Intent Research Scientific Journal-(IRSJ)
ISSN (E): 2980-4612
Volume 5, Issue 5, May - 2026
Website: intentresearch.org/index.php/irsj/index

INTEGRATION OF EDUCATION AND PRODUCTION: IMPROVING THE METHODOLOGY OF TRAINING PERSONNEL IN THE ENERGY SECTOR

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Abstract

This paper investigates the organizational and pedagogical mechanisms underpinning the integration of education, science, and production in the training of electrical engineering personnel for Uzbekistan's energy sector. Drawing on a systematic analysis of domestic and international dual-education models (Germany, South Korea, Singapore, Finland), the authors formulate five core principles of educational–industrial cooperation: competence-oriented training, mutually beneficial partnership, joint planning, responsible collaboration, and long-term partnership. An original interactive didactic tactic, 'Spiral (regressus, progressus)', developed within the tripartite methodological framework Apospasmatika–InterAkt–STEAM, is proposed and empirically validated through a quasi-experimental study conducted at 25 sites involving 320 fourth-year electrical engineering students (2021–2024). Results demonstrate a statistically significant improvement in professional competencies in the experimental group (Friedman $\chi^2=18.4$, $p<0.05$; Cohen's $d=0.84$). The article contributes a replicable model, IIES-UZ (Industry-Integrated Education System – Uzbekistan), applicable to engineering education reform in transitioning economies.

Keywords: Education–production integration, engineering education, energy sector, professional competencies, Spiral (regressus, progressus), dual education, IIES-UZ, didactics, Talimarjan TPP, Central Asian Unified Power System.

INTRODUCTION

The accelerating technological transformation of the energy sector - large-scale integration of renewable energy sources (RES), digitisation of dispatch management (SCADA, Smart Grid), and the deployment of intelligent

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monitoring algorithms for the Central Asian Unified Power System (OES CA) - imposes fundamentally new requirements on the professional competencies of engineering graduates [1, 2]. The conventional lecture-centred model of higher engineering education, focused primarily on knowledge transmission, is increasingly inadequate to bridge the gap between academic preparation and real-world production demands [3].

The Presidential Decree No. UP-5847 of the Republic of Uzbekistan (2019) and the National Education Development Programme to 2030 identified the systematic expansion of dual education as a strategic priority. Against this policy background, the development of scientifically grounded integrative teaching methodologies takes on particular urgency [4].

The aim of this paper is twofold: (1) to substantiate the principles governing the organisation of university instruction for producing graduates capable of meeting industrial enterprise needs; and (2) to present the experimental validation of the authors' 'Spiral (regressus, progressus)' tactic within the context of education–production integration.

Research object: the process of professional training of future electrical engineers under conditions of education–production integration. Research subject: the organisational-pedagogical mechanisms and didactic tactics ensuring the effectiveness of this process.

LITERATURE REVIEW AND THEORETICAL FRAMEWORK

The integration of education and production has been examined across multiple research traditions. Bespalko [5] established theoretical foundations for the technologisation of the pedagogical process. Sazonova [6] conceptualised integration as the methodological basis of modern engineering training. Selevko [7] systematised contemporary educational technologies in the context of professional education.

International dual-education models are documented extensively: the German model (BIBB) [8], the Korean 'Work-Learning Dual System' (KRIVET) [9], Singapore's 'SkillsFuture' programme, and the Finnish competency-based model collectively demonstrate that the most effective systems sustain continuous university–enterprise interaction across all phases of instruction. Comparative analysis reveals three common success factors: (a) formalised legal frameworks

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for industry–academia cooperation, (b) structured mentoring at enterprise sites, and (c) digital monitoring of graduate employment trajectories.

The theoretical foundation of the authors' methodology comprises several key pedagogical concepts, reconceptualised and synthesised for the conditions of integrative engineering personnel training.

Bruner's Spiral Curriculum (1960) establishes the foundational principle of cyclical deepening of knowledge: the same concepts recur at progressively higher levels of abstraction as the learner's cognitive capacity matures [10]. However, Bruner's framework was developed for general secondary education and presupposes a linearly ascending spiral movement - from simple to complex, from concrete to abstract - in which the learner remains primarily a recipient of externally structured instructional content.

