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MODERNISATION OF THE MATERIAL AND TECHNICAL BASE OF THE BIOMEDICAL ENGINEERING SPECIALITY: THE PATH TO COMPETITIVENESS AND COMPLIANCE WITH STANDARDS

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Abstract. The article discusses the possibilities of using medical diagnostic equipment for measuring blood pressure, heart rate, saturation and body temperature, purchased within the framework of the Horizon Europe international project «WIDE AcrossEU» (101158561), to improve the effectiveness of the educational process and conduct scientific research in the specialty G22 «Biomedical Engineering». The experience of using the ChoiceMMed medical monitor in laboratory work, training courses, student project activities and during scientific research is analysed. The prospects for the use of the equipment in interdisciplinary educational programmes, in particular in the fields of telemedicine, medical IoT systems, biomedical signal processing, modelling of adaptive responses of the body and the creation of intelligent health monitoring systems, have been identified. The role of modern diagnostic equipment in shaping the competencies of future biomedical engineers and developing

the scientific and educational infrastructure of higher education institutions has been outlined.

Keywords: biomedical engineering; medical measurements; pulse oximetry; digital health; telemedicine; IoT in medicine; physiological signals; training laboratories; ChoiceMMed; Horizon Europe.

Relevance of the study. The current development of medicine and healthcare, characterised by rapid digitalisation, places fundamental demands on the quality of training for specialists in the field of biomedical engineering. Today, biomedical engineers must possess not only thorough theoretical knowledge, but also in-depth practical skills in working with medical devices, sensors, hardware and software complexes, and algorithms for processing physiological signals. The need to modernise the material and technical base of higher education institutions is critical to ensuring that students and researchers have access to modern means of measuring human vital signs, which directly affects their competitiveness in the labour market.

The World Health Organisation clearly emphasises the need to increase the number of biomedical engineers capable of designing, evaluating, regulating, maintaining and teaching the safe use of medical devices in healthcare systems. This creates an urgent need for Ukrainian higher education institutions to align their educational programmes and material and technical base with European and global standards.

The modernisation of biomedical engineering education infrastructure should be based on the clear requirements of the global and European labour market. The European Alliance for Medical and Biological Engineering and Science (EAMBES) actively supports and promotes education, training and accreditation programmes in this field. EAMBES recommendations emphasise the need to develop practical skills in students, in particular the ability to work with different types of medical devices and to master methods of processing biomedical signals.¹ This also includes the development of interdisciplinary thinking.

National educational standards in Ukraine for the specialty «Biomedical Engineering» require, among other things, the ability to work in a multidisciplinary team, which emphasizes the importance of team engineering projects, as well as the ability to conduct scientific and applied research with the subsequent implementation of its results.

Employers – medical institutions, private clinics, service centres, medical equipment manufacturers and IT companies working in the field of eHealth – have clear requirements for the competencies of applicants: the ability to work with medical sensors and measuring complexes, skills in calibrating and maintaining equipment, the ability to analyse physiological signals and integrate medical devices into digital information systems.

Training that meets these requirements ensures the competitiveness of graduates in the context of the digital transformation of medicine.

The modern labour market in the field of biomedical engineering is characterised by a rapidly growing demand for specialists who have both sound engineering

knowledge and practical skills in working with medical diagnostic systems, digital platforms and intelligent health monitoring tools. In this context, the use of modern vital signs monitors in the educational process is an important element of technical education reform. It provides students with real access to the medical technology they will work with in clinical practice and develops practical skills that directly meet market requirements. It is particularly important to prepare students to work with portable devices, telemedicine platforms, medical IoT systems and biosignal analysis methods – these are the competencies that determine the competitiveness of graduates in the context of the digital transformation of medicine.

The inclusion of training courses on working with diagnostic equipment contributes to bringing Ukrainian training standards into line with European requirements, which is important in the context of integration into the European Higher Education Area.

The aim of the work is to analyse the relevance and systematise strategic ways of modernising the material and technical base of the Biomedical Engineering speciality, namely the experience of successful implementation of modern diagnostic equipment in the educational process, its role in the formation of key professional competencies and the development of the infrastructure of higher education institution laboratories.

