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Organizing Creative Engineering Activities in Teaching the Course “Hydraulics and Hydraulic Systems”: Integration of Pedagogical and Technical Approaches

Meyliyeva Shoxista Rustamovna
Assistant, Department of Land Reclamation and
Land Cadastre, Karshi State Technical University

Annotatsiya. Maqolada “Gidravlika va gidravlik tizimlar” fanini o‘qitishda bo‘lajak muhandislarning ijodkorlik kompetentligini rivojlantirishga yo‘naltirilgan ta’lim jarayonini tashkil etish masalasi pedagogika va texnika fanlari integratsiyasi nuqtayi nazaridan yoritilgan. Respublika pedagog olimlarining ijodkorlik, kompetensiyaviy yondashuv, loyiha asosida o‘qitish va fanlararo integratsiyaga oid ishlari gidravlika sohasidagi A.M. Arifjanov, S.N. Xoshimov, Z.I. Ibragimova, D.A. Abduraimova va boshqa mutaxassislarning o‘quv-metodik ishlanmalari bilan qiyosiy bog‘langan. Natijada o‘qituvchilar uchun “Muammo–Dalil–Variant–Qaror–Refleksiya”, “Tajriba–Hisob–Simulyatsiya–Loyiha” va “Ikki konturli dars loyihalash” nomli uchta namunaviy metodika taklif etildi. Metodikalarda pedagogik maqsad texnik mazmun bilan, ijodiy topshiriq esa gidravlik hisob, laboratoriya tajribasi, raqamli model, muqobil yechim va mezonli baholash bilan bog‘lanadi. Taklif etilgan yondashuv o‘qituvchiga an’anaviy hisoblash va laboratoriya mashg‘ulotlarini ochiq muhandislik muammolari, loyiha faoliyati va refleksiv baholash bilan boyitish imkonini beradi.

Kalit so‘zlar: muhandislik ta’limi, gidravlika, gidravlik tizimlar, ijodkorlik kompetentligi, fanlararo integratsiya, pedagogik texnologiya, muammoli ta’lim, loyiha asosida o‘qitish, laboratoriya tajribasi, simulyatsiya, refleksiya, muhandislik qarori.

Аннотация. В статье рассматривается организация образовательного процесса, направленного на развитие творческой компетентности будущих инженеров при преподавании дисциплины «Гидравлика и гидравлические системы», на основе интеграции педагогических и технических подходов. Педагогические идеи компетентностного, проектного, проблемного и междисциплинарного обучения сопоставлены с предметным содержанием гидравлики, расчетами, лабораторным экспериментом и цифровым моделированием. Для преподавателей предложены три примерные методики: «Проблема–Доказательство–Вариант–Решение–Рефлексия», «Эксперимент–Расчет–Симуляция–Проект» и «Двухконтурное проектирование занятия».

Ключевые слова: инженерное образование, гидравлика, гидравлические системы, творческая компетентность, междисциплинарная интеграция, проблемное обучение, проектное обучение, лабораторный эксперимент, симуляция, инженерное решение.

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Abstract. The article examines the organization of an educational process aimed at developing future engineers' creative competence in the course "Hydraulics and Hydraulic Systems" through the integration of pedagogical and technical approaches. Pedagogical ideas related to competency-based, project-based, problem-based and interdisciplinary learning are linked with hydraulic calculations, laboratory experiments and digital simulation. Three exemplary teaching methodologies are proposed for instructors: "Problem–Evidence–Alternative–Decision–Reflection", "Experiment–Calculation–Simulation–Project", and "Dual-Loop Lesson Design". The methodologies connect pedagogical objectives with technical content and transform conventional exercises into open engineering tasks requiring alternative solutions, verification and reflective evaluation.

Keywords: engineering education, hydraulics, hydraulic systems, creative competence, interdisciplinary integration, problem-based learning, project-based learning, laboratory experiment, simulation, engineering decision.

