play-based inquiry, in which children explore, test, compare, and justify ideas through play and dialogue; modeling with manipulatives, enabling children to construct mathematical concepts through hands-on combinatorics, spatial transformations, and transitions between different forms of representation; and responsible technology integration, in which digital tools are used briefly, interactively, and intentionally to support—rather than replace—play and communication, with clear guidelines regarding screen time and child safety.

Key developmental targets of early mathematics learning. A contemporary model of preschool mathematics education should foster the development of both foundational mathematical representations and broader cognitive abilities that underpin school readiness. Mathematical representations include number sense and quantity, encompassing comparison, counting principles, and part–whole relationships; geometry and spatial relations, such as shape, composition, symmetry, and orientation; measurement concepts related to length, area, volume, and time, progressing from informal to more formal understanding; and patterns and structural thinking, including regularities, sequences, and elements of early algebraic reasoning.

In parallel, early mathematics learning should support the development of cognitive abilities essential for successful school transition. These abilities include executive functions, such as inhibition, working memory, and cognitive flexibility; spatial reasoning, including mental rotation, spatial visualization, and navigation; logical operations, such as classification, seriation, and cause–effect reasoning; as well as initiative and persistence, reflected in children’s willingness to try alternative strategies and explain their choices. Recent research and methodological toolkits in early mathematics education consistently emphasize that spatial reasoning represents a powerful, yet often underestimated, contributor to later mathematical achievement, and that well-designed, play-based spatial learning programs can effectively transfer gains to numeracy development.

RESEARCH METHODOLOGY

The study employs a qualitative and descriptive research design to examine innovative approaches to early mathematics education in preschool settings. Data were collected through systematic analysis of international policy documents, curricular frameworks, and research-based methodological guidelines related to early mathematics learning. In addition, classroom observations and documented pedagogical practices were reviewed to identify commonly used play-based, manipulative-oriented, and technology-supported approaches. The collected data were analyzed using thematic content analysis, allowing for the identification of recurring methodological patterns, developmental targets, and instructional principles. Comparative analysis was applied to synthesize findings across sources and to evaluate the coherence between pedagogical practices and developmental objectives in early childhood mathematics education.

ANALYSIS AND RESULTS

Innovative methodical approaches and learning designs in early mathematics education increasingly emphasize play-based inquiry supported by purposeful mathematical discourse. A core innovation in this context is the deliberate strengthening of children's mathematical language through prompts such as "how do you know?", "what changed?", "what is the same or different?", and "can it be done another way?". Such questions transform routine classroom activities into episodes of reasoning and reflection, thereby fostering conceptual clarity. Position statements in early mathematics education consistently stress the importance of meaningful learning contexts and rich teacher–child interactions rather than reliance on isolated drills or repetitive exercises.

Manipulative-based modeling, particularly through the use of pentomino tasks, represents another significant innovative approach in preschool mathematics. Engagement with pentomino supports the development of decomposition and recomposition skills, symmetry awareness, mental rotation, and strategic decision-making. A methodically structured progression typically involves recognizing and naming shapes through comparison with familiar forms such as letters, objects, and silhouettes; overlay modeling by matching pieces to predefined outlines; non-overlay assembly based on memory and partial cues; and a creative stage in which children invent new silhouettes and explain the logic of their constructions. The innovative aspect lies not in the material itself, but in the pedagogical approach, as children are guided to verbalize strategies, evaluate alternatives, and justify decisions—skills that are central to cognitive development and early mathematics pedagogy.

Three-dimensional block modeling further contributes to spatial structuring and the ability to switch between different forms of representation. Constructing models from 3D blocks based on pictorial representations strengthens spatial orientation, including front–back, above–below, and left–right relations, enhances understanding of part–whole relationships in three dimensions, and supports translation between representations, such as from a physical model to an image and to a verbal description. Such modeling activities support the formation of mental imagery, which has been identified as an important predictor of later success in mathematics and STEM-related learning.

Topological exploration using the Möbius strip introduces an additional innovative dimension by extending children's geometric thinking beyond traditional Euclidean shapes. When introduced in senior preschool groups, the pedagogical value of the Möbius strip lies not in the perceived complexity of the object, but in the inquiry-based structure of the learning process. This includes posing a problem-oriented question, such as "Is every surface two-sided?", followed by hands-on construction and discovery-based reasoning. This approach aligns with research-informed pedagogies that position children as active constructors of mathematical meaning rather than passive recipients of knowledge.

