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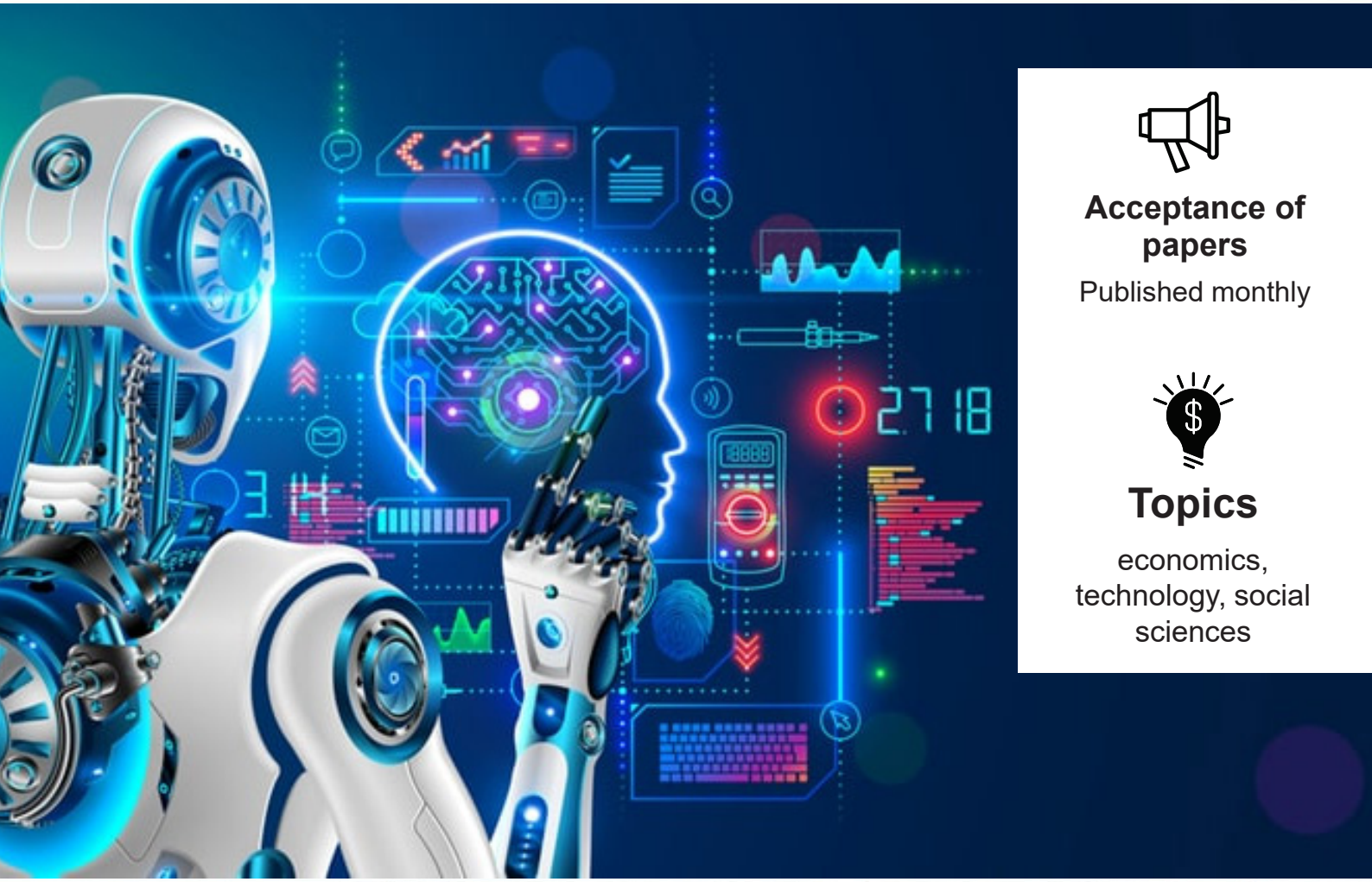

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INTEGRATED EDUCATION MODEL IN TEACHING WATER-SAVING IRRIGATION TECHNOLOGIES

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Abstract: Developing a teaching methodology based on interdisciplinary integration principles that allows students to deeply master the theoretical foundations, technical capabilities, practical application, and effectiveness of water-saving irrigation technologies.

