Chapter 12

DIGITALISATION OF PHARMA: REFORMING OF THE SCIENTIFIC, EDUCATIONAL, MANUFACTURING AND MARKETING LANDSCAPE

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DOI https://doi.org/10.30525/978-9934-26-430-6-12

INTRODUCTION

In recent years, the pharmaceutical industry has undergone a profound transformation driven by digitalization. The convergence of advanced technologies, data analytics, and innovative strategies has revolutionized every facet of the pharmaceutical ecosystem, reshaping the scientific, educational, manufacturing, and marketing landscape[1,2].

Digitalization in the pharmaceutical industry has ushered in a new era of scientific discovery and innovation. Advanced computational tools, artificial intelligence (AI), and machine learning algorithms are enabling researchers to accelerate drug discovery, predict molecular interactions, and optimize therapeutic interventions with unprecedented speed and precision[3,4,5]. The digital transformation of pharmaceutical education is revolutionizing learning methodologies and expanding access to knowledge. Online learning platforms, virtual laboratories, and interactive simulations are empowering students and professionals to acquire specialized skills, stay abreast of industry developments, and engage in lifelong learning from anywhere in the world. In pharmaceutical manufacturing, digital technologies are driving optimization and efficiency across production processes. Automation, data analytics, and real-time monitoring systems are enhancing quality control,

[1] Hole G., Hole A. S., McFalone-Shaw I. Digitalization in Pharmaceutical Industry: A Recent Perspectives. *Innovations in Science and Technology*. 2022. Vol. 5. P. 146–166

[2] Shashi M. Sustainable Digitalization in Pharmaceutical Supply Chains Using Theory of Constraints: A Qualitative Study. *Sustainability*. 2023. Vol. 15. 8752.

[3] Tetteh M. G., Jagtap S., Salonitis K. (2023). Pharma 4.0: Revealing Drivers of the Digital Transformation in the Pharma Sector. *Manufacturing Driving Circular Economy. GCSM 2022* / Eds. H. Kohl, G. Seliger, F. Dietrich. Lecture Notes in Mechanical Engineering. Cham : Springer, 2023. P. 528–535.

[4] Digital health: trends, opportunities and challenges in medical devices, pharma and biotechnology / N. Kasoju et al. *CSIT*. 2023. Vol. 11. P. 11–30.

[5] Incorporating Technology in Pharmacy Education: Students' Preferences and Learning Outcomes / A. Alhur et al. *Cureus*. 2023. Vol. 15. e50158.

reducing production costs, and enabling agile manufacturing practices that respond swiftly to market demands and regulatory requirements.

Moreover, the digitalization of pharmaceutical marketing is reshaping how companies engage with healthcare professionals and consumers. Digital marketing strategies, personalized messaging, and data-driven insights are enabling targeted outreach, improving customer engagement, and facilitating more efficient allocation of marketing resources[6].

However, the digitalization of the pharmaceutical industry also presents new challenges and considerations. Data privacy, cybersecurity, and regulatory compliance are paramount concerns as companies navigate the complex landscape of digital health technologies, patient data, and regulatory frameworks.

Despite these challenges, the digitalization of pharma holds immense promise for driving innovation, improving patient outcomes, and addressing unmet medical needs. By harnessing the power of data, technology, and collaboration, the industry is poised to usher in a new era of healthcare that is more efficient, accessible, and patient-centric than ever before[7].

By embracing digitalization, pharmaceutical companies can unlock new opportunities for innovation, differentiation, and growth in an increasingly competitive and dynamic market. From precision medicine and personalized therapies to smart manufacturing and data-driven decision-making, digital technologies are driving a paradigm shift in how medicines are discovered, developed, manufactured, and delivered to patients worldwide. By fostering a culture of innovation, collaboration, and continuous learning, the pharmaceutical industry can harness the full potential of digitalization to create value, improve healthcare outcomes, and positively impact lives around the globe.

