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AN OVERVIEW OF DEVELOPMENT OF DIGITAL TECHNOLOGY IN PHARMACEUTICALS SCIENCES

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Abstract:

The pharmaceutical sector has been greatly impacted by digitalisation, which has resulted in fresh and creative approaches to medication development, clinical trail management, and patient care. The two main technologies causing this change are tele medicine ad artificial intelligence. The fields of medication discovery, clinical decision making, and patient monitoring employee AI algorithms and machine learning models. By enabling remote patient diagnosis and treatment, telemedicine improves access to care while cutting expenses but there are drawbacks to digitalisation as well, like worries about data and privacy, the need to comply with regulations, and the requirements for qualified personal to handle the technology. In equalities in healthcare already exist may be made worse by the digital device in technology infrastructure and healthcare access.

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INTRODUCTION:

The operational, strategic, and competitive landscapes of many industries have been redefined over the last ten years by digital transformation (DT) (e.g., Song et al., 2024; Appio et al., 2021; Gastaldi et al., 2018; Llopis-Albert et al., 2021; Leão and da Silva, 2021 to mention a few). This issue has drawn a lot of attention from academics and industry professionals because to the internet's rapid convergence with future technologies and automation (Appio et al., 2023) (Hausberg et al., 2019; Vial, 2019). However, DT's journey is still being played out in the Pharmaceutical Industry (PI), a sector where innovation is both a key issue and a persistent demand (Achilladelis and Antonakis, 2001; Malerba and Orsenigo, 2015). The investigation of DT in PI, especially via a management study With DT providing previously unheard-of chances to improve drug Value Chain Phases (VCP) from Drug Discovery (DD) and Clinical Trials (CT) to Manufacturing (MK), Supply Chain (SC), and Market Access (MA), the PI is at a pivotal point in time. Technologies with the potential to bring about revolutionary changes include the Internet of Things (IoT), Blockchain, Cybersecurity, Augmented Reality (AR), Artificial Intelligence (AI), 3D Printing, Digital Twins, Virtual Reality (VR), Robotics, and Big Data (e.g., Silva et al., 2020; Kulkov, 2021; Sharma et al., 2022; Reinhardt et al., 2020). But the scholarly conversation around these technology integrations in PI is still in its infancy, particularly when it comes to managerial viewpoints. The conversation is frequently restricted to phenomena that are practice-oriented, with significant discoveries being hidden in practitioner journals or generalised Four essential research domains were discovered during the analytical journey through these chosen works: stakeholder theory research, operations management research, strategic management research, and organization's theory research. The many domains provide distinct perspectives for analysing and comprehending the complex effects of DT within PI, highlighting the need for a strong theoretical framework that can direct academic research as well as real-world implementations. The goal of this paper is to provide a comprehensive overview of the current status of DT research in PI, bringing together the disparate fields of study and establishing a well-organised research agenda that will serve as a foundation for future investigations. This study aims to accomplish two goals: first, it will compile the existing literature into a coherent summary that clarifies the present state of DT in PI, with a focus on management implications IN summary, this paper is not merely a plea for filling in the theoretical gaps in PI-DT; rather, it is an appeal to the academic community to participate in, discuss, and further the discourse on digital transformation in the pharmaceutical industry. By providing a clear and organised explanation of the research gap and the objectives of the study, it hopes to enhance the ongoing discourse surrounding DT by providing a framework for both theoretical development and empirical investigation, guaranteeing that the transformative potential of DT is fully realised in improving healthcare outcomes. The paper begins by outlining the research gaps identified, using a structured approach for clarity. It then outlines the investigation methodology, sifting through the chosen articles to extract significant themes and insights. Finally, it concludes with a thorough discussion.

