

THE ROLE OF PRACTICAL AND LABORATORY CLASSES IN DEVELOPING PROFESSIONAL COMPETENCE OF FUTURE METROLOGICAL ENGINEERS

Karshiyev Zokhidjon Abdirakhim ugli

Bukhara State Technical University

Department of "Standardization, Metrology, and Conformity Assessment" assistant

Аннотация. В диссертации анализируется роль практической и лабораторной подготовки в формировании профессиональной компетентности будущих метрологов-инженеров. В качестве основных механизмов развития компетентности обосновываются поэтапная организация физической, виртуальной и гибридной лабораторной подготовки, цифровая обработка результатов измерений, оценка неопределенности, документирование в соответствии с требованиями стандартов и защита инженерных решений.

Ключевые слова: метрология; профессиональная компетентность; лаборатория; практическая подготовка; измерение; калибровка; неопределенность; виртуальная лаборатория; инженерное образование; цифровые технологии.

Abstract. This paper analyzes the role of practical and laboratory sessions in shaping the professional competence of future metrology engineers. It substantiates the step-by-step organization of physical, virtual, and hybrid laboratory sessions—along with the digital processing of measurement results, uncertainty evaluation, documentation in compliance with standards, and the defense of engineering decisions—as key mechanisms for competence development.

Keywords: metrology; professional competence; laboratory; practical session; measurement; calibration; uncertainty; virtual laboratory; engineering education; digital technology.

Introduction

Theoretical knowledge alone is not sufficient for the professional activity of a modern metrological engineer. A metrological engineer must be able to formulate a measurement task correctly, select a measuring instrument, assess the technical condition of an instrument, plan an experiment, process results, calculate measurement uncertainty, and document decisions based on standard requirements. Therefore, practical and laboratory classes are considered the central environment for developing professional competence.

The ABET criteria for engineering education identify conducting experiments, analyzing and interpreting data, and drawing conclusions based on engineering judgment as important learning outcomes [1]. The CDIO approach, in turn, requires design–implementation experience, active learning, and modern engineering learning environments [2]. These requirements demonstrate the need to transform laboratory work in metrology from merely repeating instructions into real problem-based activity. The strength of traditional laboratory classes lies in the student’s direct work with real measuring instruments, connections, operator actions, environmental conditions, and the physical limitations of instruments. Under such conditions, students can observe sources of error that are not visible in theory. Since ISO/IEC 17025 emphasizes laboratory competence, impartiality, and consistent operation, students should acquire documentation, consistency, and quality-control skills alongside practical experimentation [3].

A virtual laboratory, meanwhile, enables safe repetition, rapid changes in parameters, visualization of complex processes, and greater student participation when the number of available instruments is limited. A meta-analysis of virtual laboratories demonstrates their positive impact on engineering education; however, it is advisable to use them not as a complete replacement for physical laboratories, but as a supportive and preparatory environment [4]. A 2026 case study on a LabVIEW virtual laboratory bench in metrology education also shows that measurement and digital competencies can be developed together under conditions of appropriate pedagogical design [5].

Therefore, it is proposed to organize practical and laboratory classes based on a three-phase model. The first phase is virtual preparation: students study the experimental algorithm, safety requirements, instrument range, and expected relationships through simulation. The second phase is the physical experiment: measurements are performed using a real instrument, and sources of uncertainty and real operating conditions are recorded. The third phase is digital analysis: data are processed using a spreadsheet or Python/LabVIEW tools, after which a graph, uncertainty budget, and technical conclusion are prepared.

When assessing professional competence, not only the final numerical answer but also the quality of the process should be taken into account. The assessment criteria should include the correctness of the measurement scheme, consistency of data recording, justification of uncertainty components, correct use of standards, safety, the technical report, and oral defense of the result. The student’s laboratory journal and electronic portfolio demonstrate the dynamics of individual development.

In conclusion, practical and laboratory classes are the main mechanism for developing the professional competence of future metrological engineers. The most effective

pedagogical model combines physical experimentation with virtual preparation and digital analysis. As a result, students do not limit themselves to operating measuring instruments; they also acquire skills in data analysis, uncertainty evaluation, application of standard requirements, documentation, and substantiation of engineering decisions.

References

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