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EDUCATION OF HEALTH CARE PERSONNEL IN THE CONTEXT OF THE 4.0 REVOLUTION IN MEDICINE

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Purpose: The article attempts to identify the competences of health care specialists in the context of the 4.0 revolution based on the learning outcomes of postgraduate studies devoted to new technologies in health care.
Design/methodology/approach: An analysis of existing data (desk research) was carried out, focused on the planned learning outcomes in the 4 newest postgraduate fields of study devoted to the implementation of technology in health care facilities.
Findings: Universities focus on the development of technological and partly methodological competences, taking little into account social and personal competences, which are equally important for the implementation of medicine 4.0. Some universities design broad programs addressed to various health care specialists, and some universities focus on selected areas of medicine where technology may have the greatest application.
Research limitations: The offer of studies combining medicine and technology is still developing, therefore only 4 fields of postgraduate studies were analyzed.
Practical implications: The analyzes conducted showed two approaches to teaching technology in medicine, the first one notes the use of technology in various fields of health care, the second one focuses on specific medical specialties. The advantages and disadvantages of both approaches are discussed. It is also necessary to implement learning outcomes regarding personal or social competences, such as employees' attitudes towards rapid technological changes, motivation to learn and competences regarding interdisciplinary cooperation.
Social implications: Implementing changes in study programs will allow for more effective education of health care specialists in the area of new technologies, which is necessary to improve the quality of treatment.
Originality/value: The conducted study showed gaps in study programs, which will allow for their improvement and, as a result, increase the quality of teaching in the field of new technologies.
Keywords: education, health care, medicine 4.0, revolution 4.0, new technologies.
Category of the paper: Research paper.

1. Medicine 4.0

The fourth industrial revolution (revolution 4.0), resulting from the development of technology, leads to many organizational transformations in subsequent sectors of the economy, improving communication processes, data analytics, and various simulations (Bujak, 2017; Furmanek, 2018; Kiraga, 2016). The 4.0 revolution also increasingly covers the health care sector. Modern technologies enable personalization of therapy, which can reduce costs and at the same time increase its quality (Gaciong, 2016; Jose et al., 2022; Mathur, Sutton, 2017). New technologies in medicine significantly improve the effectiveness of treatment, enabling more precise disease diagnosis and analysis of specific disease indicators. Through increasing access to clinical databases, the use of artificial intelligence (AI) and big data analysis algorithms, specialists are able to treat increasingly complex medical cases (Seyhan, Carini, 2019; Sgro, Blancafort, 2020).

Despite the numerous benefits associated with the implementation of new technologies, medicine remains one of the slowest adapting sectors (Chanchaichujit, Tan, Meng, Eaimkhong, 2019; Jose et al., 2022). One of the key challenges of modern medicine in the area of technology is the integration of telemedicine, server applications and machine learning algorithms. Their synchronization can increase the level of health care (Rakhimov, Mukhamediev, 2022). At the same time, the development of technology requires improving the competences of health care specialists. Although technologies are widely used in various fields of medicine, the level of their use and their necessity vary depending on the specialization (Konttila et al., 2019). The result is a diversified demand for competences in the field of health technologies among the staff of individual specialties (Foadi, Varghese, 2022; Kirchberg, Fritzmann, Weitz, 2020; Torrent-Sellens, Soler-Ramos, 2018). However, most physicians are not adequately trained in new technologies, which limits their ability to fully utilize these tools. Low technological competences may lead to medical errors and also cause psychological barriers in the use of modern solutions (Foadi, Varghese, 2022). Therefore, there is a need to improve European educational standards in this area. The European Union should develop uniform standards for competencies related to Medicine 4.0 and adapt them to the needs and capabilities of member states, taking into account differences in the level of digitization of healthcare systems across these countries. It is also necessary to standardize terminology and establish precise guidelines regarding the scope of training for physicians in the field of Medicine 4.0. Postgraduate education programs should be based on clearly defined competencies that physicians will acquire upon completing their studies. The current lack of coherence in this field leads to significant discrepancies in the programs offered. At the same time, it is essential to outline a strategy in which technology is viewed as an integral tool in medical practice, with its importance appropriately reflected in physician training programs. In addition to investing in the digitalization of healthcare facilities, the European Union should simultaneously focus on

developing digital competences among healthcare workers, as it is crucial to maintain a balance between the use of technology and fostering empathetic relationships between doctors and patients (Jidkov et al., 2019).