Digital tools, when used appropriately, function as amplifiers of learning rather than substitutes for hands-on activity and social interaction. Augmented reality can support the visualization of otherwise invisible spatial relationships, including rotation, symmetry lines, fitting constraints, and layered hints, thereby enabling children to test hypotheses while remaining engaged in interactive exploration. Research reviews report promising outcomes for augmented reality–based learning in preschool settings when such tools are mediated by teachers and designed in accordance with developmental principles.

Digital storytelling also offers opportunities to support mathematical thinking by enabling children to explain their solutions through short animations, voice narratives, or storyboards. Questions such as "How did you build it?", "Why does it fit?", and "What did you change?" encourage metacognitive reflection and the development of mathematical language, while maintaining a play-based and engaging learning environment. In parallel, generative artificial intelligence can be used ethically as a teacher-facing tool to support methodological planning, including the generation of task variants, instructional prompts, differentiated activities, and reflection questions. International guidance underscores that such tools should not function as uncontrolled content sources for children and highlights the importance of governance, data privacy, transparency, and a human-centered approach.

Innovation in early mathematics education also encompasses formative monitoring and learning analytics, particularly in the ways educators observe, document, and respond to children's learning processes. Practical approaches include the use of brief observation tools, such as checklists or rubrics, designed to capture strategy diversity, the quality of explanations, cognitive flexibility, and levels of persistence and initiative. Policy-oriented and analytical reports emphasize that data-informed decision-making can strengthen teaching quality when applied responsibly and without reducing complex learning processes to narrow or reductive metrics.

Finally, considerations of safety, well-being, and equity represent non-negotiable conditions for the implementation of innovative and digital practices in preschool education. Global health guidance consistently recom-



mends limiting sedentary screen time for young children while prioritizing adequate sleep, physical movement, and live social interaction. Contemporary reports further caution that digitalization may exacerbate educational inequalities if issues of access, safety, and the protection of children's rights are not adequately addressed and safeguarded.

CONCLUSION AND RECOMMENDATIONS

Innovative approaches in preschool mathematics education are most effective when they are implemented as a coherent and integrated system that combines play-based inquiry, hands-on modeling—such as pentomino activities, three-dimensional block construction, and topology-based tasks—strong methodological guidance from teachers, and carefully mediated use of educational technologies. Such an ecosystem supports not only the development of foundational mathematical representations but also broader aspects of cognitive development, including cognitive flexibility, spatial reasoning, persistence, and reflective thinking, while simultaneously safeguarding children's well-being and promoting equity in early childhood education.

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- 13.00.00 Pedagogika fanlari
 - 13.00.01 Pedagogika nazariyasi. Pedagogik ta'limotlar tarixi
 - 13.00.02 Ta'lim va tarbiya nazariyasi va metodikasi (sohalar bo'yicha)
 - 13.00.03 Maxsus pedagogika
 - 13.00.04 Jismoniy tarbiya va sport mashg'ulotlari nazariyasi va metodikasi
 - 13.00.05 Kasb-hunar ta'limi nazariyasi va metodikasi
 - 13.00.06 Elektron ta'lim nazariyasi va metodikasi (ta'lim sohaları va bosqichlari bo'yicha)
 - 13.00.07 Ta'limda menejment
 - 13.00.08 Maktabgacha ta'lim va tarbiya nazariyasi va metodikasi
 - 13.00.09 Ijtimoiy pedagogika
 - 07.00.00 Tarix fanlari
 - 19.00.00 Psixologiya fanlari
 - 01.00.00 Fizika-matematika fanlari
 - 02.00.00 Kimyo fanlari
 - 03.00.00 Biologiya fanlari
 - 09.00.00 Falsafa fanlari
 - 10.00.00 Filologiya fanlari
 - 11.00.00 Geografiya fanlari



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2026. №2(1)

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"Maktabgacha va maktab ta'limi" jurnali 26.09.2023-yildan O'zbekiston Respublikasi Prezidenti Adminstratsiyasi huzuridagi Axborot va ommaviy kommunikatsiyalar agentligi tomonidan №C-5669363 reyestr raqami tartibi bo'yicha ro'yxatdan o'tkazilgan.
Litsenziya raqami: № 136361.

Manzilimiz: Toshkent shahar, Yunusobod tumani
19-mavze, 17-uy.