REVIEW METHODOLOGY:

The Systematic Literature Review (SLR) methodology (Tranfield et al., 2003) has been applied to assist this study. In order to analyse the body of knowledge regarding a particular construct or technology (Sivarajah et al., 2017), investigate, and dedicate the available evidence to a particular research question in order to replicate it (Kitchenham and Charters, 2007; Nassif et al., 2019; Xiao and Watson, 2019), SLR is a logical, transparent, and reproducible research methodology. An SLR can be carried out for a number of reasons, including suggesting the state of the art about a particular construct or offering a reference framework that identifies present research gaps and possible issues for future research (Sivarajah et al., 2017). This study's review strategy employs a three-phase methodology.

GOOD MANUFACTURING WITH IN PHARMACEUTICALS:

Good Manufacturing Practice Regulations, or GMPs, are enforced by national regulatory bodies to control licensing and authorisation (Cramer, 2006). These rules enable manufacturers, processors, and packagers of pharmaceuticals, medical devices, food, and blood to take proactive steps to ensure the efficacy and safety of their products (Beri and Wolton). By requiring a quality-oriented approach to manufacturing, GMP standards enable companies to minimise or completely eradicate errors, contamination, and mix-ups. The consumer is thereby shielded from choosing a product that is hazardous or ineffectual (Patel and Chotai, 2011). Furthermore, GMP systems outline a number of quality-based operational controls, such as operating procedures, management systems, dependable testing, high-quality raw materials, detection, and deviation investigation (Villa, 1984).

TARGET IDENTIFICATION:

AI's capacity to evaluate enormous datasets, including omics data, phenotypic and expression data, disease connections, patents, publications, clinical trials, and research grants, is advantageous for target identification, the first stage of drug discovery. AI can learn about the biological causes of illnesses and find new proteins or genes that may be the focus of therapeutic intervention by using these datasets for training. Furthermore, AI programs such as Alpha Fold can forecast the three-dimensional configurations of target proteins, which speeds up medication development by identifying compounds that can attach to them.AI's capacity to evaluate large datasets, including omics data, phenotypic and expression data, disease connections, patents, publications, clinical trials, and research grants, is advantageous for target identification, the first stage of drug discovery.

MOLECULAR SIMULATIONS:

Another field where artificial intelligence is having a big impact is molecular simulations. High-fidelity simulations can be carried out fully on computers by utilising AI-driven algorithms, which eliminates the need for expensive physical testing of potential therapeutic molecules. Researchers may evaluate a variety of molecular attributes, including toxicity, bioactivity, and physicochemical traits, thanks to these in silico simulations.

TELE HEALTH AND ONLINE PHARMACY ADVANCEMENTS IN PANDEMIC MANAGEMENTS:

Digital health technologies have been helpful in managing the COVID-19 pandemic through surveillance, contact tracing, diagnosis, treatment, and prevention in the domain of online pharmacy and telemedicine. These technologies address the issues of accessibility and timely care, ensuring that healthcare, including pharmacy services, is delivered more effectively. In order to improve access to treatment globally, emphasis has been placed on the role that telemedicine and e-pharmacies in particular play. These platforms are improving access to healthcare, particularly in areas where traditional healthcare infrastructure is few or overburdened, by facilitating remote consultations and medication delivery. Motivated by the COVID-19 epidemic, the Canadian Virtual Care Policy Framework promotes the quick implementation and integration of virtual care. It has a strong emphasis on improving quality and access, protecting privacy and equity, and creating fair payment structures. It also addresses digital inequities and uses a cooperative, patient-centered approach. Virtual health care was quickly adopted by Canadian provinces and territories during the COVID-19 pandemic; by April 2020, 60% of visits were virtual, up from 10% to 20% in 2019. However, these additions to healthcare systems were frequently only ephemeral and incomplete. Virtual visits dropped to 40% by August 2020, with regional variances, and provinces and territories employed temporary billing codes for these services. The "Diagnostique" of the framework offers a comprehensive examination of policy.

