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Disruptive Technology in Pharmaceutical Education and Practice: Curriculum Reforms Imperative for Africa

Michael U. Adikwu

Department of Pharmaceutics, Faculty of Pharmaceutical Sciences,
University of Nigeria, Nsukka, 410001 Nigeria
michael.adikwu@unn.edu.ng

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Abstract

Disruptive technology can be defined as one that displaces an established technology and shakes up the industry or a ground-breaking product that creates a completely new industry. Globally there are developments in various areas of advanced technology which are popularly known as disruptive technology. This has affected many areas of pharmaceutical education and practice such that if the curriculum is not modified to take care of these areas, many pharmacy graduates will be outdated. The areas that affect pharmaceutical education and practice most are artificial intelligence (AI), Internet of Things (IoT), Blockchain, Big Data and a host of others. Thus, there is the need to retool the curriculum in Nigeria to bring our students up to date with developments elsewhere. The students need to be taught the basic aspects while in school to be able to apply them in the area of practice. For this to be possible the teachers need to be able to have the basic knowledge to be able to impact this on the students. Another area that is very important is the issue of pharmacy laws and jurisprudence. This is critical because of the many issues of fake drugs in the market. These are the focus of this paper.

Keywords: Disruptive innovation, Artificial Intelligence (AI), Internet of Things (IoT), Blockchain, Big Data; Pharmaceutical Education, Pharmacy Education

Introduction

Disruptive innovation is a phrase that was coined in the mid-1990s by Clayton Christensen at the Harvard Business School, who defined it as “an innovation that helps create a new market and value network that eventually disrupts existing products and services” (Christensen et al, 2000). University of Cambridge Judge Business School defined disruption as fundamental changes in ways in which organisations and ecosystems operate (University of Cambridge Judge Business School, 2021).

Today people are living in an age of disruption. As a result of these changes in innovations, organisations should no longer rely merely on product and service innovations, it needs to change its business model to survive and succeed and to grow. This is more so in the pharmaceutical sector where many disruptions are coming from new developments in bioinformatics, chemo-informatics and other new algorithms in computer sciences. As these changes in the industry continue to multiply, so are the product lines in community and hospital pharmacies.

In the present era, there are various factors that affect assessment, creation or revitalisation of business models given the disruptive innovation affecting businesses today (Christensen et al, 2000). The pace, scale and impact of innovation has accelerated over the past few years and has continued unabated today. While innovation can enhance the value of existing products and services, it can also render existing business models obsolete as new products are produced to replace old ones and as such production lines change. As such, there is the need to rethink who customers will be, while the customers themselves rethink what they value. Thus, there is the need to retool the teaching curriculum.

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Those already in the businesses may want to respond to disruption but can also be reluctant to relinquish their advantage. New products into the business world may need the support of the incumbent firms that they threaten to disrupt.

In the business world, a new company can start at the bottom of a market and then determinedly gain more and more of the market, ultimately displacing established competitors (Alsharif, 2019). In the healthcare sector, where Pharmacy belongs, disruptive innovation is needed to meet the evolving complex needs of society and the advances in technology. Thus the graduate pharmacist should also prepare his mind in one form or the other to meet these changes in the society where he finds himself.

Apart from the pharmacy graduates, pharmaceutical educators and researchers have to be involved in disruptive innovation to train their students to meet the challenges of the marketplace. They must find new and creative uses of resources and interrupt current processes and activities that do not advance the practice (Alsharif, 2019).

While new innovations can certainly lift the pharmacy profession to new heights, insensitive and fast innovation can alienate current practitioners, new graduates, the public, insurance companies, other members of the healthcare team, and other key stakeholders. Changes in a profession such as pharmacy does not mean concurrent changes in all the facets of the society where that innovation affects. Pharmacy, over the years, as a profession is used to changes in the industry and even in the market place. The main challenge is to be able to position new graduates in the line of the new invocations when they come out of school.

It should be noted that traditional community and hospital pharmacies have the comparative advantage of their physical presence and real estate in various neighborhoods, with deep roots in the community or in the hospital. The group of pharmacists in community and hospital pharmacies will not face serious challenges as those in other sectors of the profession such as those in industry and teaching professions. For some people in the teaching profession they need to continue to update their knowledge to be able to produce pharmacists that are capable of facing the challenges in the job market. For instance, many of the lecturers may have graduated at a point when no one was interested in genomics, proteomics, robotics and other forms of advanced research in pharmacy. They will need continuing education to be to meet the needs of their students. Thus the challenge of their teachers automatically becomes the challenge for the young graduate who, if not properly groomed, will face more daunting challenges in the workplace.