Therefore, the digitalization of pharma represents a transformative force that is reshaping the industry in profound ways. By embracing digital technologies and embracing a culture of innovation, the pharmaceutical sector can navigate the complexities of the digital age and emerge as a leader in driving positive change and shaping the future of healthcare.

The following review material discusses directions of the digitalisation in the pharmaceutical industry, including the training of pharmaceutical professionals, drug development, improving the production and quality control of medicines, and new trends shaping the digital transformation of the pharmaceutical industry.

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[6] Naqvi R., Das G. Pharma 2023 Marketing the Future. *Biological Sciences*. 2023. Vol. 3. P. 347–352.

[7] Shah A. M., Shah S. V. Digital therapeutics-a new era in health care. *National Journal of Physiology, Pharmacy and Pharmacology*. 2023. Vol. 13. P. 2190–2196.

1. The impact of digital tools on research and development of new medicines

In the ever-evolving landscape of medicine research and development, digital tools have emerged as a powerful ally, transforming the way new medicines are discovered and brought to market. The utilization of digital tools has revolutionized the traditional methods of research, paving the way for faster, more efficient, and precise drug development processes[8,9] (Fig. 1).

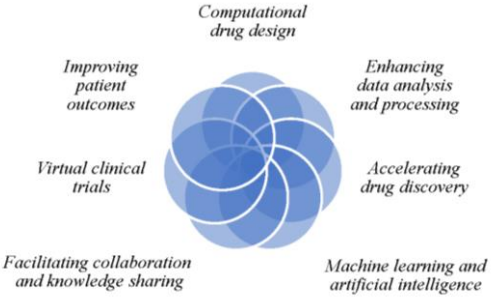

Fig. 1. Directions of digital application on research and development of medicines

Digital tools enable computational drug design, which involves the use of algorithms and simulations to predict the interactions between potential drug compounds and biological targets. This approach accelerates the identification of promising drug candidates and reduces the time and resources required for experimental validation[10].

One of the significant impacts of digital tools on medicine research is the enhancement of data analysis and processing. With the ability to process vast amounts of data in real-time, researchers can uncover valuable insights, identify patterns, and predict outcomes with unprecedented accuracy. This data-driven approach not only accelerates the research process but also enables researchers to make informed decisions based on concrete evidence.

[8] Artificial Intelligence in Pharmaceutical and Healthcare Research / S.K. Bhattamisra et al. *Big Data Cogn. Comput*. 2023. Vol 7. 10.

[9] Hoppe N., Härting R. C., Rahmel A. Potential Benefits of Artificial Intelligence in Healthcare. *Artificial Intelligence and Machine Learning for Healthcare* / Eds. C. P. Lim, A. Vaidya, Y. W. Chen, V. Jain, L. C. Jain. Intelligent Systems Reference Library. Vol. 229. Cham: Springer, 2023. P. 225–249.

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Digital tools have significantly accelerated the drug discovery process by enabling virtual screening of compounds, predictive modeling of drug interactions, and simulation of clinical trials. Automated robotic systems coupled with sophisticated data analysis software allow researchers to test thousands or even millions of compounds simultaneously, significantly reducing the time and resources required to identify potential drug candidates. As a result, the development of new medicines has become more efficient and cost-effective.

Machine learning algorithms and AI-powered platforms are increasingly utilized in drug discovery to analyze complex datasets, predict molecular properties, and optimize drug design parameters. These technologies enhance decision-making processes and enable the exploration of novel therapeutic avenues that might have been overlooked using traditional methods.

Digital tools facilitate the conduct of virtual clinical trials, wherein participants remotely engage in clinical research activities using mobile health devices, wearable sensors, and telemedicine platforms. Virtual trials offer advantages such as broader participant recruitment, real-time data collection, and reduced logistical burdens, ultimately expediting the clinical development process.

Another critical impact of digital tools is the facilitation of collaboration and knowledge sharing among researchers and pharmaceutical companies. Through online platforms and virtual networks, researchers can connect, share data, and collaborate on projects in real-time, regardless of geographical distances. This seamless exchange of information has led to increased innovation, faster problem-solving, and the rapid dissemination of new discoveries in the field of medicine[11].