Virtual care enablers and solutions, highlighting the necessity of all-encompassing policy and partnership engagement [41]. The Hospital News article discusses the infrastructure and use of telepharmacy services in Canada within the framework of digital transformation in pharmacy. It also highlights the geographic difficulties and the early adoption of telepharmacy in several locations since 2003. It mentions the usage of several technologies, including videoconferencing, remote camera verification, and medication order management. The essay emphasizes the need for increased telepharmacy services despite the lack of specific quantitative data in order to guarantee consistent care quality across various locations.

Patients and providers in the United States, emphasizing programs like the Aordable Connectivity Program and Lifeline to facilitate access. Health Resources and Services Administration enhances telehealth through support services, research, and technical assistance, a significant outreach impact for the Advancement of Telehealth (OAT) under Health Resources and Services Administration (HRSA) works to improve access to quality health care through integrated telehealth services in the US. It supports direct services, research, and technical assistance, with over 6,000 tele-health technical assistance requests sent to Telehealth.

People and healthcare professionals in the US, stressing the need of access-facilitating initiatives like Lifeline and the Affordable Connectivity Program. Through research, technical assistance, and support services, the Health Resources and Services Administration improves telehealth, which has a significant outreach impact [43]. The goal of the Health Resources and Services Administration (HRSA)'s Office for the Advancement of Telehealth (OAT) is to increase US citizens' access to high-quality healthcare by implementing integrated telehealth services. More than 6,000 requests for telehealth technical assistance have been received to

Telehealth, which supports direct services, research, and technical support.

Globally, Leading the way in digital health and care in the United Kingdom is the National Health Service (NHS), which offers significant prospects for innovation through extensive data management. There are several levels of support available for digital health: discovery through groups like the Intelligent Data Analysis (IDA) research group and the Biotechnology and Biological Sciences Research Council (BBSRC); development through networks like CPRD and Catapults; and delivery through organizations like Academic Health Science Networks (AHSNs) and DigitalHealth.London. Safety and effectiveness are guaranteed by regulatory agencies such as NICE and the Medicines and Healthcare Products Regulatory Agency (MHRA). The goal of this collaborative ecosystem, which includes stakeholders from academia, healthcare, and industry, is to improve health and care services via technology.

Cross-organizational patient records are being implemented at the forefront by European countries like the Netherlands, Austria, and Italy. This is significantly improving telehealth communication and facilitating cross-border healthcare. Strong government backing is essential to the advancement of telehealth. The President of the European Commission, Ursula von der Leyen, has been a vocal supporter of electronic health. To facilitate the sharing of health data amongst member states, she suggested creating a European Health Data Space. Leading the way in telehealth law for almost ten years, France is the first country to implement a comprehensive public funding program for teleexpertise. Notwithstanding these developments, obstacles.

The Asia-Pacific area expects a spike in the use of telehealth because to changes in consumer behavior brought on by the pandemic and digital demand, whereas South East Asia is seeing widespread development in telehealth across all healthcare domains. [48]. The adoption of telehealth in the Asia-Pacific area has increased significantly between 2019 and 2021, and by 2024, it is expected to reach even higher levels. Adoption in China more than doubled to 47%, and it is predicted to reach 76%. With an estimate of 72%, Indonesia's consumption more than doubled to 51%. Both Malaysia and the Philippines expect their adoption rates to rise from 30% to 29% to 70% in the near future. India's adoption is predicted to more than double to 68%, while Singapore's is anticipated to achieve a notable boost from 5 to 45%.

AI IN CLINICAL TRAILS:

Part Of The Protracted Drug Discovery Process Involves Testing Compounds Against Samples Of Ill Cells. To identify physiologically active substances that warrant further investigation, more research is needed. Novartis research teams analyze photos using machine learning algorithms to identify which untested compounds may be worth further investigation. New data sets can be found far more quickly when this technology is used in place of traditional human analysis and laboratory experimentation. Consequently, it reduces operating costs associated with the labor-intensive analysis of every material and expedites the release of novel and effective pharmaceuticals. Artificial Intelligence (AI) has emerged as a game-changer in the field of clinical trials, offering a range of applications that will revolutionize.

