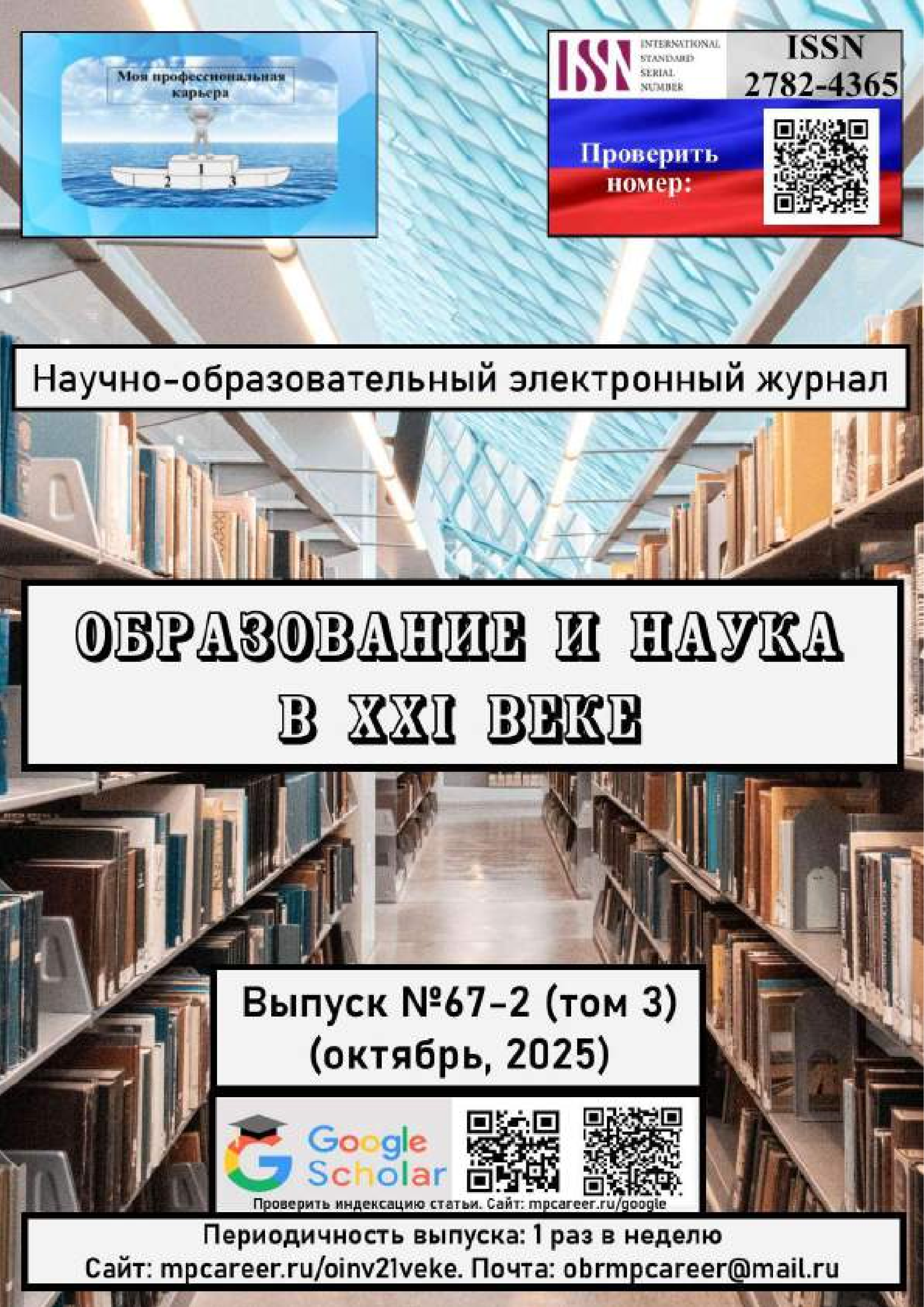

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Научно-образовательный электронный журнал

ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ

Выпуск №67-2 (том 3)
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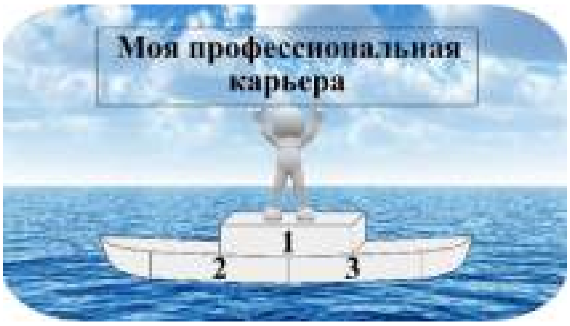

Международный научно-образовательный
электронный журнал
«ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ»

ISSN 2782-4365
УДК 37
ББК 94

Международный научно-образовательный электронный журнал «ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ». Выпуск №67-2 (том 3) (октябрь, 2025). Дата выхода в свет: 13.10.2025.

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Название публикации: «BUILDING A BIONIC PERSON: ADVANCES IN INTEGRATED BIOMEDICAL SYSTEMS»

What is a Bionic Person?