Ultimately, the integration of digital tools in medicine research and development has led to improved patient outcomes. By streamlining the drug development process, researchers can bring life-saving treatments to market faster, benefiting patients in need of urgent medical interventions. Additionally, the use of digital tools in clinical trials has enhanced patient monitoring, personalized treatment plans, and predictive analytics, leading to more precise and effective healthcare solutions[12].

2. Digital transformations in pharmaceutical education: from classroom learning to online courses

The evolution of digital technologies has catalyzed significant transformations in pharmaceutical education, reshaping traditional

[11] Advancing pharmacy and healthcare with virtual digital technologies / S. J. Trenfield et al. *Advanced drug delivery reviews*. 2022. Vol. 182. 114098.

[12] Digitizing clinical trials / O.T. Inan et al. *npj Digit. Med*. 2020. Vol. 3. 101.

pedagogical approaches and expanding learning opportunities for students and professionals in the field[13]. Below, the broader implications and applications of digital transformations in pharmaceutical education are presented (Fig. 2).

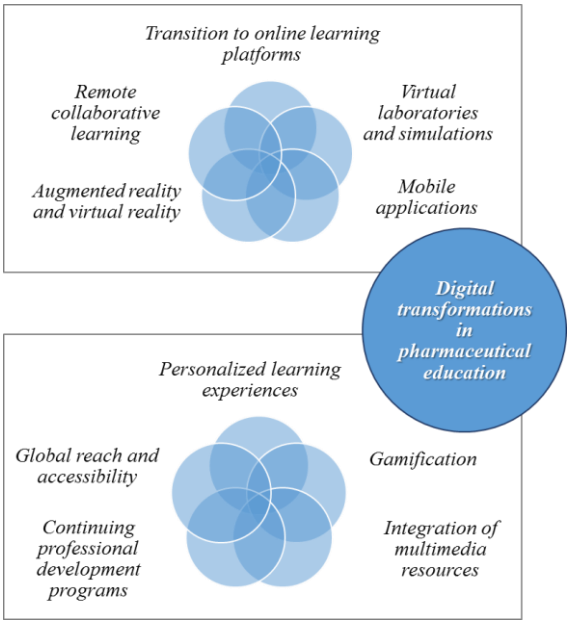

Fig. 2. Directions of digital transformations in pharmaceutical education

With the advent of online learning platforms and learning management systems, pharmaceutical education has transcended the confines of traditional classroom settings[14,15]. Institutions and educators leverage these platforms to deliver course materials, lectures, interactive quizzes, and assignments in a flexible and accessible manner, enabling learners to engage with educational content at their own pace and convenience. Examples include *Coursera*, *edX*, and *Khan Academy*.

[13] Transforming pharmaceutical education: A needs-based global analysis for policy development / A Etukakpan. *Exploratory Research in Clinical and Social Pharmacy*. 2023. Vol. 9. 100234.

[14] Digital literacy in undergraduate pharmacy education: a scoping review / M. Alowais et al. *Journal of the American Medical Informatics Association*. 2024. Vol. 31. P. 732–745.

[15] Cain J., Malcom D. R., Timothy D. The Role of Artificial Intelligence in the Future of Pharmacy Education. *AJPE*. 2023. Vol. 87. 100135.

Digital technologies facilitate the creation of virtual laboratories and simulations, providing students with immersive learning experiences in pharmaceutical sciences[16,17]. Virtual experiments allow learners to explore complex biochemical processes, drug interactions, and laboratory techniques in a risk-free environment, fostering hands-on skills development and critical thinking abilities. They provide realistic hands-on experiences without the need for physical laboratory space or equipment. Examples include *Labster*, *MyDispense*, *iLAB-X* and *PhET Interactive Simulations*.

Mobile applications designed for pharmaceutical education provide on-the-go access to educational resources, drug databases, medical calculators, and interactive learning modules[18]. These apps cater to diverse learning styles and preferences, enhancing flexibility and convenience for students. Examples include *Epocrates*, *Medscape*, and *Drugs.com*.