Many young pharmacists think that they can get all the knowledge from the Internship period when they graduate newly. That is only partially true as what is thought in the classroom is critical during pupilage. It should also be noted that the issue with which to assimilate the new knowledge depends on the area of practice. Things may be easier in the community and hospital pharmacies than in the industry and research areas. It is also advised that during internship, the pupil pharmacist should rotate to various areas of practice as doing this graduate training in a single setting leaves the pharmacist not well prepared for the job market.

The other complex area for the pharmacist is research where new ideas and technologies are introduced from time to time. In the late 1980s, it could take up to 15-20 years for a life span of knowledge to change. Presently, it is less than 2 years. Today we are talking about more advanced areas in such areas as artificial intelligence (AI). The good luck is that a lot of information is also available for the pharmaceutical researcher such as Internet of Things (IoT). In fact, the information available to the pharmaceutical researcher these days is limitless. The young pharmacist that wants to venture into research has a myriad of information at his fingertips.

The major challenge is with those working and researching in the Developing World as they usually do not manufacture the pieces of equipment that are used for research. As new product lines come into the market, the production lines in the parent companies overseas change and as such when they need new parts or even buy new equipment they also must change alongside their overseas counterparts.

Current Status of Disruptive Technology in Pharmacy Education and Practice

The use of digital technologies in pharmacy practice and education presents pharmacists with the biggest challenges in the profession's history. Digital technologies have considerably expanded

pharmaceutical care and pharmacy education globally and will continue to be used in patient care and the teaching-learning process, respectively (Oliveira et al., 2022).

Community pharmacy had a growing role as patients' initial point of contact with the healthcare system during the COVID-19 epidemic when they had health issues or needed trustworthy information and guidance (Bukhari et al., 2020; Li et al., 2021). Despite the pandemic's continuous face-to-face interactions at pharmacies in the community, the necessity for social isolation caused disturbing changes in patient care procedures. As a result, teleconsultations using the Internet and other communication tools like phones and computers became more popular for reaching out to patients who are separated by location. (Bukhari et al., 2020; Cadogan & Hughes, 2021)

There have been studies on the use of digital technologies to deliver clinical pharmacy services like chronic illness management, health education, and prescription review (Cadogan & Hughes, 2021; Dawoud, 2021; Okoro, 2021). For instance, video conferencing is being used in pharmacy for management, training, and educational purposes. The mobile phone has evolved from being just a dial and talk tool to a multimedia access tool. In order to enable remote monitoring and therapy, medical devices are being connected to phone lines, and call centers are now offering drug consultation, prior authorization, refill authorization, and formulary compliance monitoring (Cadogan & Hughes, 2021)

There are more unmet expectations for the traditional health care system as a result of consumer empowerment brought on by the Internet and their expectations for accessibility, speed, and convenience (Baines et al., 2020). Many pharmacies and healthcare organizations have websites for both organization and individual practitioners because online pharmacies and healthcare organizations are drawing the greatest attention. In addition to teleconsultations, other digital technologies being introduced into pharmacy practice include (Baines et al., 2020; Cavaco, 2021),

1. Robotic and barcode drug dispensing

2. Patient electronic health records

3. Computer-based decision support systems

4. Artificial intelligence in alert systems for drug-drug interaction checkers and drug design and development.

5. Big data

In the pharmaceutical industry, advanced Process Analytical Technology (PAT), which claims to give process and product quality data in almost real time, was introduced to pharmaceutical manufacturing during the third industrial revolution. Model-based or Quality by Design (QbD) processes, which seek to regulate target product quality profiles within a specified range of quality variables, were also advanced by the third industrial revolution. However, more technological developments are required to obtain deeper process knowledge and real-time analytics to enable better real-time release testing with high levels of product quality assurance, especially for biotechnology goods, in order to realize the full promise of PAT and QbD (Arden et al., 2021).

Disruptive Technology in Pharmacy Education

The Accreditation Council for Pharmacy Education (ACPE Standards, 2015) standard 4.3 makes emphasis on innovation as an important outcome in the process of personal and professional development of pharmacy graduates, stating that the pharmacy graduate, “is able to engage in innovative activities by using creative thinking to envision better ways of accomplishing professional goals”. The ultimate goal is to change the current status of education and practice and create new job opportunities and practice models for pharmacists to improve the health of the society (Accreditation Council for Pharmacy Education, 2015)

The new wave in pharmacy education necessitates the training of disruptive educators who can use teaching methods tailored to the digital environment and educational processes appropriate for incorporating and encouraging the use of efficient disruptive technologies, such as Internet of Things (IoT), 5G mobile network, artificial intelligence, virtual and augmented realities, big data, and wearable technology, for students who are digital natives (Baines et al., 2020; Oliveira et al., 2022) Enhanced

capacity for self-directed learning with an emphasis on employing technologies geared at care practice, such as digital serious games, is another factor to take into account while training the new generation of digital-native pharmacists (Smith & Benedict, 2015).