Research objectives

1. To analyse the areas of use of equipment in laboratory work and practical training of students.

2. To investigate examples of the use of monitors in research and educational experiments.

3. To identify opportunities for integrating equipment into digital platforms, medical IoT systems and mobile applications.

4. To assess the interdisciplinary potential of equipment for collaboration with students of other technical specialities.

5. To justify the importance of using modern diagnostic tools in the training of biomedical engineers.

6. To formulate recommendations for further improvement of educational disciplines and laboratory facilities.

Main part. The key vector that determines the modern training of biomedical engineers is digital medicine (Digital Health) and the Internet of Medical Things (IoMT). In this context, the use of modern vital signs monitors in the educational process is not just an update, but an important element of technical education reform. Specialists must be prepared to work with portable devices, telemedicine platforms, and biosignal analysis methods.

Some international universities have already formalised these requirements in their curricula, offering, for example, certification courses in Biomedical IoT Devices. These courses teach the design of IoT-based medical networks for seamless data exchange, the development of embedded systems in medical IoT, and the creation of continuous monitoring systems that provide practical medical insights.

In addition, modern engineers must have knowledge of medical communication protocols. Mastering Bluetooth/Wi-Fi data transmission systems, as well as protocols critical to eHealth, such as Health Level Seven (HL7) and Fast Healthcare Interoperability Resources (FHIR), is key to ensuring system interoperability. FHIR, as the latest standard developed by HL7, provides easy implementation and flexibility, especially when using SMART API, which allows you to quickly create applications for various clinical scenarios. Thus, engineering education must shift from a focus on individual devices to teaching system integration. The availability of hardware is a necessary but not sufficient condition; graduates become more competitive when they are able to integrate data from this equipment into centralised medical systems (EHR) using unified standards such as FHIR. This transforms the graduate's skills from simple technical maintenance to system design.

In order to improve the quality of practical training and create conditions for conducting applied physiological and bioengineering research by students and teachers of the Biomedical Engineering speciality at Zhytomyr Polytechnic State University, a ChoiceMMed medical monitor was purchased as part of the Horizon Europe international project «Widen performance in research and innovation capacity and competence Across EU» (WIDE AcrossEU, 101158561), aimed at strengthening the research capacity of universities, a ChoiceMMed medical vital signs monitor was purchased (Fig. 1). The device, equipped with sensors for blood pressure, heart rate, oxygen saturation and body temperature, opens up wide opportunities for use in the educational process and experimental research in physiology, medical engineering and biomedical measurements. In particular, the use of this device allows students to study the principles of measuring blood pressure, pulse, saturation and temperature in practice, and enables researchers to conduct experiments in biophysics, biomedical measurements, and the design and development of medical IoT systems.



Fig. 1 – ChoiceMMed vital signs monitor

The practical experience of Zhytomyr Polytechnic State University demonstrates how targeted external funding can significantly improve the educational process.

Throughout the year, this monitor was used in laboratory work and scientific research by students and teachers. The following laboratory work was developed for practical use in the educational process:

- studying the structure and principles of monitoring systems;
- studying the basics of pulse oximetry;
- studying types of tonometers and methods of measuring human blood pressure;
- studying the operation of medical thermometers and the principles of measuring human temperature;
- setting up patient records;
- recording and processing human physiological parameters;
- transferring measured physiological parameters to a central server;
- creating and configuring a medical network in a medical facility.

The use of clinical diagnostic equipment has transformed the training laboratory into a full-fledged teaching and research platform. Students have been given the opportunity not only to measure, but also to record and export physiological signals in standard formats (CSV/EDF) for further processing, including statistical research. This is key for disciplines that study the recording and processing of biosignals and medical images, where it is necessary to develop skills in the use of mathematical analysis methods. Working with real data, students can investigate noise and artefacts, apply various filters (LPF, HPF, notch) and analyse heart rate variability, compare different measurement methods and validate the accuracy of instruments.

The available equipment can be used to construct and analyse physiological signals. Students can record and export signals in CSV/EDF formats for further processing, including statistical studies; investigate noise and artefacts; use filters (LPF, HPF, notch); analyse heart rhythm and heart rate variability; compare different measurement methods and validate the accuracy of devices. These skills are key to a number of disciplines in the G22 «Biomedical Engineering» speciality.