Augmented Reality (AR) and Virtual Reality (VR) technologies are increasingly used to create immersive learning experiences in pharmaceutical education. Students can explore complex molecular structures, visualize drug interactions, and simulate clinical scenarios in virtual environments, enhancing understanding and retention of course concepts[19]. Examples include AR apps for anatomy visualization (*Anat_Hub*)[20] and VR simulations for pharmacy practice training[21].

Digital platforms enable remote collaborative learning opportunities, wherein students collaborate with peers and instructors in virtual classrooms, discussion forums, and group projects. Through online collaboration, learners engage in knowledge sharing, problem-solving, and peer-to-peer feedback, enriching their learning experiences and promoting teamwork skills essential for professional practice in the pharmaceutical industry. Digital learning technologies enable the customization of educational content to meet the

[16] MyDispense simulation in pharmacy education: a scoping review / H. K. Khera et al. *J of Pharm Policy and Pract*. 2023. Vol. 16. 110.

[17] The status of virtual simulation experiments in medical education in China: based on the national virtual simulation experiment teaching Center (iLAB-X) / Zhu, H. et al. *Medical education online*. 2023. Vol. 28. P. 2272387.

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[20] A Novel Immersive Anatomy Education System (Anat_Hub): Redefining Blended Learning for the Musculoskeletal System / A. Boomgaard et al. *Appl. Sci*. 2022. Vol. 12. 5694.

[21] Doğan E., Şahin Y. L. Virtual reality environment in pharmacy education: A cyclical study on instructional design principles. Journal of Computer Assisted Learning. 2024. 40. P. 269–287.

diverse needs and learning styles of individual students[22]. Adaptive learning algorithms analyze student performance data and tailor instructional materials and assessments accordingly, providing personalized learning pathways that optimize knowledge retention and skill acquisition.

Gamification techniques are used to gamify learning activities and motivate student engagement in pharmaceutical education[23]. Educational games, quizzes, and challenges incentivize learning, reward achievement, and foster healthy competition among students, making learning more enjoyable and effective.

Digital platforms facilitate the integration of multimedia resources, including video lectures, interactive animations, and virtual reality simulations, into pharmaceutical curricula. These multimedia resources enhance engagement and comprehension by presenting complex concepts in diverse formats and catering to diverse learning preferences, thereby fostering deeper understanding and retention of course content.

Digital technologies support the delivery of continuing professional development programs for pharmaceutical professionals seeking to update their knowledge and skills in response to evolving industry trends and regulatory requirements. Online courses offer convenient access to up-to-date information, regulatory updates, and best practices, enabling professionals to stay abreast of advancements in the field and maintain competence throughout their careers.

Online learning platforms facilitate the global dissemination of pharmaceutical education, transcending geographical barriers and enabling learners from diverse backgrounds to access high-quality educational resources. This global reach fosters cross-cultural exchange, collaboration, and networking opportunities, enriching the educational experience and promoting diversity in the pharmaceutical workforce[24].

Overall, the digital transformation of pharmaceutical education represents a paradigm shift towards more accessible, interactive, and personalized learning experiences. By leveraging online learning platforms, virtual laboratories, collaborative tools, and multimedia resources, educators can enhance student engagement, facilitate skill development, and prepare

[22] Lorenzoni A. A., Manzini F., Soares L., Soares L. E-learning in Pharmacy Education: what do we know about it? *Braz. J. Pharm. Sci*. 2019. Vol. 55. DOI: 10.1590/s2175-97902019000118100

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learners for successful careers in the dynamic and evolving pharmaceutical landscape[25].

3. Digital technologies in optimizing pharmaceutical manufacturing and quality control of pharmaceutical products

The integration of digital technologies in pharmaceutical manufacturing has revolutionized production processes, enabling enhanced efficiency, flexibility, and quality control. Below are elaborated key aspects of digital technologies in pharmaceutical manufacturing (Fig. 3).