Key words: integrated education, water-saving technologies, methodological developments, model.

Annotatsiya: Talabalarda suv tejamkor sug‘orish texnologiyalarining nazariy asoslari, texnik imkoniyatlari, amaliy qo‘llanilishi va samaradorligini chuqur o‘zlashtirishga imkon beruvchi, fanlararo integratsiya tamoyillariga asoslangan o‘qitish metodikasini ishlab chiqishdan iborat.

Kalit so‘zlar: integratsiyalashgan ta’lim, suv tejamkor texnologiyalar, metodik ishlanmalar, model.

Аннотация: Разработка методики обучения, основанной на принципах междисциплинарной интеграции, позволяющей студентам глубоко освоить теоретические основы, технические возможности, практическое применение и эффективность водосберегающих технологий орошения.

Ключевые слова: интегрированное образование, водосберегающие технологии, методические разработки, модель.

INTRODUCTION

Water scarcity and climate variability have become defining challenges for contemporary agriculture, directly affecting crop productivity, food security, and environmental sustainability. In many regions, including arid and semi-arid zones, traditional irrigation practices are no longer capable of ensuring rational water use and stable agricultural outputs. Under these conditions, water-saving irrigation technologies—such as drip irrigation, automated control systems, and digital monitoring tools—are increasingly regarded as key instruments for improving water use efficiency while minimizing ecological risks. However, the effective implementation of such technologies depends not only on technical solutions but also on the quality and structure of professional training in this field.

Modern agricultural education faces the task of preparing specialists who are able to think systemically, integrate knowledge from different scientific domains, and apply it to real production conditions. Teaching water-saving irrigation technologies within the boundaries of a single discipline limits students’ understanding of complex irrigation processes that simultaneously involve physical, biological, engineering, and informational components. Therefore, an interdisciplinary and integrative educational approach is required, allowing students to perceive irrigation systems as holistic, dynamic, and technologically advanced objects of professional activity.

In this context, interdisciplinary integration in education serves as a methodological foundation for forming comprehensive theoretical knowledge, practical skills, and technological competencies. The integration of natural sciences (physics, biology, chemistry), engineering disciplines (hydraulics, irrigation engineering), mathematics, and information technologies creates conditions for the development of analytical thinking, modeling abilities, and evidence-based decision-making skills. At the same time, ensuring continuity and succession between different levels of education—technical school, bachelor’s, and master’s programs—makes it possible to build a logically consistent system of professional training, where knowledge and competencies are gradually deepened and expanded.

The relevance of this study is determined by the growing demand for specialists capable of designing, operating, and improving modern water-saving irrigation systems under conditions of limited water resources and increasing environmental requirements. The purpose of this article is to scientifically and methodologically

substantiate integrative and interdisciplinary approaches to teaching water-saving irrigation technologies, to propose an integrative educational model, and to justify effective forms and methods for organizing the educational process aimed at developing students' practical and technological competencies.

REVIEW OF LITERATURE ON THE SUBJECT

The problem of rational water use and the introduction of water-saving irrigation technologies has been widely examined in international scientific literature, with particular attention paid to technological efficiency, environmental sustainability, and human capital development. In recent decades, researchers increasingly emphasize that the effectiveness of modern irrigation systems depends not only on engineering solutions, but also on the quality of interdisciplinary training of specialists capable of managing complex agro-hydrological processes.

Fundamental scientific approaches to irrigation water management are presented in the works of Richard G. Allen, Luis S. Pereira, Dirk Raes, and Martin Smith. Their FAO-based research published in 1998 established a unified methodological framework for calculating crop water requirements through evapotranspiration models. This framework integrates climatology, plant physiology, soil science, and hydrology, demonstrating that irrigation processes are inherently interdisciplinary. These studies remain a core scientific basis for both irrigation system design and educational curricula in agricultural engineering.

Technical and economic aspects of water-saving irrigation technologies are thoroughly analyzed in the studies of Jack Keller and Roger Bliesner. Their research published in 2000 shows that drip and low-pressure irrigation systems significantly increase water use efficiency compared to traditional surface irrigation methods. The authors highlight the importance of engineering calculations, hydraulic modeling, and system optimization, which requires strong integration of mathematics, physics, and engineering disciplines in the training of irrigation specialists.