There are plans to develop a training repository of physiological signals collected during laboratory classes and scientific and experimental research. This will allow the creation of a database of signals for analysis in coursework and theses; provide students with the opportunity to work with data of different types and quality; and enable the creation of an open educational dataset for modelling and developing machine learning algorithms, statistical data processing, etc.

Since the purchased monitor has an output for transferring data to a computer and a cloud server, students learn the basics of integrating the device with mobile applications and IoT. This allows students to learn how to create their own medical monitoring applications and work with APIs, implement real-time transmission of real signals to a smartphone or tablet, visualise data in mobile applications, etc.

Students also gain skills in working with clinical equipment, namely connecting and servicing various sensors, calibrating devices, debugging before use, learning to

work with Bluetooth/Wi-Fi data transmission systems, reading documentation and protocols (HL7, FHIR, BLE GATT), and performing technical diagnostics of medical devices. This develops the competencies of a medical engineer, which are particularly in demand in hospitals and service centres.

The joint use of the monitor and the equipment available at the department for measuring ECG, spirometric indicators, and supplementing the laboratory with accelerometer modules for studying motor activity and additional PPG sensors will allow for the creation of comprehensive laboratory classes that simulate multi-parameter patient monitoring in a real clinic setting.

The monitor has become a tool for conducting applied research, such as:

- determining the body's response to increased physical activity. A control group of students was studied during physical education classes (standard norms, active games), and a group of students was studied while performing exercises on a bicycle ergometer with varying degrees of load. The results of the research were used to develop a methodology for studying the body's adaptive responses to physical exertion. Laboratory work will also be developed to record changes in physiological parameters during various stress tests.

- assessment of the impact of peripheral blood supply and movements on accuracy and artefacts when measuring blood oxygen saturation SpO₂ and PPG measurement of heart rate (pulse).

Master's theses have been defended based on the results of both studies.

Another aspect of the use of the purchased equipment is project work and course design, as well as student research. The new set of equipment allows students to create prototypes of health monitoring systems (mobile applications, cloud services) and remote monitoring systems for patients with chronic diseases; test the operation of portable IoT devices for telemedicine developed by students; develop intelligent algorithms for early detection of anomalies (arrhythmias, SpO₂ drops, tachycardia).

The equipment provides opportunities to conduct research and present its results at scientific conferences, student competitions, medical engineering start-up competitions, and for use in student research clubs.

An important example of use is the integration of devices into interdisciplinary educational modules. The equipment can be used in collaboration with students from other specialities to conduct joint laboratory work and joint scientific research, for example, creating team projects to participate in engineering-oriented start-ups and hackathons. In particular, collaboration is possible with students of the following specialities:

- Electronics, electronic communications, instrument engineering and radio engineering (medical data transmission, noise-resistant coding, data encryption);

- Software engineering (development of software for medical information systems, medical IoT systems, development of mobile applications, development of medical websites);

- Computer science (ML and AI signal analysis);

– Cybersecurity (cybersecurity in eHealth).

This contributes to the creation of comprehensive innovative solutions.

Thus, the specified equipment has become an important element of the educational and scientific infrastructure, providing opportunities for laboratory work, experiments and research in the field of physiology, biomedical engineering and telemedicine.

Overall, the proposed areas of focus make it possible to significantly improve the quality of practical training for future biomedical engineers, modernise laboratory infrastructure and bring the content of academic disciplines into line with current labour market requirements and European standards for engineering education.

Conclusions. The experience of using a modern medical vital signs monitor as part of international project 1 confirms that modern equipment transforms learning into a practice-oriented research platform, which allows:

- improve the quality of the educational process,
 - develop students' practical skills,
 - create innovative projects,
 - train highly qualified biomedical engineers who are ready to meet the challenges of modern medicine.

Thus, the use of a medical vital signs monitor in the educational process not only improves the quality of practical training for future engineers, but also plays a key role in modernising educational programmes, ensuring their relevance to the current needs of the labour market and harmonising the training of specialists with international and European standards. Further modernisation should be comprehensive, covering key modules: bioinstrumentation, biomechanics and tissue engineering, creating synergy between them.

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