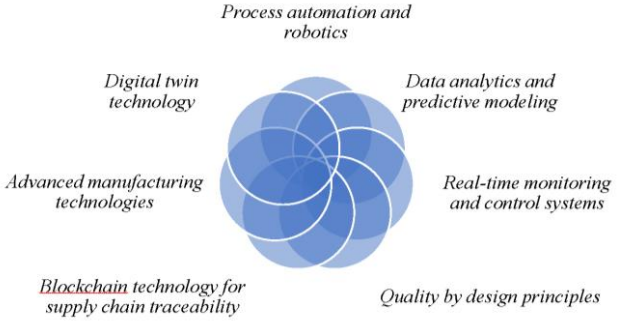

Fig. 3. Directions of digital technologies in optimizing pharmaceutical manufacturing

Digital technologies automate various aspects of pharmaceutical manufacturing, including formulation, mixing, granulation, and packaging. Robotics systems perform repetitive tasks with precision and consistency, reducing human error and improving production efficiency[26]. For example, robotic arms are used in filling and labeling operations to ensure accurate dosage and product labeling.

Digital platforms leverage data analytics and predictive modeling to optimize manufacturing processes and predict equipment performance. Advanced analytics algorithms analyze production data in real-time, identify inefficiencies, and suggest process improvements to enhance productivity and quality. For instance, predictive maintenance models predict equipment

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[26] Saharan V.A. Robotic Automation of Pharmaceutical and Life Science Industries. Computer Aided Pharmaceutics and Drug Delivery / Eds. V. A. Saharan. Singapore : Springer, 2022. P. 381–414.

failures based on sensor data, enabling proactive maintenance interventions to prevent downtime[27, 28].

Digital monitoring and control systems provide real-time visibility into manufacturing operations, enabling proactive decision-making and rapid response to deviations. Integrated sensor networks collect data on critical process parameters such as temperature, pressure, and humidity, ensuring adherence to quality specifications. For example, supervisory control and data acquisition systems monitor and control manufacturing equipment to maintain process stability and consistency.

Digital technologies facilitate the implementation of Quality by Design (QbD) principles in pharmaceutical manufacturing. QbD frameworks leverage process understanding, risk assessment, and design of experiments to ensure product quality and consistency throughout the manufacturing process[29]. For example, QbD software tools facilitate the design and optimization of manufacturing processes based on scientific principles and risk assessment criteria.

Blockchain technology enhances supply chain transparency and traceability in pharmaceutical manufacturing. Blockchain-based systems create an immutable record of product lifecycle events, including raw material sourcing, production, and distribution, ensuring data integrity and preventing counterfeit products[30]. For example, blockchain platforms track the movement of pharmaceutical products from manufacturing facilities to end-users, enabling verification of product authenticity and compliance with regulatory requirements.

Digital technologies enable the adoption of advanced manufacturing technologies such as continuous manufacturing, 3D printing, and personalized medicine production. Continuous manufacturing processes streamline production workflows, reduce cycle times, and minimize resource consumption. For example, continuous tablet manufacturing lines use integrated sensors and control systems to monitor and adjust process parameters in real-time, optimizing tablet quality and production efficiency.

Digital twin technology creates virtual replicas of manufacturing processes, equipment, and products, enabling simulation, optimization, and

[27] Hernandez I., Zhang Y. Using predictive analytics and big data to optimize pharmaceutical outcomes. *American Journal of Health-System Pharmacy*. 2017. Vol. 74. P. 1494–1500.

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[29] A., Naquvi K. J., Haider F., Khan M. A. Quality by design– newer technique for pharmaceutical product development. *Intelligent Pharmacy*. 2024. Vol. 2. P. 122–129.

[30] Blockchain technologies in pharmaceutical industry: A comprehensive overview / M. S. Zade et al. *IP Int J Compr Adv Pharmacol*. 2024. Vol. 9. P. 24–30.

predictive analytics[31]. Digital twins facilitate virtual experimentation and scenario analysis, enabling manufacturers to identify potential process improvements and optimize resource allocation. For example, digital twins of pharmaceutical manufacturing plants simulate production scenarios, allowing operators to test different operating conditions and optimize process parameters for improved efficiency and quality[31].