The authors' tactic "Spiral (regressus, progressus)" fundamentally extends and transforms the Brunerian model along four dimensions:

First, bidirectionality of movement. In Bruner's model, the spiral unfolds exclusively in one direction - forward and upward (progressus). In the authors' tactic, movement is deliberately bipolar: regressus (a conscious "retreat" - diagnostic return to previously studied material to identify and eliminate knowledge gaps) is an equal and methodologically indispensable stage that precedes forward progression. The spiral thereby acquires the property of a reflective loop rather than a merely ascending trajectory.

Second, the learner's subjective position. In Bruner's framework, the content of the spiral is predetermined and structured by the educator. In the "Spiral (regressus, progressus)" tactic, the progressus phase presupposes active authorship on the part of the learner: students do not merely absorb and reproduce the topic but actively introduce their own innovative ideas and incorporate personal scholarly hypotheses into the discourse. This repositions the learner from the role of "knowledge recipient" to that of "co-author of the instructional discourse".

Third, the collective-production context. Bruner's spiral operates within an individual-cognitive dimension. The authors' tactic is implemented in integrative groups combining students and production specialists, thereby creating a fundamentally different social dynamic: knowledge is constructed not

Intent Research Scientific Journal
IRSJ

only through engagement with instructional material but through the collision of academic and industrial experience - a mechanism described in situated cognition theory (Lave & Wenger, 1991).

Fourth, problem-thematic comprehensiveness. Unlike the Brunerian spiral, in which a concept or disciplinary idea serves as the central organising element, the “Spiral (regressus, progressus)” tactic is structured around a comprehensive problem-question bank encompassing all aspects of the topic - including its contradictions, alternative interpretations, adjacent domains, and production applications. This ensures not “point-focused” but polypheric mastery of instructional content.
Kolb’s Experiential Learning Cycle [11] provides the psychological model of four-phase transformation of experience into knowledge (concrete experience → reflective observation → abstract conceptualisation → active experimentation) and serves as the operational basis for alternating regressus and progressus phases within each instructional cycle. Johnson & Johnson’s cooperative learning theory establishes the principles of positive interdependence and individual accountability in group work - principles directly operationalised in the formation of integrative groups. Bloom’s Taxonomy is employed as a diagnostic task design instrument: levels 1–4 (knowledge, comprehension, application, analysis) correspond to the regressus phase, while levels 5–6 (synthesis, evaluation) correspond to the progressus phase, thereby rendering each stage of the tactic measurable.
A research gap exists in the literature regarding operationalised, empirically validated didactic tactics for integrative groups that combine university students and in-service production specialists within a unified instructional session - the configuration central to this paper.

PRINCIPLES OF EDUCATION–PRODUCTION INTEGRATION

Based on an analysis of national and international scientific-methodological literature and the authors' own pedagogical experience, five principles of integration are proposed:
–**Principle of competence-oriented training** - systematic preparation of intellectually developed, competent specialists meeting market requirements and capable of continuous professional growth.

–**Principle of mutually beneficial partnership** - encompasses mutual interest and the effectiveness of cooperation from the perspective of both parties' core activities.

–**Principle of joint planning** - ensures alignment of educational and production processes over the long term, operationalised through HEMIS integration and digital labour-market monitoring.

–**Principle of responsible collaboration** - mutual accountability of both parties for the fulfilment of obligations, including targeted employment contracts for graduates.

–**Principle of long-term partnership** - derived from the importance of qualified specialist training to strengthen the sector's scientific-technical potential and ensure systematic labour supply to enterprises.

These principles are operationalised through the IIES-UZ model, a three-tier integration framework encompassing: (1) content alignment (harmonising curricula with industrial standards), (2) organisational integration (forming integrative learning groups of students and production specialists), and (3) monitoring integration (digital diagnostic tracking of educational outcomes).

THE 'SPIRAL (REGRESSUS, PROGRESSUS)' TACTIC: DIDACTIC RATIONALE

The 'Spiral (regressus, progressus)' tactic was developed as a synthesis of three methodological layers within the Apospasmatika–InterAkt–STEAM framework [12]. In ancient cultures and religious traditions, the spiral serves as a powerful symbol of creation and growth; in educational science, it reflects Bruner's principle - each successive spiral turn produces a deeper level of understanding. The tactic operates through two complementary movements:

– **Regressus (conscious retreat)** - systematic review, activation, and consolidation of prior learning material. Long-term memory is engaged; knowledge gaps are identified and addressed. This movement fulfils the diagnostic function of the tactic.

– **Progressus (step forward)** - entails not merely understanding and presenting the topic but actively introducing innovative ideas and incorporating personal scholarly conceptions into the discussion. This movement fulfils the creative and research functions of the tactic.