Need for New Compulsory Courses in Pharmacy Education

There is the need for new courses to be added to the Pharmacy courses. A few years ago, I did a postdoctoral fellowship in computational chemistry at the University of Dusseldorf in Germany. I was a greenhorn because I had not been exposed to it here in Nigeria. The research I did there got me some publications (Adikwu and Hoeltje, 2001; Adikwu and Hoeltje, 2002). When I returned to Nigeria, I gave a topic in that area to one of my students for his master's degree research, to predict drug absorption through molecular orbitals using computational tools. When he finished his research, I could not get an external examiner for him because the area was not being taught in Nigeria. That makes it imperative for the introduction of such courses where they are not being taught if Africa.

Thus, computational tools should be included in Pharmacy curriculum to strengthen the educational component of various forms of disruptive technology. The following specific curriculum reforms may be proposed.

i. There should be new compulsory courses Pharmacy Informatics and Data Analytics for Pharmacists. Presently only simple computational studies for life sciences are taught to Pharmacy students.

ii. To enhance the understanding of various disruptive technologies, interdisciplinary teaching in engineering and life sciences and computing should be carried out.

iii. Similarly, there should be upskilling programs for the educators. These are the lecturers that teach the students through continuous professional development. This should be part of the mandatory professional development programmes that is conducted in various countries after graduation from school and during professional practice.

iv. Various pedagogical tools should be taught to students. Such tools should be in the areas of virtual reality (VR) and augmented reality (AR) as well as various simulation software. Details about Artificial Intelligence (AI) should be thoroughly taught to the students.

Internet of Things (IoT) in Pharmacy

Internet of Things (IoT) has been identified as a disruptive technology because of its potential to penetrate every aspect of our lives and generate new business opportunities. The pharmaceuticals and life sciences industries are generally requiring quite advanced technology to compete with the worldwide market share (Alagarsamy et al., 2019). Pharmaceutical and life science companies now invest more time, effort and money into digitalization of their business than ever before. It was estimated that by 2020, there would be 50 billion connected devices, and in another five years, 80 % of companies were expected to utilize IoT in their digitized firms (Alagarsamy et al., 2019). IoT revolutionizes the pharmaceutical sector by providing and automating pharmaceutical manufacturing, discovery of drugs and remote monitoring of patients and more. Digitization holds tremendous potential to help pharmaceutical companies address various challenges. Pharmaceutical companies are using machine learning to analyse data that they have gathered on patients to be able to design treatments that are more personalized in order to have each treatment be more effective and come with fewer side effects, so that patients are happier with their treatment.

In healthcare practice, IoT can automate patient care workflow with the help healthcare mobility solution and other new technologies, and next-gen healthcare facilities. IoT in healthcare enables interoperability, machine-to-machine communication, information exchange, and data movement that makes healthcare service delivery effective.

Artificial Intelligence (AI) in Pharmacy

Pharma companies around the world are leveraging advanced machine learning (ML) algorithms and AI-powered tools to streamline the drug discovery process. These intelligent tools are designed to identify intricate patterns in large datasets, and hence, they can be used to solve challenges associated with complicated biological networks.

During the peak period of the pandemic of the corona virus (COVID-19), AI was most useful to avoid direct contact with the patient. I am sure this role will continue to grow. Apart from the pandemics of the future, bedside dispensing will continually become an essential aspect of AI whereby drugs can be dispensed even at midnight when nurses and/or doctors should be asleep. That will become a leading role in translational pharmacy.

Artificial intelligence (AI) will transform the pharmaceutical industry in the coming years by delivering productivity improvements and efficiencies across the entire pharma value chain, says GlobalData, a leading data and analytics company (globaldata.com, 2021). GlobalData report for 2021 reveals that AI is expected to be the emerging technology that will have the greatest impact on the pharmaceutical industry in 2021, as indicated by 36 % of 198 surveyed pharmaceutical industry professionals (globaldata.com, 2021). In drug discovery, many pharmaceutical companies have partnered with AI vendors or start-ups to take advantage of their technology and expertise. Examples of leading AI vendors operating in this space include Exscientia, Atomwise, Recursion Pharma, Insilico Medicine, and BenevolentAI. Pharma companies are also beginning to set up more in-house capabilities, as seen by GSK and Novartis. Additionally, in February 2020, Eli Lilly's Olumiant (baricitinib) was identified in just three days by UK-based start-up BenevolentAI as having the potential to treat COVID-19, and it received Emergency Use Authorization (EUA) by the Food and Drug Administration (FDA) in November of 2020.

Using AI in clinical operations has made it simpler for healthcare experts to access data for millions of patients and provide seamless treatment. Machine learning has made it simple for pharmaceutical companies to generate and track relevant data, which is then used for research and development processes.