In the pharmaceutical industry, ensuring the quality and safety of medicinal products is paramount. The advent of digital technologies has revolutionized the processes involved in quality control, offering enhanced efficiency, accuracy, and regulatory compliance. Below are key aspects of digital quality control in pharmaceuticals (Fig. 4).

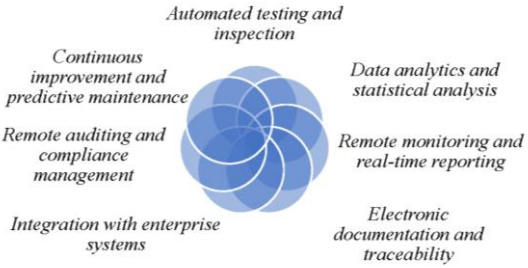

Fig. 4. Directions of digital technologies in quality control of pharmaceutical products

Digital technologies enable the automation of testing and inspection processes, reducing human error and increasing throughput in quality control laboratories. Automated systems equipped with sensors, robotics, and machine vision capabilities perform routine assays, analyses, and inspections with precision and consistency, ensuring compliance with stringent quality standards.

Digital quality control platforms leverage data analytics and statistical analysis techniques to interpret test results, detect trends, and identify deviations from established quality specifications. Advanced algorithms analyze large datasets generated from testing procedures, enabling real-time monitoring of product quality and proactive identification of potential quality issues[32]. Digital quality control systems support remote monitoring of

[31] Patel A. K., Patel A., Patel K. M. Digital Twin in Pharmaceutical Industry. *Digital Twin Technology* / Eds. M. Vohra. Hoboken : Wiley, 2022. p. 173–187.

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manufacturing processes and product quality parameters. Digital quality control platforms facilitate electronic documentation and traceability of testing procedures, results, and quality assurance records. Electronic batch records, electronic signatures, and secure data storage systems ensure compliance with regulatory requirements and enable efficient retrieval of quality-related information during audits and inspections.

Digital quality control systems seamlessly integrate with enterprise resource planning (ERP) and laboratory information management systems, streamlining data flow and information exchange across the pharmaceutical manufacturing ecosystem[33]. Integration with ERP systems enables automated data transfer from quality control to production and inventory management modules, facilitating seamless coordination of manufacturing processes and quality assurance activities.

Digital quality control platforms facilitate remote auditing and compliance management through virtual inspection capabilities and electronic documentation systems. Regulatory authorities can conduct virtual inspections of quality control laboratories, review electronic records, and assess compliance with Good Manufacturing Practices (GMP) and other regulatory standards without physical presence, reducing the need for travel and minimizing disruptions to manufacturing operations.

Digital quality control systems support continuous improvement initiatives and predictive maintenance strategies to optimize equipment performance and ensure reliable operation. Predictive analytics algorithms analyze equipment performance data to forecast maintenance needs, prevent equipment failures, and minimize downtime, thereby enhancing overall efficiency and productivity in quality control operations.

In summary, digital quality control in pharmaceuticals represents a paradigm shift towards more efficient, accurate, and data-driven approaches to ensuring product quality and regulatory compliance. By leveraging automation, data analytics, remote monitoring, and integration with enterprise systems, pharmaceutical companies can achieve higher levels of quality assurance, operational excellence, and patient safety throughout the product lifecycle.

4. Digital marketing in the pharmaceutical industry

The advent of digital marketing has revolutionised the way pharmaceutical companies communicate with their target audiences. The target audience for pharmaceutical marketing includes both direct consumers and purchasers of pharmaceutical products, as well as doctors and pharmacists who act as

[33] Sarkar R. D. Pharma Software – A Complete Overview. *International Journal of Science and Healthcare Research*. 2023. Vol. 8. 166–177.

intermediaries between the manufacturer and the consumer. The physician audience is particularly important for the promotion of prescription medicines, as it is the physician who decides which medicine to prescribe to a patient. In addition to traditional marketing communications, digital channels such as social media, search engines, influencers and eDetailing are coming to the fore (Fig. 5). Digital platforms offer a cost-effective way to interact with consumers and providers of healthcare products and services, leading to increased brand awareness and customer acquisition.