2. Educational needs in health care from the perspective of the development of new technologies

The implementation of new technologies generates the need to improve the education of specialists in health care 4.0 (Jose et al., 2022). It is important for the development of technology in medicine to create appropriate conditions by health care managers, who play a decisive role in shaping an environment open to innovation and in change management (Jose et al., 2022). Key technological competencies that should be developed in doctors include: information management and security, digital communication, empowering the patient in therapy and the ability to use new technologies (Jidkov et al., 2019; Foadi, Varghese, 2022).

In addition to hard competences in the field of technology, critical thinking, independent acquisition of knowledge and the ability to use technology are important, which is becoming an increasing challenge because some tasks are taken over by machines and some still remain human (Kao et al., 2023). The development of technology in medical education solves many problems related to traditional education, e.g. medical simulators solve the problem of access to actors playing various disease states, and machines enable safe training and improvement of skills in controlled conditions. However, it is important to understand the relationship between the costs of implementing new technologies and the benefits for the development of competences (Scalese, Obeso, Issenberg, 2008), including social ones, because technologies can improve communication between health care specialists and patients (Blahun et al., 2022).

Despite the increasing precision of technological innovations and their popularity in medicine, there are doubts about the reliability of tools, the accuracy of diagnoses and the susceptibility of algorithms to errors (Seyhan, Carini, 2019). It is worth emphasizing, however, that technology alone is not enough for the full development of medicine. Social aspects and focusing on the needs of individual patients are also important (Ioppolo, Vazquez, Hennerici, Andres, 2020). When working with a patient, although precise diagnosis, data collection and analysis using technology are crucial, they are not enough to achieve therapeutic success. An important element of therapy, especially in the case of chronic treatment, is the patient's motivation. As health improves, patients may lose determination, which negatively affects the effects of treatment (Chen, Tang, Guo, 2022; Tavakoly, Behzhad, Ferns, Peyman, 2020). For this reason, apart from technology, the patient's psychophysical and emotional aspects, as well as the reactions of his loved ones, are also important.

Currently, the literature on the subject lists several key competencies regarding the implementation of changes related to the Industrial Revolution 4.0, these are technical, methodological, social and personal competencies (Hecklau et al., 2016; Jose et al., 2022). Technical competencies refer to the use of technology information and communication, including processing large amounts of data, while methodological competences are the area of being innovative, engaging in strategic tasks and solving emerging problems, and continuous learning. The area of social competences in the implementation of Industry 4.0 is the ability to cooperate with people from various backgrounds, use knowledge and skills and share them with others. In turn, a key personal competence is flexibility, which manifests itself, among other things, in adapting to changes resulting from the development of technology, supporting new initiatives and coping with emerging challenges. Basic competencies in particular areas are presented in table 1.

Table 1.
Key competencies for the effective implementation of Industry 4.0

Technical Competency	Methodological Competency	Social Competency	Personal Competency
▪ State-of-the-artknowledge ▪ Technical skills ▪ Process understanding ▪ Handling smartdevices, apps, smart media ▪ Data/information processing skills ▪ Understanding IT security	▪ Creativity ▪ Entrepreneurial thinking ▪ Problem solving ▪ Conflict solving ▪ Decision making ▪ Analytical skills ▪ Research skills ▪ Efficiency orientation	▪ Intercultural skills ▪ Language skills ▪ Communication skills ▪ Networking skills ▪ Ability to work in a team ▪ Ability to be compromise and cooperative ▪ Ability to transfer knowledge ▪ Leadership skills	▪ Flexibility ▪ Ambiguity tolerance ▪ Motivation to learn ▪ Ability to work under pressure ▪ Sustainable mindset ▪ Compliance

Source: Hecklau et al., 2016; Jose et al., 2022, p. 3.