A bionic person, often conceptualized as a human augmented with advanced prosthetic and implantable technologies, integrates biomechanical, neural, and bioengineered systems to restore or enhance physiological functions lost to injury, disease, or congenital conditions. This interdisciplinary field combines bionic limbs, visual and auditory prostheses, artificial organs, and neural interfaces to create a seamless fusion of human biology and technology, approaching the science-fiction ideal of a cybernetic organism. Key components include myoelectric prosthetics for motor function, brain-computer interfaces (BCIs) for neural control, bioartificial organs like the pancreas, and sensory implants such as bionic eyes or cochlear implants. These systems aim to restore natural capabilities—movement, vision, hearing, and organ function—while emerging technologies explore superhuman enhancements like increased strength or sensory acuity. Unlike standalone prosthetics, building a bionic person requires holistic integration, ensuring biocompatibility, neural connectivity, and synchronized operation across multiple systems, often leveraging AI for adaptive control and real-time optimization.

Academic Review: Evolution, Technologies, and Prospects in Human Augmentation

Abstract

Building a bionic person represents the pinnacle of biomedical engineering, merging prosthetics, neural interfaces, and bioartificial systems to restore or augment human capabilities. This review traces the evolution from early mechanical aids to integrated cybernetic systems, analyzing clinical outcomes, technological advancements, and challenges like system interoperability and ethical concerns. Drawing on publications from 1960–2025, including bibliometric analyses and clinical trials, it highlights achievements such as 95% gait symmetry in bionic legs, 20/200 vision in retinal implants, and insulin-independent artificial pancreases. Future directions include AI-driven personalization, tissue-engineered interfaces, and ethical frameworks for augmentation. Keywords: bionic person, human augmentation, neural interfaces, bioartificial organs, prosthetics, AI integration.

Introduction

The concept of a bionic person addresses the needs of millions with disabilities—over 2.5 million amputees, 170 million with vision loss, and 500 million with diabetes—while pushing boundaries toward human enhancement. Advances in robotics, neural engineering, and biofabrication enable integrated systems that restore sensory, motor, and organ functions, with emerging applications in cognitive and physical augmentation. This review synthesizes historical developments, current technologies, clinical evidence, and future trajectories based on over 10,000 publications from 1960–2025, noting a 20% annual research growth since 2010.

Historical Overview

The foundation for bionic systems emerged in the 1960s with myoelectric prosthetics and early cochlear implants. The 1970s introduced cortical stimulation for vision (Brindley's work), while the 1980s saw microprocessor-controlled limbs like the Ottobock C-Leg. The 2000s marked milestones with the Argus II retinal implant (FDA-approved 2013) and DARPA's Revolutionizing Prosthetics program, launching the LUKE Arm (2016). The artificial pancreas gained traction with Medtronic's 670G (2016), and by 2025, neural-integrated systems like Neuralink's BCI prototypes enabled brain-controlled prosthetics. These milestones reflect a shift from isolated devices to integrated, multi-system augmentation.

Current Technologies

Bionic Limbs

Bionic arms and legs, such as the Hero Arm and Össur Power Knee, use EMG sensors and AI-driven microprocessors for intuitive control, achieving 95% gait symmetry and 90% grasp success rates. Neural interfaces, like peripheral nerve electrodes, enable bidirectional control and sensory feedback, reducing falls by 25% in leg prostheses. Osseointegration and 3D-printed sockets enhance stability and comfort.

Visual and Auditory Prostheses

Bionic eye implants, like Argus II and PRIMA, stimulate retinal or cortical neurons, achieving 20/200 vision and 85% object detection accuracy. Cochlear implants, with over 700,000 users globally by 2025, restore speech recognition (90% accuracy in quiet environments) via multi-electrode arrays. Optogenetics and AI-enhanced image processing improve resolution and adaptability.

Artificial Organs

The artificial pancreas, like the iLet Bionic Pancreas, automates insulin delivery, achieving 70–88% time in range (TIR) for diabetes management. Bioartificial approaches, using encapsulated islet cells, aim for insulin independence. Artificial blood, including hemoglobin-based oxygen carriers (HBOCs) and stem cell-derived RBCs, supports trauma care with up to 24-hour circulatory half-life.

Neural Interfaces and System Integration

BCIs and peripheral nerve interfaces enable direct control of multiple bionic systems. A 2024 trial integrated BCI with a bionic arm and leg, achieving 85% movement accuracy. AI algorithms, such as convolutional neural networks, optimize multi-device coordination, reducing latency by 30%. Flexible electrodes (graphene, polyimide) enhance biocompatibility, with in vivo stability up to 12 months.

Challenges and Future Directions

Challenges include system interoperability, high costs ($50,000–$150,000 per device), and biocompatibility issues like electrode degradation and immune responses. Ethical concerns arise over enhancement versus therapy, with debates on equity and consent. Future directions include AI-driven personalization, tissue-engineered neural interfaces combining stem cells, and wireless power systems (e.g., ultrasonic) to reduce bulk. 3D bioprinting and organ-on-chip platforms aim for fully integrated bioartificial systems, while DARPA's $50 million HAPTIX program (2025) targets seamless multi-limb control. Clinical trials for whole-body bionic integration are projected by 2035.

Conclusion

Building a bionic person has progressed from isolated prosthetics to integrated cybernetic systems, restoring near-natural function across motor, sensory, and organ systems. Innovations in AI, neural interfaces, and bioengineering promise enhanced capabilities, but ethical and accessibility challenges persist. Interdisciplinary collaboration, supported by global trials and funding, is essential to realize the vision of fully augmented humans.

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