INTRODUCTION

The process of training a future engineer in higher technical education is not limited to mastering only theoretical knowledge and standard calculation algorithms. A modern engineer must be able to analyze the operating conditions of a real object, take into account uncertainties and limitations, develop several technical solutions, compare them with experience and calculation evidence, and justify his decision. It is noted in scientific journals that scientific and methodical recommendations on the development of creativity, interactive methods, competence approach and strengthening of innovative educational mechanisms are being developed in the pedagogical researches of Uzbekistan [1]. In researches on technical higher education, attention is focused on connecting motivational, cognitive, active-process and reflexive contents and creative tasks with engineering competencies [2].

"Hydraulics and hydraulic systems" is a convenient subject area for pedagogical and technical integration. A.M. Arifjanov and S.N. Hoshimov's textbook covers hydrostatics, hydrodynamics, calculation of pipelines and hydrosystems, hydrodynamics, and methods of solving problems using modern technologies [3]. Z.I. Ibragimova, D.A. Abduraimova and S.N. The laboratory manual prepared by Hoshimov methodically provides the experimental component of the science [4]. U.I. Bahranova founded the didactic possibilities of using virtual laboratories in the integration of hydraulic and thermal engineering with general physics [5]. Thus, there is technical content, laboratory and digital tools; the pedagogical task is to combine them into a didactic script that creates creative engineering activity of the student.

The purpose of the article is to organize an educational process aimed at developing the creative competence of future engineers in teaching the science of "Hydraulics and hydraulic systems" based on the collaboration of pedagogy and technical sciences, and to develop model methodologies that can be used in practice for teachers.

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LITERATURE REVIEW AND METHODOLOGY

This article is theoretical and methodological in nature, employing methods such as content analysis, comparative analysis, interdisciplinary integration, pedagogical modeling, and methodological construction. Regarding pedagogical sources, the study selected domestic works concerning creativity, project-based competence, interdisciplinary integration, and innovative approaches; regarding technical sources, it utilized educational-methodological materials related to hydraulics, hydraulic systems, laboratory sessions, and virtual laboratories.

In the pedagogical sphere, Y.M. Hamraqulov links the development of design-engineering competence in technical higher education to project-based learning, interactive methods, and digital technologies [6]. B.Y. Begmatov and M.A. Kamolova identify issues such as the lack of seamless interconnection between curricula, insufficient methodological support, and weak integration of practical sessions in the context of interdisciplinary integration [7]. G.Q. Madmarova emphasizes the necessity of a cohesive, phased, and modern methodological system for developing professional-pedagogical creativity [8]. These pedagogical perspectives highlight the need to shift the teacher's role in hydraulics education from a mere "provider of formulas and instructions" to a "designer and moderator of problem-based engineering activities."

In the technical sphere, A.M. Arifjanov and S.N. Khoshimov's textbook *Hydraulics and Hydraulic Systems* covers the hydraulic calculation of pipelines and hydraulic systems, hydraulic drives, review questions, and problems enriched with modern technologies [3]. Course materials from TIIAME NRU also recommend local educational literature on hydraulics, including works by K.Sh. Latipov, A.M. Arifjanov, Kh. Qodirov, B. Toshov, and other scholars [9]. Pedagogically restructuring this technical foundation creates a significant opportunity to develop creative competence.

The methodological concept of the analysis was defined as follows: pedagogy answers the question "how to teach and what activities to facilitate?", while hydraulics addresses "which physical laws, parameters, experiments, and technical solutions are to be utilized?" Through their collaboration, the educational unit is designed not merely as "topic + method," but rather as "hydraulic problem + creative activity + technical evidence + assessment criterion."

RESULTS AND DISCUSSION

As a result of the study, three interconnected model methodologies for organizing the educational process were developed for teachers. These are not merely renamings of existing pedagogical methods; rather, they aim to integrate pedagogical objectives with the core activities of the hydraulics discipline—calculation, measurement, experimentation, modeling, and technical decision-making—into a unified scenario.