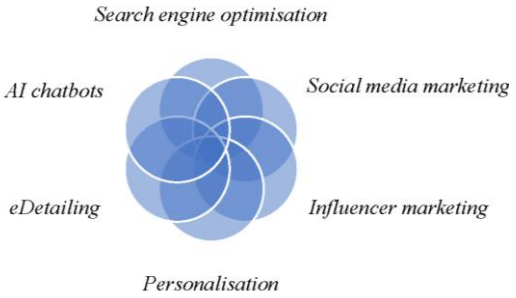

Fig. 5. Directions of digital marketing in the pharmaceutical industry

According to a study conducted in the pharmaceutical industry, digital marketing includes such key tools as search engine optimisation (SEO), content marketing and social media marketing (SMM)[34, 35]. The SEO tool involves the selection of keywords for the company's website according to trends in a specific space and time, the analysis of keywords placed in the website settings and in textual information messages about the company, its products and other thematic content. Content marketing is a strategy for creating and distributing valuable and useful content to attract and retain target audiences. Social media marketing is the use of social media to attract and retain a customer base. This tool can include the creation of special promotions, contests, advertising campaigns, etc. Social media marketing has become the most important digital communication channel for pharmaceutical companies. Platforms such as Facebook, Twitter, and LinkedIn allow companies to create targeted advertising and reach their desired audience. Social media also provides an opportunity to share educational content,

[34] Protsenko V. M., Protsenko A. V. Digital Marketing in the development of pharmaceutical companies: The current aspects and Perspectives. *Business Inform*. 2022. Vol. 11. P. 277–283.

[35] Кравченко М. О., Михалін Б. С. Цифровий фармацевтичний маркетинг. *Бізнес, інновації, менеджмент: проблеми та перспективи* : зб. тез доп. II Міжнар. наук.-практ. конф., м. Київ, 22 квіт. 2021 р., 2021. С. 288.

increase brand awareness and engage with consumers. With the increasing use of mobile devices, mobile marketing has also become important to reach a wider audience[36].

Another popular digital marketing trend in the pharmaceutical industry is influencer marketing[37]. Influencers, i.e. individuals with a significant number of followers on social media, are used to target pharmaceutical brands and their products. In the healthcare sector, influencers can be doctors, pharmacists, patients or their relatives (e.g. parents in advertising for children), or healthcare professionals who provide information about treatments and medicines. Clinical opinion leaders recognised professional authorities in a particular field of medicine and are used to promote medical products among medical and pharmaceutical professionals. By leveraging the influence and authority of leaders and their opinions, pharmaceutical companies can effectively reach and engage their target audiences.

Personalisation is a key aspect of digital marketing in the pharmaceutical industry[38]. By analysing patient data, pharmaceutical companies can provide personalised recommendations based on medical history and current health status. This allows companies to conduct more targeted and effective marketing campaigns. Data analysis is crucial for tracking the effectiveness of digital marketing efforts and attributing conversions.

eDetailing is actively used in the marketing of pharmaceutical companies[39]. Digital presentations on mobile devices allow to build a professional dialogue between a pharmaceutical company representative and a medical representative, demonstrating the benefits and features of using a drug or treatment.

Technological advances such as VR and AR have had a significant impact on pharmaceutical marketing[40]. They are used to create immersive learning experiences for consumers and healthcare professionals. Artificial intelligence is another technology that is transforming pharmaceutical marketing. AI chatbots can provide 24/7 support and answer queries from consumers and healthcare professionals.

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[36] Khanom M. T. Using social media marketing in the digital era: A necessity or a choice. *International Journal of Research in Business and Social Science*. 2023. Vol. 12. P. 88–98.

