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Challenges in Developing Creative Competence in Engineering Education: A Methodological Approach Integrated with the Course “Hydraulics and Hydraulic Systems”

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Annotatsiya. Maqolada muhandislik ta’limida ijodkorlik kompetentligini rivojlantirishning dolzarb muammolari “Gidravlika va gidravlik tizimlar” fanining predmet xususiyatlari bilan integratsiyada tahlil qilingan. Nazariy va qiyosiy tahlil asosida an’anaviy algoritmik masala yechish, qat’iy yo‘riqnomali laboratoriya ishlari, raqamli vositalardan reproduktiv foydalanish hamda faqat yakuniy javobni baholash ijodiy muhandislik faoliyatini to‘liq namoyon etmasligi asoslangan. Respublika olimlarining gidravlik hisob, laboratoriya mashg‘ulotlari, axborot texnologiyalari va virtual laboratoriyalardan foydalanishga oid ishlari hamda xorijiy tadqiqotlarning loyiha asosida o‘qitish, virtual laboratoriya va fluid mechanics ta’limiga doir natijalari qiyosiy o‘rganilgan. Muallif tomonidan gidravlik muammoni aniqlash, ma’lumotlarni tahlil qilish, hisob–tajriba–simulyatsiya dalillaridan foydalanish, muqobil texnik yechimlar ishlab chiqish, ularni mezonlar bo‘yicha qiyoslash, qarorni asoslash va refleksiv baholashni birlashtiruvchi metodik zanjir taklif etiladi. Ushbu yondashuv amaliy mashg‘ulot, laboratoriya va loyiha topshiriqlarini yagona ijodiy muhandislik sikliga integratsiyalash imkonini beradi.

Kalit so‘zlar: muhandislik ta’limi, ijodkorlik kompetentligi, gidravlika, gidravlik tizimlar, muammoli ta’lim, loyiha asosida o‘qitish, laboratoriya tajribasi, virtual laboratoriya, simulyatsiya, muqobil texnik yechim, refleksiya.

Аннотация. В статье анализируются актуальные проблемы развития творческой компетентности в инженерном образовании во взаимосвязи с предметной спецификой дисциплины «Гидравлика и гидравлические системы». На основе теоретического и сравнительного анализа обосновано, что алгоритмическое решение задач, лабораторные работы по жесткой инструкции, репродуктивное использование цифровых средств и оценивание только конечного ответа не позволяют в полной мере выявить творческую инженерную деятельность. Предложена методическая цепочка, объединяющая постановку гидравлической проблемы, анализ данных, использование расчетных, экспериментальных и симуляционных доказательств, разработку альтернативных технических решений, их критериальное сравнение, обоснование решения и рефлексивную оценку.

Ключевые слова: инженерное образование, творческая компетентность, гидравлика, гидравлические системы, проблемное обучение, проектное обучение, лабораторный эксперимент, виртуальная лаборатория, симуляция, техническое решение, рефлексия.

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Abstract. The article analyzes current problems of developing creative competence in engineering education in integration with the subject-specific features of the course “Hydraulics and Hydraulic Systems”. Theoretical and comparative analysis indicates that algorithmic problem solving, highly prescriptive laboratory work, reproductive use of digital tools, and assessment focused only on the final answer do not fully reveal creative engineering activity. The paper proposes a methodological chain that integrates hydraulic problem identification, data analysis, calculation–experiment–simulation evidence, generation of alternative technical solutions, criteria-based comparison, justification of engineering decisions, and reflective evaluation. The approach connects practical classes, laboratory experiments and project assignments within a unified creative engineering cycle.

Keywords: engineering education, creative competence, hydraulics, hydraulic systems, problem-based learning, project-based learning, laboratory experiment, virtual laboratory, simulation, alternative technical solution, reflection.

Introduction

Modern engineering activities require a specialist not only to apply ready-made formulas and technological instructions, but also to identify problems in ambiguous and multi-variant situations, take into account technical constraints, develop alternative solutions, compare them based on evidence, and make informed decisions. Therefore, the development of creative competence as an integral part of professional competence in higher technical education is becoming an important pedagogical task. Modern research on engineering education in Uzbekistan also notes the need to strengthen independent practical-creative thinking, systematic thinking, problem-based learning, and task-oriented tasks [1].

The subject "Hydraulics and Hydraulic Systems" has great didactic potential for solving this task. Fluid mechanics is directly related to the balance and movement of fluids, the calculation and design of pipelines and hydraulic systems, and it combines theoretical principles, mathematical calculations, laboratory experiments, and technical solutions. A.M. Arifjanov, Kh. Fayziyev and A.U. The textbook by Tashkhodjayev presents methods for using information technologies in calculating processes in pipelines, channels, and hydraulic structures [2]. A.M. Arifzhanov and S.N. In Khashimov's textbook "Hydraulics and Hydraulic Systems", issues related to hydraulic systems, hydraulic devices, and their calculations are enriched with modern technologies [3]. These sources show that hydraulic education is integrated with computational and digital tools, but these tools need to be reorganized based on a specific pedagogical scenario to develop creative competence.