1.THE"PROBLEM–EVIDENCE–OPTION–DECISION–REFLECTION" METHODOLOGY

The objective of this methodology is to ensure that, before reducing a hydraulic situation to a ready-made formula, the student comprehends the problem, gathers evidence, formulates alternative solutions, and justifies their decision. The teacher initiates the lesson with an open-ended scenario,

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such as: “Pressure loss in the pipeline network has exceeded the standard limit. How can the problem be resolved without replacing the entire system?” The student hypothesizes the causes of the problem, identifies the necessary parameters, obtains data through hydraulic calculations or experiments, develops at least two or three technical options, and compares them based on criteria such as energy loss, technical feasibility, safety, and economic viability.

Table 1. Problem-Solving Stages and Indicators

Stage	Teacher Activity	Student Activity	Technical Evidence	Creativity Indicator
Problem	Creates an open hydraulic problem situation	Identifies the problem and constraints	Schematic diagram, initial boundary conditions	Autonomous problem formulation
Evidence	Guides toward relevant information sources	Obtains calculation, measurement, or modeling results	Q, D, L, Δh/Δp, Re, λ, etc.	Cause-and-effect analysis
Variant	Moderates with questions and assessment criteria	Generates 2–3 alternative technical solutions	Option calculations & trade-off metrics	Variant thinking / Multivariance
Decision	Organizes criteria-based comparative evaluation	Substantiates the optimal solution	Comparative table / matrix / chart	Evidence-based selection
Reflection	Asks corrective and reflective questions	Identifies errors, constraints, and next steps	Reflective journal / notes	Self-assessment and correction

This methodology integrates problem-based learning, an activity-based approach, and reflective assessment from a pedagogical perspective, while combining hydraulic calculations, measurements, and engineering decision-making from a technical standpoint. Consequently, the decision-making process itself—alongside the "correct answer"—becomes a learning outcome.

2.THE EXPERIMENT–CALCULATION–SIMULATION–PROJECT” METHODOLOGY

The second methodology aims to bridge the gap often found in practical and laboratory sessions. U.I. Bahranova’s methodological insights regarding the use of virtual laboratories in interdisciplinary integration [5], along with the laboratory work framework developed by Ibragimova, Abduraimova,

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and Xoshimov [4], serve as a crucial methodological foundation for this integration. In this methodology, a single topic is explored through four distinct activities: a real-world experiment demonstrates the phenomenon; calculation provides the theoretical value; simulation allows for the free adjustment of parameters; and the project requires making a decision based on various options.

Table 2. Activity Types and Pedagogical Outcomes

Activity	Sample Topic	Teacher Assignment	Student Product	Pedagogical Outcome
Experiment	Head loss along the pipe length	Measure Q and Δh under various operating modes	Measurement table, graph	Observation and hypothesis formation
Calculation	Head loss calculation via Darcy–Weisbach	Calculate theoretical h_f and compare with experimental data	Calculation sheet, relative deviation	Analytical thinking
Simulation	Effects of D, Q, L, and local head losses	Create 3 scenarios by varying hydraulic parameters	Scenario matrix / charts	Forecasting and variant thinking
Project	Minimizing pressure/head loss	Develop 2–3 technical solutions and defend the optimal choice	Mini-project portfolio	Creative engineering decision-making

In this methodology, the digital tool is employed not as an independent pedagogical outcome, but as a means to support the activity sequence of "prediction → verification → comparison → option selection → decision-making." Consequently, rather than limiting the simulation to a mere demonstration of a pre-made animation, the teacher requires students to purposefully modify parameters and verify the model's results against real-world experiments.

3. THE "DUAL-LOOP LESSON DESIGN" METHODOLOGY

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The third methodology is designed specifically for the teacher's lesson preparation. In the first—the pedagogical loop—the teacher defines the objective, competency component, method, form of collaboration, and assessment indicators. In the second—the technical loop—the hydraulic system, governing principles, measurable parameters, calculation formulas, the experiment or simulation, and the engineering solution are determined. These two loops are integrated into a single lesson scenario.