3. Own research methodology

3.1. Subject and purpose of research

The research purpose of the work was to identify the necessary competences of health care specialists in the context of the development of Industry 4.0 based on the learning outcomes of postgraduate studies dedicated to the implementation of technologies in health care. It is also important to compare the assumed effects in study programs to the model of key competencies of Industry 4.0: technological, methodological, personal competencies and social. The practical purpose of the work was to formulate recommendations for people building programs and study plans in the field of health care, as well as to present the possibilities of developing current staff through postgraduate studies or certification courses. The main research question posed in the

study was: what key competencies for the effective implementation of Industry 4.0 are included in postgraduate study programs addressed to health care specialists?

3.2. Research sample

The study was conducted by analyzing existing data (desk research). Postgraduate study programs were analyzed. The key to selecting the research sample was the financing of the postgraduate studies program from the state budget as part of competitions announced by the Medical Research Agency. Four postgraduate programs were used in the analyses:

1. Postgraduate program at the Jagiellonian University "Future technologies in clinical applications" (polish version: *Technologie przyszłości w zastosowaniu klinicznym)*[1].
2. Postgraduate study program carried out at the Faculty of Medical Sciences in Zabrze, Medical University of Silesia in Katowice "Artificial intelligence and robotics in medicine*"* (polish version: *Sztuczna inteligencja i robotyka w medycynie)*[2].
3. MBA study program at Lazarski University „MBA Healthcare Innovation & Technology”[3].
4. 4.Postgraduate program at Lazarski University "Hospital assessment of innovative medical technologies" (polish version: *Szpitalna ocean innowacyjnych technologii medycznych*)[4].

[1] According to the information included in the study program, "The studies are carried out under Project No. 2023/ABM/06/00004 Mon. "Innovations in medical education and practice (InnoWMed) - Increasing the competences of medical staff in the field of education, translational medicine, computational techniques, 3D visualization techniques with elements of Artificial Intelligence", financed by the Medical Research Agency under competition No. ABM/2023/6".https://www.mckp.uj.edu.pl/studiaabm/technologie-przyszlosci-w-zastosowaniu-klinicznym/#program

[2] According to the information included in the study program: Postgraduate course developed in connection with the implementation of the contract concluded with the Medical Research Agency, the subject of which is the implementation of the project: "Innovative medicine based on facts, IT, AI and robotics". Project financed by the Medical Research Agency, Poland, competition number No. ABM/2023/6 for the development and implementation of an original postgraduate program in the field of biomedical sciences. https://medycynainnowacyjna.sum.edu.pl/wp-content/uploads/2024/04/Zacznikr1doUchwayNr24_2024.pdf

[3],[4] The program was developed and implemented as part of the project entitled "Competences for the development of an innovative health care sector. Innovations and technologies are the key to increasing health value and building a sustainable system", under contract No. 2023/ABM/06/00010 - 00. The project is financed from the state budget by the Medical Research Agency under the competition No. ABM/2023/6 for the development of and implementation of an original postgraduate program in biomedical sciences.
https://ckp.lazarski.pl/mba/mba-healthcare-innovation-technology-mba-hit/#pick-5
https://ckp.lazarski.pl/studia-podyplomowe/akademia-rynku-ochrony-zdrowia/szpitalna-ocena-innowacyjnych-technologii-medycznych-hb-hta/#pick-20

4. Presentation of results

Common to the studies surveyed is a focus on artificial intelligence (AI), 3D printing issues and big data analytics. These are key issues for the implementation of Industry 4.0. In addition to universal knowledge, there are also issues specific to medical technologies.

As part of the postgraduate studies "Technologies of the future in clinical application", learning outcomes are assumed that relate, among others, to:

- standards and management of medical data (e.g. source data analysis, cleaning, pseudo-anonymization, data quality assessment),
- the process of designing and improving three-dimensional representations of biological objects and structures used in medicine, preparing pre-operative processes,
- 3D printing process and three-dimensional visualizations using immersive technologies,
- design and implementation of applications using immersive technologies for medical education and improvement of medical practices,
- design, synthesis and development of drugs using three-dimensional models,
- programming neural networks and analyzing medical data, creating predictive models, automating processes and creating medical applications.

The presented learning outcomes therefore focus on technical and methodological competences (problem solving, decision making, analytical skills, research skills). There are 29 knowledge and skill outcomes in total.

