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PSYCHOLOGICAL AND PEDAGOGICAL FOUNDATIONS OF DEVELOPING TECHNOLOGICAL COMPETENCIES IN FUTURE PRIMARY SCHOOL TEACHERS THROUGH ROBOTICS, 3D MODELING, AND LEGO TECHNOLOGIES

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Abstract: The rapid development of digital technologies and the global transformation of educational systems have significantly increased the demand for innovative pedagogical approaches in teacher education. In contemporary educational environments, future primary school teachers are expected not only to possess theoretical pedagogical knowledge but also to demonstrate technological literacy, creative thinking, problem-solving abilities, and psychological readiness for innovation-oriented teaching. This article examines the psychological and pedagogical foundations of developing technological competencies in future primary school teachers through robotics, 3D modeling, and LEGO technologies within the framework of STEAM education. The study analyzes the influence of innovative technological environments on cognitive development, motivation, emotional engagement, and creative self-expression among teacher trainees. Particular attention is devoted to the psychological aspects of technological learning, including constructivist learning theory, motivation, cognitive flexibility, collaborative interaction, and emotional intelligence in digital educational environments. The article also discusses the integration of robotics and modeling technologies into higher pedagogical education, identifies current challenges in teacher preparation, and proposes effective pedagogical conditions for developing technological competencies in future educators. The findings indicate that robotics, LEGO technologies, and 3D modeling significantly contribute to the development of technical creativity, reflective thinking, communication skills, and psychological adaptability among future primary school teachers.

Keywords: Primary education, robotics, 3D modeling, LEGO technologies, psychological readiness, technological competence, STEAM education, innovative pedagogy, digital learning environment, future teachers.

Introduction: The twenty-first century is characterized by rapid scientific and technological progress, digital transformation, and the increasing integration of artificial intelligence into almost every sphere of social life. Under such conditions, educational systems worldwide are facing new challenges related to preparing future generations for technologically advanced societies. Contemporary education no longer focuses solely on the transmission of theoretical knowledge. Instead, it aims to develop creativity, critical thinking, technological literacy, adaptability, collaboration skills, and emotional resilience among learners. Consequently, the role of teachers has fundamentally changed. Modern educators are expected to become facilitators of innovative learning processes capable of integrating technology into teaching and supporting students' cognitive and psychological development.

Primary education plays a decisive role in shaping children's intellectual, emotional, and social foundations. At this stage, learners begin to develop logical thinking, creativity, communication

skills, and interest in scientific and technological phenomena. Therefore, the professional preparation of future primary school teachers requires innovative approaches that combine pedagogy, psychology, and technology. In recent years, robotics, 3D modeling, and LEGO technologies have emerged as effective tools for enhancing technological competence and psychological engagement in educational settings. The implementation of robotics and modeling technologies in teacher education has become an important aspect of modern pedagogical reform. International educational systems increasingly integrate STEAM education principles into primary education curricula to prepare students for future professions and technological realities. Countries such as Finland, South Korea, Singapore, the United States, and Germany actively incorporate robotics laboratories, coding programs, and design-oriented learning environments into primary education. These innovations require teachers who possess not only methodological knowledge but also psychological readiness to work in technology-rich educational environments.

The Republic of Uzbekistan has also initiated significant reforms aimed at digitalizing education and modernizing teacher preparation systems. National development strategies emphasize the importance of technological competence, innovative pedagogy, and digital literacy among future educators. Nevertheless, there remains a need for scientific research focused on the psychological and pedagogical foundations of preparing future primary school teachers through robotics, 3D modeling, and LEGO technologies. This article aims to analyze the role of robotics, 3D modeling, and LEGO technologies in developing technological competencies and psychological readiness among future primary school teachers. The study explores theoretical perspectives, pedagogical opportunities, psychological impacts, and practical implications associated with technology-based teacher education.

Theoretical Foundations of Technological Competence Development. Technological competence is considered one of the most essential components of professional competence in modern pedagogy. It refers to the ability to effectively use technological tools, digital resources, and innovative methods in educational practice. According to constructivist educational theory, learners actively construct knowledge through interaction with their environment, practical activities, and social communication. Robotics and 3D modeling technologies provide ideal conditions for constructivist learning because they encourage experimentation, creativity, collaboration, and problem-solving. Jean Piaget's cognitive development theory emphasizes the importance of hands-on experiences in the formation of logical thinking and intellectual structures. Similarly, Lev Vygotsky's sociocultural theory highlights the role of collaborative interaction and guided participation in cognitive development. Robotics and LEGO-based activities create socially interactive learning environments where future teachers collaboratively design models, solve technical tasks, and exchange ideas. Such activities contribute to the development of communication skills, self-confidence, and reflective thinking.