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Despite the wide range of digital marketing opportunities available to pharmaceutical companies, this can sometimes lead to indecision and slow implementation of strategies[41]. To overcome this problem, companies can adopt an agile methodology based on testing and experimentation.

By testing strategies on a smaller scale, companies can gain valuable insights and optimise campaigns before scaling them up. Establishing a digital presence is crucial for healthcare professionals in the pharmaceutical industry[42]. Having a professional Facebook page, a personal website, or a presence on platforms such as LinkedIn can help doctors connect with patients and provide them with valuable information. Digital interactions between doctors and patients, such as digital consultations, are becoming increasingly common.

Therefore, influencer marketing, social media marketing, personalised marketing and the use of digital technologies are key trends in the industry. It is important for pharmaceutical companies to continuously adapt to the changing digital landscape and use digital marketing opportunities to remain competitive and meet the needs of consumers, pharmaceutical manufacturers and healthcare providers.

CONCLUSIONS

The integration of digital tools into the research and development of new medicines has significantly enhanced the efficiency, speed, and success rate of drug discovery efforts. By leveraging computational approaches, big data analytics, machine learning, virtual trials, and collaborative platforms, the pharmaceutical industry is poised to continue delivering innovative therapies to address unmet medical needs. The digital transformation of pharmaceutical education represents a paradigm shift towards more accessible, interactive, and personalized learning experiences. By leveraging online learning platforms, virtual laboratories, collaborative tools, and multimedia resources, educators can enhance student engagement, facilitate skill development, and prepare learners for successful careers in the dynamic and evolving pharmaceutical landscape. The integration of digital technologies in pharmaceutical manufacturing holds tremendous potential to optimize production processes, enhance product quality, and drive innovation in the pharmaceutical industry. By leveraging automation, data analytics, real-time monitoring, and advanced manufacturing technologies, pharmaceutical manufacturers can achieve operational excellence and meet the growing demands for safe and effective pharmaceutical products. Digital marketing

[41] The effects of digitalisation on health and Social Care Work: A qualitative descriptive study of the perceptions of professionals and managers / A.-M. Kaihlanen et al. *BMC Health Services Research*. 2023. Vol. 23. 714.

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has become an integral part of the pharmaceutical industry. It offers numerous benefits, including wider reach, personalized marketing, awareness creation, and data-driven insights. However, companies need to be mindful of the regulatory landscape and ensure compliance in their marketing efforts. With the right strategies and approach, digital marketing can revolutionize the way pharma companies connect with their target audience and drive business growth. While influencer marketing, social media marketing, and personalization are powerful strategies on their own, integrating them can amplify their impact and effectiveness. Measuring the success of digital marketing efforts is crucial to determine the return on investment and make data-driven decisions. Key performance indicators can include engagement metrics (such as likes, shares, and comments), conversions, website traffic, and customer satisfaction surveys. By regularly monitoring these metrics, companies can identify areas for improvement and refine their digital marketing strategies accordingly.

SUMMARY

The digitalization of the pharmaceutical industry is rapidly reshaping its scientific, educational, manufacturing, and marketing landscape. Advancements in technology of the digitalisation in the pharmaceutical industry, including the training of pharmaceutical professionals, drug development, improving the production and quality control of medicines, and new trends shaping the digital transformation of the pharmaceutical industry are discussed. Influence on digital tools such as artificial intelligence, big data analytics, and blockchain are being leveraged to improve efficiency, and quality are considered. The use of digital technologies in the training of pharmacy professionals is an integral part of the educational process at educational institutions. The integration of digital technologies into pharmaceutical production, which allows to optimise production processes, improve product quality and stimulate innovation in the pharmaceutical industry is considered. It has been determined that marketing efforts are becoming more targeted and personalised thanks to data-driven insights, allowing businesses to connect with consumers in meaningful ways.

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3. Tetteh M. G., Jagtap S., Salonitis K. (2023). Pharma 4.0: Revealing Drivers of the Digital Transformation in the Pharma Sector. *Manufacturing Driving Circular Economy. GCSM 2022* / Eds. H. Kohl, G.

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