This postgraduate study program includes educational outcomes that the authors of the program classified as social competences. Only one of them refers to social competence (cooperation with the staff of health care units), and some of them refer to personal competence (e.g. motivation to deepen knowledge or awareness of one's own limitations). Effects in the area of social competences, assumed by the authors:

- The participant is ready to use objective sources of information.
- The participant is ready to take care of the safety and ergonomics of working conditions at positions using modern technologies in medicine.
- The participant is ready to optimize cooperation with the staff of health care units and optimize the work of interdisciplinary teams using innovative technologies.
- The participant is ready to take conscious and professional actions in the field of new technologies in medicine.
- The participant is ready to independently expand knowledge and continuous professional development.
- The participant is ready to formulate opinions on various aspects of professional activity in the implementation of modern technologies in medicine.
- The participant is ready to diagnose his or her own limitations and self-assess educational deficits and needs.

- The participant is ready to take responsibility for decisions made as part of his professional activity.
- The participant is ready to formulate conclusions based on his or her own analyzes or observations.

The postgraduate program is not dedicated to selected medical specializations, but is broadly addressed to specialists in various fields medicine, bioengineers, biotechnologists and bioinformaticians.

As part of the postgraduate studies "Artificial intelligence and robotics in medicine" learning outcomes were planned regarding artificial intelligence, robotics, big data analysis, but also modeling of various body parts based on knowledge of anatomy, physiology and biophysics. The graduate will have the ability to present and argue the advantages and threats of introducing rotary technologies or based programs on AI in individual departments of medical services. A total of 38 results have been planned in the area of knowledge and skills, which focus on technical competences (especially AI and big data) and methodological competences (including: creativity, problem-solving, decision-making, analytical skills, research skills, efficiency orientation).

Out of 9 learning outcomes categorized by the authors of the program as social competences, only two refer to the area of social and personal competence (critical evaluation of acquired knowledge combined with motivation to develop it, as well as compliance with ethical principles).

Importantly, the study program includes key areas of medicine in which artificial intelligence and robotics may have particular applications. The areas of medicine included in the postgraduate study program are: biophysics, anatomy, surgery, cardiology, and neurorehabilitation. According to the program authors, technology may be particularly useful in the following areas: implants and artificial organs, telemedicine, rehabilitation and diagnostics, e.g. musculoskeletal dysfunctions in medicine and sports, as well as hearing and speech engineering.

Lazarski University offers two fields of study financed by the medical research agency as part of the 2023 competition. One of the fields is MBA Healthcare Innovation & Technology. The study program defines 6 main areas: vision of development, Eco-system of health care, leadership 2.0, New Product Development - from idea to commercialization; clinical trial of new technology and innovator practice. Detailed content for each area is provided in Table 2.

Table 2.
Key areas of the MBA study program: Healthcare Innovation& Technology

Vision of development 1. Strategic Management 2. Change Management and Leadership 3. Decision Making 4. Sustainable Development 5. Corporate Finance 6. Budgeting and Controlling 7. Strategic Marketing 8. Digital Marketing 9. Process Management 10. Knowledge Management and Intellectual Property 11. Strategic Game	**Eco health care system** 1. Models of healthcare organization and financing 2. Value Based Healthcare - a new paradigm in healthcare 3. Innovations in healthcare 4. AI in health 5. Medical technologies - trends and development processes 6. HTA - central and hospital perspective 7. Financing healthcare services and medical technologies 8. Legal aspects of the healthcare sectorin the context of innovative medical technologies
Clinical trial of new technology 1. Introduction to Clinical Trials 2. Legal Basis for Clinical Trials 3. Ethical Basis for Clinical Trials 4. Preclinical Studies and Non-Commercial Studies 5. Clinical Trial Registration 6. The Role of the URPL 7. Biostatistical Basis for a Good Clinical Trial. Analysis of Clinical Trial Results 8. Economic Basis for a Good Clinical Trial 9. Creating Trial Documentation 10. Investigator, Coordinator, Site - Roles and Tasks 11. Clinical Trial Support Center 12. Sponsor and CRO. Feasibility. Managing a Trial as a Project 13. Monitoring Clinical Trials 14. Drug Safety and Phase IV Studies 15. Bioavailability and Bioequivalence Studies. Early Phase Studies 16. Clinical Trials of Medical Devices 17. Differences in Clinical Trials in Various Fields of Medicine	**New Product Development - from idea to commercialization** 1. Technology development path - from idea to market. Business and registration aspects 2. Experiment design and analysis. Preclinical evaluation and assessment 3. Business strategies and models in the high-tech industry 4. High-tech project management - R&D technology development. The perspective of the researcher, center, financing institution 5. Innovation business management 6. Sources of financing for innovative activities in healthcare 7. Workshop on negotiations with investors 8. Valuation of research projects for commercialization 9. Presentation and storytelling: as a tool for building strong brands 10. Marketing strategies for innovative ventures
Leadership 2.0 1. Leadership Self-Awareness Workshop 2. Conflict and Negotiations 3. Effective Communication Workshop 4. Leadership and Career Development Coaching 5. Team Leadership and Relationship Management 6. Psychology in Management 7. Creativity and Innovation Workshop 8. Networking Practice	**The Innovator's Practice** 1. Case study – Success stories 2. "Failure cases as powerful lessons" 3. Study visit to the academic Technology Transfer Center 4. Study visits to industrial partners - Innovation development practice (choice of two proposals) 5. Measuring Impact - target, breath and depth of change 6. Coaching session 7. Methodology of the diploma project. Vision, Value proposition, Validation - project pitching roadmap 8. Diploma seminar