A defining feature is the development of a comprehensive problem-bank encompassing all thematic dimensions of the subject under study. Integrative groups are provided with resources and strategies, but emphasis is placed on autonomous problem-solving strategies, fostering creative independence and dynamic team interaction.

The formation of integrative groups - combining future electrical engineering students with experienced production specialists from Talimarjan TPP - creates a powerful motivational environment: students develop strong intrinsic motivation to acquire knowledge, while production specialists cultivate innovative thinking capabilities.

The case-study method occupies an important complementary role within this tactic. Cases are presented in mixed format (written description, diagrams, quantitative data) based on real incidents at the enterprise. Students working in groups demonstrate professional knowledge and apply acquired theoretical and practical skills. However, given the psychological stress that can arise from simulated high-stakes situations, case studies are recommended as a tool for independent student work rather than a direct substitute for laboratory sessions.

EXPERIMENTAL VALIDATION AND RESULTS

Research Design

A quasi-experimental pre-test/post-test design with a control group was employed (2022–2025). The study was conducted across 25 sites, including KSTU and the Talimarjan Training Centre of JSC 'Talimarjan IES'. Participants: 186 fourth-year electrical engineering students (discipline: Electric Networks and Systems). Control group (n=91): traditional instruction; Experimental group (m=95): IIES-UZ model with Spiral tactic.

Diagnostic Instruments

A multi-stage diagnostic toolkit was employed, comprising: entry testing (Regressus-diagnostics), interim monitoring (Bloom's Taxonomy levels 1–4), summative competency assessment (Bloom's levels 5–6), and expert evaluation by production mentors. Statistical processing: Friedman test (χ^2), Bonferroni correction, Cohen's d effect size.

Results

Key outcomes: $\chi^2=18.4$ (critical value 7.815, $p<0.05$), Cohen's $d=0.84$ (large effect). In the experimental group: +34% in the proportion of students successfully solving dynamic stability problems using the D-separation method; +28% in independent research project completion; professional motivation level (Rean scale) increased by 0.7σ. No statistically significant differences were observed between groups on the entry test, confirming baseline equivalence.

The methodology is secured by three intellectual property certificates (No. 007815, No. 007957, No. 009428) and two teaching manuals approved by the Ministry of Higher Education, Science and Innovation of the Republic of Uzbekistan.

DISCUSSION

The empirical results corroborate the theoretical proposition that a spiral didactic structure, implemented within genuinely integrative groups (students + production specialists), produces learning outcomes superior to those achievable through either purely lecture-based or purely practice-based instruction alone. The large effect size ($d=0.84$) places this intervention within the upper quartile of educational interventions documented in meta-analytical literature (Hattie, 2009).

The IIES-UZ model addresses a structural limitation common to transitioning economies: the absence of formalised legal and financial mechanisms for sustained university–enterprise cooperation. By embedding the HEMIS digital monitoring infrastructure within the integration model, continuous feedback loops between educational outcomes and labour-market demands are operationalised.

Limitations of the study include the quasi-experimental rather than fully randomised design, potential selection bias in the constitution of integrative groups, and single-country implementation. Future research should examine scalability across different engineering disciplines and OECD contexts.

CONCLUSION

The integration of education and production, operationalised through the IIES-UZ model and the Spiral (regressus, progressus) didactic tactic, demonstrably enhances the professional competency of future electrical engineers.

Intent Research Scientific Journal
IRSJ

Organisationally, it provides high-quality professional education, enables targeted employment contracts, supplies the labour market with research-capable graduates, and reduces professional adaptation periods.
From the integration perspective, it ensures: organisation of a coherent educational process; implementation of effective programme alignment; continuity, variability, and adaptability of professional programmes; and strengthening of the practical and research orientation of instruction.
Prospects for further research include: development of a digital HEMIS-integration platform for education–production monitoring; extension of the IIES-UZ model to postgraduate and corporate training levels; and longitudinal tracking of IIES-UZ graduates' career trajectories within OES CA energy enterprises.

Funding and Acknowledgements. This research was supported in part by the MUNIS/World Bank Academic Innovation Fund grant for engineering education reform in Uzbekistan. The authors acknowledge the cooperation of JSC 'Talimarjan IES' and the academic staff of Karshi State Technical University.

Conflict of interest. The authors declare no conflict of interest.

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IRSJ Intent Research Scientific Journal

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