Pedagogical foundations of interdisciplinary and integrative education are rooted in the classical works of John Dewey, Jerome Bruner, and Lev Vygotsky. Jerome Bruner's concept of the spiral curriculum, formulated in 1960, substantiates the idea of continuity and succession in education, where knowledge is gradually deepened and structurally expanded at each educational stage. This approach is particularly relevant for teaching irrigation technologies, as it allows learners to progress from basic physical and technical concepts to advanced system modeling and innovation-oriented problem solving.

The role of digital technologies and simulation tools in irrigation research and education is highlighted in the works of Jiří Šimůnek, Martinus Th. van Genuchten, and Miroslav Šejna. Their development of the HYDRUS modeling software, widely applied since 2012, enables detailed simulation of soil moisture dynamics, solute transport, and root water uptake. These tools provide significant opportunities for virtual laboratories and data-driven learning environments, reinforcing the integration of information technologies into irrigation education.

Issues of sustainable agricultural water management are comprehensively addressed in studies conducted under the leadership of David Molden at the International Water Management Institute. Research published in 2010 emphasizes that technological modernization alone is insufficient without well-trained specialists who possess interdisciplinary competencies and systems thinking. This conclusion directly supports the need for integrative educational models that connect environmental science, engineering, and digital technologies.

Overall, the analysis of existing literature demonstrates that teaching water-saving irrigation technologies requires a systematic interdisciplinary approach supported by continuity and succession in education. The reviewed studies confirm that integrative models combining natural sciences, engineering, mathematics, and information technologies are essential for developing professional competencies capable of addressing modern challenges in agricultural water management.

RESEARCH METHODOLOGY

The research methodology is based on a mixed-methods approach. Data were collected through analysis of scientific literature, review of educational curricula, observation of the teaching process, and expert assessments. The obtained data were analyzed using comparative analysis, synthesis, and logical generalization to identify effective interdisciplinary integration mechanisms and evaluate their impact on competency formation.

ANALYSIS AND RESULTS

Methodological approaches based on the principles of interdisciplinary integration in teaching water-saving irrigation technologies, effective forms and methods of organizing the educational process, as well as ways of forming practical and technological competencies in students are scientifically and methodologically substantiated. Currently, the shortage of water resources, increasing the efficiency of agriculture, ensuring

environmental safety, and the need to introduce modern irrigation systems make in-depth and integrated training in this area one of the urgent tasks. Therefore, it is necessary to approach the teaching of water-saving irrigation technologies not only within the framework of one subject, but also on the basis of the interconnection of various natural, technical, and information sciences [1].

Creation of an integrative model for teaching water-saving technologies. An integrative model is an approach that serves the systematic formation of the student's theoretical and practical knowledge, skills, and abilities by combining various disciplines, pedagogical methods, and innovative technologies in the educational process [3]. The integrative model for teaching water-saving irrigation technologies includes the following components (Figure 1):

Figure 1. Integrative model of teaching water-saving irrigation technologies

The component of interdisciplinary integration includes such disciplines as biology, chemistry, hydrology, mathematics, engineering, information technology. Therefore, the student combines knowledge from various disciplines and develops system analysis and practical solutions. As a result, the student's integrative thinking skills are developed, they are able to solve real problems with an interdisciplinary approach.

The technological component allows real-time monitoring of soil moisture using sensors and drone technologies, modeling of irrigation systems through virtual laboratories and simulations, safe and effective conduct of experiments, optimization of the educational process through online courses, MOOCs and artificial intelligence systems through digital educational platforms. As a result, students consolidate practical experience using digital tools and make systematic decisions [4].

Model of continuity and succession in education. Continuity and consistency in education is a pedagogical principle that ensures the logical development of all stages of the educational process from stage to stage, the sequential formation of knowledge and competencies. This model provides for the growth of the student (student) by didactic levels in accordance with the level of training, age characteristics, knowledge potential, and needs of the specialty. The main goal of the model is to ensure that topics, learning activities, methods, and skills in the educational process do not repeat each other, but rather complement each other; to ensure that the student has solid, systematic, and consistent knowledge [5].

The principles of continuity and succession in the educational process ensure interdisciplinary connections, logical sequence between educational stages, and the gradual development of competencies. Below is a model of continuity in teaching water-saving irrigation technologies at three levels of the education system - technical school, bachelor's and master's degrees.