Table 3. Integrated Lesson Units (Pedagogical & Technical Contours)

Pedagogical Contour	Technical Contour	Integrated Lesson Unit
Objective: Develop variant thinking	Effect of pipe diameter and flow rate on head loss	Calculation for various diameters + scenario analysis + optimal variant selection
Method: Problem-based questioning	Operating modes of pump-pipeline system	Comparing 2–3 system control variants when demand changes
Collaboration: Small group work	Flow distribution in parallel pipelines	Groups develop distinct solutions and debate based on technical evidence
Assessment: Rubric and reflection	Discrepancies between calculation, experiment, and model	Joint evaluation of decision quality + evidence + reflective correction

This methodology enables the teacher to elevate lesson planning from the "topic–objective–questions" level to the "pedagogical objective–technical activity–observable evidence–assessment" level. Given that research on interdisciplinary integration at the national level has highlighted a lack of integration between methodological support and practical exercises [7], the dual-loop design approach aims to methodologically bridge this very gap.

SAMPLE 80-MINUTE LESSON PLAN FOR TEACHERS

Topic: "Alternative technical solutions for reducing head loss in a pipeline network." Objective: To develop students' skills in problem identification, analysis of hydraulic data, formulation of 2–3 alternative solutions, and evidence-based decision-making.

Table 4. Lesson Time Breakdown and Activity Flow

Time	Stage	Teacher Action	Student Action	Evidence / Assessment
0–10 min	Problematic Introduction	Presents real schematic and problem situation	Formulates problem and notes potential causes	Problem card

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Time	Stage	Teacher Action	Student Action	Evidence / Assessment
10–25 min	Analysis & Calculation	Clarifies required parameters and boundary conditions	Calculates parameters based on Q, D, L, λ, Σζ	Calculation sheet
25–40 min	Experiment / Modeling	Provides measurement or simulation environment	Obtains results and compares with initial predictions	Data table / Graph
40–58 min	Variant Generation	Provides evaluation criteria and guidelines	Develops 2–3 technical solution variants	Variants matrix
58–70 min	Decision & Defense	Asks probing questions and demands evidence	Selects the optimal variant and defends choice	Assessment rubric
70–80 min	Reflection	Asks corrective and reflective questions	Records errors, constraints, and next steps	Reflective journal / log

ASSESSMENT MECHANISM

When assessing creative competence, a final technical answer alone is insufficient. Literature on technical education presents approaches that systematize creativity through motivational, cognitive, activity-process, and reflective components [2]. In this article, this logic is adapted to the context of hydraulics, and a "task → indicator → evidence → rubric → correction" chain is proposed.

Table 5. Competence Assessment Matrix (0–3 Scale)

Component	Assignment	Indicator	Evidence	0–3 Scale Criteria

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Component	Assignment	Indicator	Evidence	0–3 Scale Criteria
Motivational-Value	Substantiate professional significance of problem	Initiative, purposefulness, safety/resource criteria	Problem & goal statement	0: None; 1: General; 2: Justified; 3: Criteria-based & professional
Cognitive-Analytical	Analyze parameters and cause-effect relationships	Key data processing, underlying laws, transferability	Calculations, graph, commentary	0: Incorrect; 1: Partial; 2: Correct; 3: Systematic & evidence-backed
Operational-Creative	Generate and verify 2–3 solution variants	Variant thinking, verification/validation	Schematic, experiment/model, options	0: None; 1: Reproductive; 2: Independent; 3: Variant-driven & justified
Reflective-Evaluative	Document constraints and corrective measures	Error analysis, continuous improvement focus	Reflective journal	0: None; 1: General; 2: Specific; 3: Critical & self-corrective

SCIENTIFIC-METHODICAL MODEL OF PEDAGOGICAL AND TECHNICAL SCIENCES COLLABORATION

Collaboration of pedagogy and technical sciences is carried out at three levels. The first level is meaningful collaboration: indicators of pedagogical competence are connected with hydraulic activities. The second level is technological collaboration: problem-based learning, project,

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collaboration and reflection are integrated with computing, laboratory and simulation. The third level is diagnostic collaboration: the pedagogical rubric is filled based on technical product and engineering evidence. As a result, the pedagogical result cannot be separated from the technical activity.