Source: postgraduate program https://ckp.lazarski.pl/mba/mba-healthcare-innovation-technology-mba-hit/?gad_source=1&gclid=Cj0KCQiAlsy5BhDeARIsABRc6Zs3posb8syoH6LMmMK_taMDjI1isSHKKsKY9cMJDHLuVJyBss49e2gaAjYEEALw_wcB#pick-5, 12.11.2024.

The learning outcomes proposed in the study program refer to technical and methodological competency. One of the modules: Leadership 2.0 refers to social and personal competency in 6 out of 8 topics (only Leadership Self-Awareness Workshop and Conflict and Negotiations can be more closely assigned to methodological competency). The postgraduate program consists of 460 hours in total, of which the Leadership 2.0 module covers 64 hours, which is 13.91% of classes. The postgraduate studies are dedicated to various specialists related to health care, the authors of the studies do not distinguish specific areas of medicine.

The second field of study at Lazarski University, financed by the Medical Research Agency, is postgraduate studies: "Hospital assessment of innovative medical technologies". Similarly to the MBA studies, the program distinguishes 6 main areas: hospital innovation management, introduction to HB-HTA (Hospital Based - Health Technology Assesment), HB-HTA practice, organization of the HB-HTA unit, team management and communication for the development of innovation hospital and diploma module. Details are presented in Table 3.

Table 3.
Key areas of the postgraduate program Hospital evaluation of innovative medical technologies

Hospital Innovation Management 1. The Place of the Hospital in the Healthcare System and Directions of Transformation 2. Legal, Organizational, and Financial Aspects of Hospital Operations 3. Managing Hospital Development Based on Innovations 4. Sources of Financing for Innovative Medical Technologies	**Organization of the HB-HTA unit** 1. Organization of the HB-HTA unit - study visit 2. Evaluation and monitoring of the implementation of innovative technology
Introduction to HB-HTA 1. Health Technology Assessment. HTA versus HB-HTA 2. The role of the HB-HTA report in the implementation and financing of innovative health technologies 3. Introduction to the HB-HTA methodology and evaluation of HB-HTA reports 4. Analysis of the decision problem 5. Clinical analysis 6. Economic analysis 7. Organizational analysis	**HB-HTA Practice** 1. Tools in the HB-HTA process 2. Decision problem analysis workshop 3. Clinical effectiveness and safety of medical technology analysis workshop, taking into account patient opinions 4. Impact of medical technology on hospital service provision workshop 5. Economic efficiency and impact of medical technology on hospital/unit budget analysis workshop 6. Reporting and presentation of HB-HTA analysis
Team management and communication for the development of hospital innovation 1. Team Management and Communication 2. Conflict Management	**Diploma module** 1. Mentoring session 2. Diploma seminar

Source: postgraduate program https://ckp.lazarski.pl/studia-podyplomowe/akademia-rynku-ochrony-zdrowia/szpitalna-ocena-innowacyjnych-technologii-medycznych-hb-hta/#pick-20access 12.11.2024

However, the module: Team management and communication for the development of hospital innovation, includes 16 hours of classes out of 190 for the entire postgraduate studies. This means that 8.42% of classes are dedicated to social and personal competency, and the rest are focused on technical and methodological competency.