The purpose of the article is to clarify the problems of developing creative competence in engineering education using the example of the subject "Hydraulics and Hydraulic Systems" and to substantiate a methodological solution that integrates practical exercises, laboratory experiments, digital simulations, and project assignments.

LITERATURE REVIEW AND METHODOLOGY

The study used theoretical analysis, comparative analysis, pedagogical modeling, and didactic analysis of the content of science. The content of the subject of hydraulics, laboratory work, the use

of information technologies and virtual laboratories were studied as sources of the republic. The didactic potential of project-based learning, virtual laboratories, physical models, and digital simulation tools in fluid mechanics education was analyzed based on foreign sources.

In the work of scientists of the republic, the connection of hydraulic process calculations with information technologies seems to be an important direction. Arifjanov and his co-authors point out the need to perform hydraulic calculations using computers and enrich the problems with practical solutions [2]. Arifjanov and Khoshimov discuss the possibilities of solving problems related to the calculation of hydraulic systems and volumetric hydraulic drives using modern technologies [3]. The laboratory manual prepared by Ibragimova, Abduraimova, and Khoshimov shows the place of experimental activities in the educational process in the subject "Hydraulics and Hydraulic Systems" [4].

U.I. Bahranova analyzed the didactic possibilities of increasing motivation and learning efficiency by using virtual laboratories in teaching the subject "Hydraulics. Thermal Engineering" integrated with general physics [5]. Sh. Meyliyeva's work on the development of creative competence in the context of digital technologies proposes the idea of integrating project-based learning, problem-based tasks, electronic portfolios, digital collaboration, formative assessment, and reflection into a single methodological model [6]. Y.M. Hamrakulov focuses on project-based learning, interactive methods, and the use of CAD/CAM/CAE technologies in developing engineering design competencies [7]. These works demonstrate the relevance of digital and project-based approaches in engineering education.

Foreign studies have also shown the need for fluid mechanics courses to integrate theory, experiment, and project. Shah and Thareja have been involved in designing active, student-centered experience through “Design your Experiment” project approach in the lab, and have noted that this approach supports fundamental concepts, communication, leadership and teamwork skills [8]. Cioc and co-authors described a model that combines project-based learning, information literacy, and collaboration in an advanced fluid mechanics course [9]. In a study of physical model projects, 83.7% of 49 mechanical and civil engineering students reported that the project had a positive impact on their learning experience [10]. These results suggest the potential of PBL, but the results of such a survey should not be interpreted as a direct measure of creativity competence.

In a 2025 study by Aurich and co-authors on the Virtual laboratory, a smartphone-based virtual laboratory on the pump-tube system was linked to increased self-assessed competence, as well as high motivation and activity in working with certain methodological knowledge and real fluid systems in 26 pairs of pre/post responses [11]. Hirshfield and co-authors found that in a virtual lab project, Student Communities exhibited more divergent thinking compared to physical lab projects, but no direct correlation was found between divergent thinking and solution quality [12]. This provides an important methodological conclusion: the digital environment can enhance the generation of options, but convergent analysis, verification, and criterion-based evaluation are also necessary for quality engineering decision-making.

RESULTS AND DISCUSSION

As a result of the analysis, five main methodological problems were allocated in the science of “hydraulics and hydraulic systems”, which prevent the development of creativity competency. The first problem is that problems are often directed to a single algorithm and a single numerical answer. While such assignments are necessary to reinforce hydraulic principles, they do not adequately require the student to restate the problem, identify technical constraints, and develop alternatives. Therefore, traditional computational problems should be supplemented with open-ended engineering situations.

The second problem is that the laboratory exercise remains in the form of "instruction → measurement → formula → final result". To develop creative competence in the laboratory, students must formulate a hypothesis before the experiment, justify the choice of measurable parameters, predict the calculated result, compare the results of the experiment and the model, and explain the reasons for the differences. For example, when studying pressure loss in a pipe, a student will make an initial hypothesis about the effect of pipe length, diameter, flow rate, and local resistance on the result; then compares the measurement and calculation results graphically and develops system improvement options.

The third problem is the tendency to accept a digital tool or simulation as an innovative result in itself. A digital model can only be creative if the student purposefully manipulates the parameters, "if ... if?"- type scenarios become a developmental tool if one pre-predicts the outcome, checks the model outcome with real experience and theoretical calculation, and explains the model's limitations. Otherwise, simulation can also become a form of repeating a ready-made algorithm. While foreign virtual laboratory studies show the potential of the digital environment for motivation, methodological knowledge, and divergent thinking, they also show that solution quality should be assessed with specific criteria [11; 12].