Another important theoretical perspective is experiential learning theory proposed by David Kolb. Experiential learning involves knowledge acquisition through concrete experience, reflective observation, conceptual understanding, and active experimentation. Robotics and 3D modeling activities allow teacher trainees to engage in experiential learning processes by constructing prototypes, testing solutions, and evaluating outcomes. This process significantly enhances technological understanding and practical pedagogical competence.

From a psychological perspective, innovative technologies also influence learners' emotional engagement and motivation. Self-determination theory developed by Deci and Ryan suggests that intrinsic motivation increases when individuals experience autonomy, competence, and social connectedness. Robotics and LEGO technologies support these psychological needs by providing

opportunities for independent project creation, collaborative teamwork, and successful problem-solving experiences.

Psychological Aspects of Robotics and LEGO-Based Learning. Psychological readiness is an essential factor in the professional preparation of future teachers. It includes motivation, emotional stability, adaptability, communication skills, and positive attitudes toward innovation. Technology-based learning environments can significantly influence these psychological characteristics. Robotics activities stimulate cognitive curiosity and increase emotional involvement in learning processes. When future teachers design robots or create digital models, they actively participate in creative problem-solving situations that require concentration, analysis, and experimentation. Such experiences contribute to the development of cognitive flexibility and analytical thinking.

LEGO technologies are particularly effective in reducing learning anxiety and increasing psychological comfort among students. Educational psychologists note that game-based learning environments create emotionally supportive conditions that encourage risk-taking, creativity, and active participation. LEGO-based tasks often involve teamwork, storytelling, and practical construction activities, which help future teachers improve social communication skills and emotional intelligence. Moreover, robotics and modeling technologies positively affect self-efficacy beliefs. Albert Bandura's social cognitive theory emphasizes that successful experiences increase individuals' confidence in their abilities. When teacher trainees successfully complete technological projects, program robots, or design 3D models, they develop stronger confidence in their professional and technological capabilities.

Creativity is another important psychological factor developed through robotics and modeling activities. Modern educational psychology considers creativity as a combination of divergent thinking, imagination, originality, and flexibility. Robotics and 3D design tasks encourage learners to generate multiple solutions, experiment with different ideas, and apply innovative approaches to educational challenges.

Collaborative technological projects also contribute to the development of interpersonal communication skills. Future primary school teachers must be capable of organizing cooperative learning environments and maintaining effective communication with students. Robotics and LEGO activities require teamwork, negotiation, leadership, and peer support, thereby improving social interaction competencies.

Robotics in Primary Teacher Education. Educational robotics has become one of the most innovative areas of modern pedagogy. Robotics involves the design, construction, programming, and operation of robotic systems for educational purposes. In teacher education, robotics serves as both a technological tool and a pedagogical methodology. The integration of robotics into teacher preparation programs offers several pedagogical advantages. First, robotics supports interdisciplinary learning by combining science, technology, mathematics, engineering, and creativity. Second, it promotes active learning and student-centered instruction. Third, robotics enhances future teachers' understanding of problem-based learning and project-oriented methodologies. Robotics education also contributes to psychological development by encouraging perseverance, responsibility, and resilience. Technical projects often involve challenges and errors that require patience and persistence. Future teachers learn to analyze failures, modify strategies, and continue working toward solutions. Such experiences strengthen emotional regulation and stress management skills.

In primary education contexts, robotics can be used to teach mathematics, natural sciences, language development, and logical thinking. Therefore, future primary school teachers need

methodological preparation for integrating robotics into interdisciplinary classroom activities. Educational robotics platforms such as LEGO Mindstorms, Arduino, micro:bit, and LEGO Spike Prime are increasingly used in teacher training institutions worldwide. Research findings indicate that robotics-based instruction improves learners' engagement, creativity, and academic achievement. Furthermore, robotics activities support inclusive education because they allow students with different learning styles and abilities to participate actively in collaborative projects.

Educational Potential of 3D Modeling Technologies. 3D modeling technologies have transformed modern educational practices by introducing interactive and visually rich learning environments. These technologies enable learners to create digital representations of objects, structures, and concepts using specialized software applications. For future primary school teachers, 3D modeling offers numerous pedagogical and psychological benefits. It develops spatial imagination, visual literacy, design thinking, and creative problem-solving skills. Through modeling activities, teacher trainees learn how to transform abstract ideas into concrete visual products.

Educational psychologists emphasize that visual learning significantly improves comprehension and memory retention. 3D models make complex concepts more understandable and engaging for young learners. For example, future teachers can use 3D models to explain geometric shapes, natural phenomena, architectural structures, or scientific processes in primary classrooms. Software platforms such as Tinkercad, Blender, SketchUp, and AutoCAD provide accessible opportunities for educational modeling. These tools support experiential learning and project-based education by enabling users to design, modify, and present original creations. From a psychological perspective, 3D modeling activities promote self-expression and intrinsic motivation. Students often experience satisfaction and pride when they successfully complete digital design projects. Such positive emotional experiences contribute to increased learning motivation and professional self-confidence. Moreover, 3D modeling enhances metacognitive skills. During design processes, learners must plan tasks, evaluate progress, identify mistakes, and make strategic decisions. These reflective practices improve critical thinking and self-regulation abilities.