Postgraduate studies are aimed at various specialists related to health care and do not distinguish specific areas of medicine.

5. Conclusions

The analyzes carried out lead to the conclusion that the study programs largely refer to the area of technological and partly methodological competences. The creators of the studies focus on hard competencies, on current knowledge, technical skills, and understanding of processes, including new technologies, applications and devices.

Few effects refer to other areas of key competencies for Industry 4.0, such as: ability to work under pressure, team, interprofessional and intercultural cooperation, leadership skills, and flexibility in adapting to new challenges. Postgraduate study programs pay little attention to social and personal competences, which are as important as technological competences for the challenges of Industry 4.0 (Hecklau et al., 2016; Jose et al., 2022). Unfortunately, the above-mentioned areas are covered only to a small extent in study programs.

Some universities try to show the importance of technology in various areas of health care: drug production, surgery, medical diagnosis (data analysis), or the use of 3D printing. In turn, some universities focus their content on key areas of medicine where Industry 4.0 technology is particularly useful, such as: biophysics, anatomy, surgery, cardiology, neurorehabilitation. The question remains open about the effectiveness of both approaches to acquiring technological competences by health care specialists and the coherence between first-cycle, second-cycle or uniform studies (enabling participation in postgraduate studies) and the content taught during postgraduate studies. The basic learning outcomes of medical studies include outcomes relating to new technologies and their use in medicine (Regulation of the Minister of Science and Higher Education, 2019, 2023, 2024), universities also independently expand the basic effects listed in the regulations with content related to industry 4.0 technologies (Barłóg, Mendryk, 2024), however, in practice, there are large differences in this area of competence among specialists in various fields of medicine (Foadi, Varghese, 2022; Kirchberg, Fritzmann, Weitz, 2020; Torrent-Sellens, Soler-Ramos, 2018). This is not a Polish problem only; in other European countries, including the UK, postgraduate programs related to medicine 4.0 also focus on selected areas of medicine, completely omitting some of them, e.g. psychiatry (Jidkov et al., 2019).

It seems that some of the content planned for postgraduate studies should also be included in long-cycle studies, so that each graduate has the basic competences necessary for the implementation of industry 4.0 technologies in health care facilities. It is important to take into account not only technological and methodological, but also social and personal competences (Hecklau et al., 2016; Jose et al., 2022). Additional, expanded research should address specific

areas of medicine and competency needs for future developments. However, the presented theses require empirical verification through research on health care staff, both managers and specialists - practitioners.

The presented study has limitations regarding the size of the research sample and to a large extent it can be understood as a pilot, but particularly important due to the growing trend of technological directions addressed to health care specialists. The analyzed fields of study appeared to a large extent in the university's offer in recent months, which is an important need, considering the strategic importance of health care for the functioning of society and the financing of these postgraduate study programs from external funds. It is also worth noting that postgraduate studies are not the only ones recently offered by universities that combine the issues of industry 4.0 and medicine. This article is limited to postgraduate studies, taking into account their specificity, including (Article 160 of the Act of 20 July 2018 - Law on Higher Education and Science): length of study (studies last no less than 2 semesters) or obtaining qualifications (postgraduate studies enable only partial qualifications at level 6, 7 or 8 of the Polish Qualifications Framework). The adoption of partial effects results in concentration on a relatively narrow thematic scope and omission of teaching/developing other, more general skills. It would be interesting to see how the graduates of these studies use the acquired skills and whether they feel they are sufficient.

The considerations presented in the article are based on analyses of the learning outcomes of postgraduate studies conducted at selected Polish universities. It is important to emphasise that the problems associated with the education of health professionals in the context of contemporary challenges are global in nature. The development of technology and techniques brings new possibilities for diagnosis and treatment of patients. It is becoming necessary to develop new competencies. Universities around the world are facing this challenge. The issues raised in the article and the research method used can be used both for research based on international comparisons and for analyses aimed at changing the educational programmes implemented at universities in every region of the world.

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