The fourth problem is the organization of Practical Training, Laboratory and project activities, disconnected from each other. To eliminate this problem, it is advisable to integrate these activities in the sequence “hydraulic experience → calculation → simulation → project solution”. In this case, real experience provides empirical evidence of the phenomenon, the theoretical basis of the account, the simulation provides parametric scenarios, and the project provides criterion-based decision-making among alternatives.

The fifth problem is that the assessment is focused only on the final answer or the finished product. In creative engineering activities, the path to decision must also be evaluated. Therefore, it is necessary to link the indicators observed in the motivational-value, cognitive-analytical, operational-creative, and reflexive-evaluative components with the task, product, and rubric. For example, for the operational-creative component, the task is to “develop at least 2–3 alternative technical solutions and verify them through calculations/experiments/simulations”; as an indicator, variability and verification; In the rubric, reproductive, productive, and creative levels can be defined.

Problem / Challenge	Manifestation in Hydraulics Education	Methodological Solution	Student Product	Creativity Indicator
Algorithmic closed problem	Single formula and single right answer	Open hydraulic scenario and 2–3 alternatives	Options / variants table	Problem formulation, multivariance
Rigidlab instruction	Repeating a ready-made step-by-step sequence	Hypothesis → Experiment → Comparison → Interpretation	Measurements, graphs, error analysis	Inquiry skills, reflection
Reproductive simulation	Simply running a pre-built model	Parametric scenario and real-world experimental validation	Model results / output	Forecasting, verification
Fragmented activities	Practical, laboratory, and project tasks are isolated	Experiment → Calculation → Simulation → Project integration	Integrated project portfolio	Systems engineering thinking
Evaluating final answer only	Learning process remains invisible	Task → Indicator → Rubric → Scoring system	Portfolio / Reflection log	Decision justification and self-correction

Table 1. Problems and methodological solutions for the development of competency of creativity in hydraulics

The proposed methodological mechanism is expressed in the following chain: problem → information → calculation/experience/model → alternative solution → criterion comparison → engineering decision → reflection. “” “” “” “” “” Problem “in this chain means that the student perceives the situation and puts a question;” “information” separates the initial parameters and constraints; ""calculation/experiment/model" creates theoretical and empirical evidence; "alternative solution" divergent thinking; "criterion analogy" convergent analysis; "decision" provides professional argumentation; and "reflection" provides error, limitation, and subsequent correction.

The authorship of this mechanism lies not in the announcement of existing computational, laboratory, numerical modeling, and design tools in the field of hydraulics as innovations, but in their integration into a single subject-didactic cycle leading to a creative engineering decision. This shifts the student's focus from finding a ready-made solution to creating and selecting options based

on evidence. This approach transforms creativity from a general personal quality into a clearly observable professional activity.

In terms of republican experience, textbooks and educational and methodological resources in hydraulics contain sufficient subject matter for information technologies, modern computational methods, and practical and laboratory exercises [2–5]. The pedagogical task is to enrich this base with open problems, alternative options, comparisons of real and virtual experiences, project products, and reflective assessment. This direction is in line with pedagogical strategies in Uzbekistan's engineering education that are focused on innovative, problem-solving, and practical-creative thinking [1; 7].

CONCLUSION

The problem of developing creative competence in engineering education is particularly relevant in the subject of "Hydraulics and Hydraulic Systems", since this subject allows for the natural integration of theoretical laws, calculations, real experiments, numerical models, and technical design. The analysis of the literature showed that republican scientists have created a scientific and methodological basis for integrating hydraulic calculations with information technologies and developing laboratory and virtual laboratory capabilities. Foreign studies show that PBL, physical modeling, and virtual laboratories in fluid mechanics education can support student engagement, practical problem solving, and some creative thinking [8–12].

However, technology alone is not enough to develop creativity competence. The main didactic condition is for the student to independently identify the hydraulic problem, analyze information and limitations, use computational experimental simulation evidence, develop several alternative technical solutions, compare them by criteria, substantiate and defend the selected decision and reflexively assess the result. Therefore, integrating practical training, laboratory and project assignments in the “problem → information → calculation/experiment/model → alternative solution → decision → reflection” chain can be seen as a methodological direction that reinforces the creativity-promoting potential of hydraulics science.

In future empirical studies, it is advisable to test the effectiveness of this methodological chain using control and experimental groups, open hydraulic tasks, project rubrics, expert assessment, reflective diaries, and statistical criteria. Creativity should be assessed not only by the final product, but also by the process of problem formulation, option search, verification, decision justification, and correction.

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