LEGO Technologies and Constructive Learning Environments. LEGO Education technologies represent one of the most effective tools for constructive and game-based learning in primary education. LEGO-based instruction combines play, engineering, creativity, and collaboration within educational contexts. The psychological effectiveness of LEGO technologies can be explained through play theory and constructivist learning principles. Educational games stimulate emotional engagement, curiosity, and exploratory behavior. Young learners naturally enjoy manipulating objects, constructing models, and participating in imaginative scenarios. Consequently, LEGO activities create positive emotional learning environments. For future primary school teachers, LEGO technologies provide opportunities to master interactive teaching strategies and learner-centered methodologies. Teacher trainees learn how to organize collaborative tasks, facilitate problem-solving activities, and integrate storytelling into educational processes.

LEGO technologies also support inclusive and differentiated instruction. Since construction activities can be adapted to various difficulty levels, they accommodate learners with diverse cognitive abilities and learning preferences. This aspect is particularly important for primary school teachers who work with heterogeneous classrooms. Additionally, LEGO projects encourage reflective communication and peer interaction. Collaborative construction tasks require students to share ideas, negotiate solutions, and support each other during learning processes. These social experiences strengthen empathy, communication skills, and emotional intelligence.

Challenges in Integrating Technology into Teacher Education. Despite the significant educational potential of robotics, 3D modeling, and LEGO technologies, several challenges hinder their effective integration into teacher education systems.

One major challenge is the insufficient availability of technological infrastructure in many higher education institutions. Robotics laboratories, 3D printers, and advanced software applications require financial investment and technical maintenance. Educational institutions with limited resources may face difficulties implementing technology-rich programs. Another challenge concerns teacher educators' professional preparedness. Many instructors lack sufficient experience with robotics programming, digital modeling, or STEAM methodologies. Therefore, professional development programs and specialized training courses are necessary.

Curriculum limitations also affect the integration process. In some teacher education programs, technology-related disciplines remain theoretical and disconnected from practical classroom applications. Future teachers require more opportunities for hands-on experimentation, project-based learning, and interdisciplinary collaboration.

Psychological barriers should also be considered. Some students experience technological anxiety or fear of failure when working with complex digital tools. Educational environments must therefore provide supportive and motivating conditions that encourage experimentation and reduce stress. Time constraints and assessment difficulties present additional obstacles. Technology-based projects often require extended periods for design, testing, and reflection. Traditional assessment systems may not adequately evaluate creativity, collaboration, and innovative thinking.

Pedagogical Conditions for Effective Technology-Based Teacher Preparation. Effective preparation of future primary school teachers through robotics and modeling technologies requires specific pedagogical conditions.

First, higher education institutions should establish STEAM laboratories equipped with modern technological resources. These laboratories should provide access to robotics kits, 3D printers, digital modeling software, and interactive learning materials.

Second, teacher education curricula should integrate interdisciplinary STEAM modules that combine pedagogy, psychology, engineering, and digital technologies. Such integration would help future teachers understand the practical application of technological tools in primary education.

Third, project-based learning methodologies should become central components of teacher preparation programs. Project-oriented instruction promotes independence, creativity, collaboration, and reflective thinking.

Fourth, psychological support mechanisms are essential for maintaining students' motivation and reducing technological anxiety. Positive learning environments that encourage experimentation and constructive feedback contribute to psychological well-being and confidence.

Fifth, continuous professional development programs should be organized for university instructors and practicing teachers. Such programs would ensure the effective implementation of innovative educational technologies.

Conclusion. The integration of robotics, 3D modeling, and LEGO technologies into teacher education represents an important direction for modern pedagogical development. These technologies contribute not only to the formation of technological competencies but also to the psychological and emotional development of future primary school teachers. Robotics activities promote analytical thinking, resilience, creativity, and collaborative problem-solving. 3D modeling technologies develop visual literacy, design thinking, and reflective skills. LEGO-based learning environments enhance emotional engagement, communication competencies, and motivation.

Psychological readiness for technological innovation is becoming increasingly important in contemporary education. Future primary school teachers must be prepared to work in digital learning environments, integrate innovative methods into classroom instruction, and support students' creative and cognitive development.

The findings of this study indicate that technology-based teacher preparation should be supported by interdisciplinary curricula, modern educational infrastructure, STEAM laboratories, and psychologically supportive learning environments. Furthermore, the successful integration of robotics and modeling technologies into teacher education requires continuous methodological improvement and professional development. In conclusion, robotics, 3D modeling, and LEGO technologies possess significant pedagogical and psychological potential for developing technologically competent, creative, and emotionally resilient future primary school teachers. Their integration into higher pedagogical education can contribute to the modernization of educational systems and the preparation of innovative educators capable of meeting the demands of the digital era.

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