Table 6. Pedagogical-Technical Equivalents

Pedagogical Construct	Hydraulic-Technical Equivalent	Integrating Activity	Expected Product
Problem-Based Learning	Real-world situations (head loss, pump modes, flow distribution)	Identifying problems and technical constraints	Problem card
Project-Based Learning	Pipeline/hydraulic system optimization	Variant generation and criteria-based selection	Mini-project portfolio
Digital Learning	Parametric hydraulic model / numerical simulation	Scenario testing, forecasting, and model validation	Model results / Simulation output
Formative Assessment	Evidence from calculations, measurements, and models	Applying rubrics and expert evaluation	Competence growth profile
Reflection	Discrepancy between calculation-experiment and model limits	Explaining error sources and designing corrections	Reflective conclusion / report

DISCUSSION

The proposed methodologies link the conclusions drawn by the republic's pedagogical scholars regarding innovative approaches, project-based activities, creativity, and interdisciplinary integration with the actual subject matter of hydraulics. Hamraqulov's views on developing engineering-design competence through projects and digital technologies [6] are reflected in the "variant creation–design solution" stage; the issues of interdisciplinary integration raised by Begmatov and Kamolova [7] are addressed in the "dual-loop lesson design" methodology; and Madmarova's approach to professional-pedagogical creativity [8] is embodied in the creative design of the teacher's methodological activities.

Meanwhile, the work of technical scholars provides the subject-specific substance for these methodologies. The calculations for pipes and hydraulic systems found in the textbook by Arifjanov and Xoshimov [3] serve as the theoretical basis for open-ended engineering tasks; the laboratory manual by Ibragimova, Abduraimova, and Xoshimov [4] provides the foundation for the experimental

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component; and Bahranova's virtual laboratory methodology [5] acts as the basis for the didactic integration of real and virtual experiments. Thus, this collaboration represents not merely the addition of a pedagogical method to a technical subject, but the pedagogical reorganization of the technical activity itself.

The methodological novelty of the article lies in the proposal of three model methodologies within a unified system: the first methodology addresses the micro-process of creative decision-making; The second aspect represents the interplay between practical, laboratory, digital, and project-based activities; the third represents the mechanism by which the teacher designs the lesson along parallel pedagogical and technical lines. Their general formula is: pedagogical goal → hydraulic problem → active technical evidence → alternative solution → criterion-based decision → reflection and correction.

As this article is a theoretical-methodological study, it does not present percentage-based effectiveness data derived from experimental and control groups. The empirical effectiveness of these methodologies should be verified in a subsequent stage using a bank of open-ended hydraulic problems, mini-project rubrics, expert evaluation sheets, reflective journals, and pre- and post-assessment diagnostics. This approach allows for verification via measurable indicators rather than the premature announcement of results.

CONCLUSION

Developing the creative competence of future engineers within the "Hydraulics and Hydraulic Systems" course requires not the addition of a specific "creativity topic" to the curriculum, but rather the organization of existing hydraulic calculation, experimental, and project activities according to a new didactic logic. The competency-based, innovative, project-oriented, and interdisciplinary approaches of the Republic's pedagogical scholars, combined with the work of hydraulics experts on textbooks, laboratory setups, and digital tools, provide the scientific-methodological foundation for such integration. The "Problem–Evidence–Option–Decision–Reflection" methodology proposed for teachers focuses on the student's decision-making process; the "Experiment–Calculation–Simulation–Project" methodology emphasizes the integration of real-world and digital activities; and the "Dual-Loop Lesson Design" methodology aims to harmonize pedagogical objectives with technical content within a single lesson scenario. Their practical application enriches traditional problem-solving and laboratory work by incorporating open-ended engineering situations, alternative solutions, evidence-based selection, and reflective assessment.

In future pilot testing of these methodologies, it is advisable to employ measurement tools addressing the motivational-value, cognitive-analytical, operational-creative, and reflective-evaluative components of creative competence, and to conduct a joint analysis of the technical product alongside evidence from the pedagogical process.

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