Clinical trials are undergoing a revolution, with a wide range of applications that are revolutionizing patient care and medical research. One of the main achievements is the ability to transform a variety of biomedical and healthcare data into computer models that accurately depict individual patients. This innovation makes it possible to provide personalized medication to a wider audience and choose the best course of action for individual patients. AI is also essential to the analysis of medical records, which speeds up the process of finding possible subjects for clinical trials. It further automates the process of matching cancer patients to appropriate trials by using genetic analysis and personal medical histories, increasing the efficacy and success rates of these investigations. AI also aids in improving pathology analysis.

AI IN PHARMA INDUSTRY :

Pharma sector: Thanks to the integration of Radio Frequency Identification (RFID) technology, the pharmaceutical industry has been seeing notable breakthroughs in the application of the Internet of Things (IoT) in its manufacturing and supply chain activities. IoT devices that use RFID technology transfer real-time data to other connected devices over the Internet without the need for human scanning, in contrast to traditional bar codes. As a result, pharmaceutical product tracking and inventory management over the whole lifecycle are now more accurate and efficient. In addition to its effects on supply chain optimization and manufacturing, IoT has become essential to the pharmaceutical industry's provision of medical services. Through the integration of IoT devices into a range of applications, such as

distribution, manufacturing, patient monitoring, and customized health solutions, a thoroughof IoT-driven RFID tags in manufacturing has revolutionized inventory management, reduced errors, and optimizing production workflows by providing real-time data on product locations, stock levels, and expiration dates. This automation empowers manufacturers to maintain optimal stock levels, prevent shortages, and eliminate the distribution of expired medications. In the supply chain, IoT has introduced increased transparency and efficiency, as RFID-enabled devices enable real-time tracking and monitoring of pharmaceutical shipments, mitigating product losses, theft, and counterfeiting. Moreover, IoT's integration into medical services has resulted in patient-centric healthcare, as smart devices such as IoT-enabled pill dispensers and wearable health monitors empower patients to actively manage their medications, while allowing healthcare providers to remotely monitor patient health. This convergence of IoT and pharmaceuticals has triggered a paradigm shift in the industry, driving it toward greater digitization, automation, and interconnectedness, ultimately enhancing the overall quality of services provided in the pharmaceutical sector.

APPLICATION OF MACHINE LEARNING IN PHARMACEUTICALS SCIENCE:

Applications of machine learning in the pharmaceutical industry have ranged from early drug discovery to late stages of development. Three main pharmaceutical science fields that have seen extensive application of ANNs together with several other machine learning techniques are presented in the sections that follow. These studies fall into three categories: formulation studies, preformulation studies, and drug design and discovery research.Applications of machine learning in the pharmaceutical industry have ranged from early drug discovery to late stages of development. Three main pharmaceutical science fields that have seen extensive application of ANNs together with several other machine learning techniques are presented in the sections that follow. These investigations fall into three categories: preformulation, medication design and discovery.

CONCLUSION:

A revolutionary change with enormous potential for the future of the pharmaceutical industry is the digitization of the sector. The integration of cutting-edge technology, including as cloud computing, artificial intelligence (AI), big data analytics, and the Internet of Things (IoT), has been studied in this review article along with its significant effects on several aspects of pharmaceutical operations. Pharmaceutical manufacturing is being revolutionized by IoT-enabled real-time monitoring and data collection, which results in better process control, less downtime, and proactive maintenance techniques. Research and development, medication discovery, and clinical trials are being optimized by AI applications like machine learning and predictive analytics, which eventually result in significant time and cost savings. Cloud computing technologies are improving data accessibility and storage, which supports cost-efficiency in the pharmaceutical industry. By utilizing large datasets, big data analytics.

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