1. Technical School Stage:

At the technical school stage, students acquire the most basic knowledge of water, soil, physical processes, technical means, and the basics of irrigation. The main task of this stage is the formation of general technical training necessary for subsequent stages of higher education.

The foundations of science that will be formed at this stage:

• Physics: properties of water, pressure, flow rate, filtration processes.

• Technology: irrigation methods, structure of simple technical devices, agrotechnical requirements.

The essence of continuity lies in the fact that the physical and technological concepts formed in the technical school later create the foundation for the competence of calculating and modeling technical systems in the bachelor's degree.

2. Bachelor's degree:

The bachelor's degree deepens the basic concepts given in the technical school. Students learn to perform calculations on the mathematical model of the irrigation process, hydromodules, water consumption, pressure losses, water balance, and melioration indicators.

Integration of core disciplines:

• Mathematics: differential equations, functions, graphoanalytical modeling.

• Engineering: hydraulics, pumps, pipes, construction of irrigation systems.

The essence of continuity is that at this stage, the student develops technical thinking, engineering calculations, and modeling skills. These skills will become the basis for the creation of innovative systems at the master's level.

3. Master's degree:

At the master's level, students are oriented towards research activities. The main goal is the design of integrated technologies such as water-saving irrigation, drip irrigation, digital monitoring, and automated control systems.

Integrated disciplines:

• Biology: plants' water needs, transpiration, physiological processes.

• Agrotechnology: land cultivation, agrotechnical norms, technologies for increasing fertility.

The essence of continuity is that in the master's program, the student creates complete models of innovative irrigation systems by combining physics-technology-mathematics-engineering knowledge formed at previous stages. At this stage, modern technologies such as Hydrus, GIS, sensor monitoring, and digital automation will be applied.

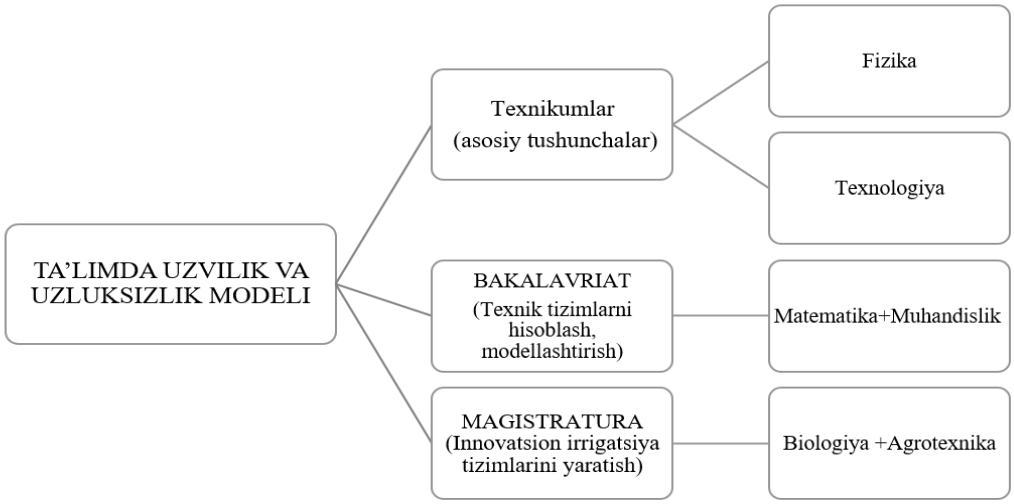
The main advantages of this model are:

• Interdisciplinary integration is deepening from stage to stage.

• Continuity is ensured in the form of scientific and theoretical knowledge → practical skills → innovative projects.

• Teaching water-saving technologies is systematically developed based on fundamental → technical → innovative principles.

• The student improves in three stages: knowledge - skills - competence – qualifications (Figure 2).



Uzluksizlik (Vertikal integratsiya) sxemasi

Figure 2. Continuity (Vertical integration) scheme

CONCLUSIONS AND SUGGESTIONS

The study showed that the integrative approach to teaching irrigation processes not only reinforces the student's theoretical knowledge, but also plays a decisive role in the development of their practical skills, increasing their ability to solve problem situations, and forming professional competencies. Interdisciplinary integration demonstrates that irrigation processes are inextricably linked with physics, chemistry, biology, geodesy, mechanics, information technology, and ecology.

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