Similarly, AI can assist in structure-based drug discovery by predicting the 3D protein structure because the design is in accordance with the chemical environment of the target protein site, thus helping to predict the effect of a compound on the target along with safety considerations before their synthesis or production.

Pharmacists should use scientific approaches to determine the degree to which AI is used to automate specific medication-use tasks (ashp.org, 2021). Full automation using AI should be reserved for algorithmic tasks for which it is demonstrated that AI performs as well or better than pharmacists. AI of proven value should be adopted and used so that pharmacists can make better decisions and focus their expertise on solving new and confounding problems for patients, families, and organizations. Pharmacists are uniquely positioned to be key contributors and domain experts in the advancement of AI in healthcare. Pharmacists should lead the design, implementation, and ongoing evaluation of AI-related applications and technologies that affect medication-use processes and tasks. Pharmacists should define appropriate medication-related use cases for AI-enabled technology and provide foresight for anticipated future applications. It is also important for pharmacists to assist in validating AI for clinical use. At a minimum, AI should be evaluated for accuracy and interpretability. In addition, pharmacists should be prepared to adapt to AI through education and continued engagement.

From the above information on Internet of Things (IoT) and Artificial Intelligence (AI), it has become much more critical, in this era, than before that pharmaceutical education should have courses on computing. There are various forms of informatics that are purely computer based. Thus, the regular "introduction to computer" courses taught to pharmacy students is no longer sufficient for this age.

Blockchain Technology

Blockchain is a specific type of database. It differs from a typical database in the way it stores information; blockchains store data in blocks that are then chained together. As new data comes in it is entered into a fresh block (Browning, 2020).

The mechanics of blockchain are extremely complex, although, the basic idea is simple: to decentralize the storage of data so that such data cannot be owned, controlled or manipulated by a central actor (Chatham House Primer, 2021). The recent surge in and subsequent collapse of the value of Bitcoin has brought renewed attention to the blockchain architecture that underpins cryptocurrencies. Blockchain's

uses, however, go far beyond virtual money. The technology could change the way that ownership, privacy, uncertainty and collaboration are conceived of in the digital world, disrupting sectors and practices as diverse as financial markets, content distribution, supply chain management, the dispersal of humanitarian aid and even voting in a general election.

Blockchain can be very useful in pharmaceutical practice. To prevent counterfeit drugs from being distributed, a system is needed that can trace and track drug delivery at every stage. Blockchain is the latest innovation that can handle the complex supply chain and track the product at every stage. Blockchain was designed to store the transactions log for Bitcoin.

Pharmaceutical companies have struggled for years to track their products throughout their supply chains, making it possible for counterfeiters to introduce fake drugs into the market.

To counteract this problem, a new system to trace and track drugs is needed. Researchers think that blockchain may provide the technological foundation for such a system because it can successfully track drugs and help prevent the circulation of fake ones. Before diving into how blockchain could become a solution, we must examine the source of the problem.

The Need to Integrate these Technologies into Learning

Counterfeit Medicine

Counterfeit drugs are defined by the World Health Organization (WHO) as "drugs that are manufactured fraudulently, mislabeled, with low quality, hiding the source detail or identity and do not follow the defined standard" (Burci, 2013). While these drugs may contain some genuine ingredients, they may also contain toxic ingredients at the production level. If consumed, these drugs can cause serious health problems. Sometimes, the manufacturers of counterfeit medications use the logos of reputable companies to allow their product to enter the market. Although this is a worldwide problem, developing countries are disproportionately affected by this issue.

Counterfeit drugs are distributed throughout a very complex network, making them difficult to detect and remove. To prevent counterfeit drugs from being distributed, a system is needed that can trace and track drug delivery at every stage. Blockchain is the latest innovation that can handle the complex supply chain and track the product at every stage.

Other Blockchain Applications

Blockchain has a great future and potentials and is becoming increasingly popular**.** Blockchain was designed to store the transactions log for Bitcoin. It provides a rich ledger software to store data records, which are transaction logs arranged in several blocks. A blockchain system collects data related to the time, date, price, and participants involved in each transaction. When one block of information changes, all the pieces update accordingly, giving up to date information for every transaction. When applied to the pharmaceutical supply chain, blockchain offers an electronic ledger where everyone in the network can see and validate transaction information.

To create a secure drug supply-chain management system, the use of blockchain with Hyperledger fabric was proposed. This ledger software is capable of monitoring and tracking all parts of the drug delivery process. The Hyperledger fabric can configure multiple world state databases to maintain the set of current values, and, when applied to the pharmaceutical world, it enables medicine to be accurately traced regardless of where it is in the world.

The Drug Supply-chain Management and Recommendation system (DSCMR)

Researchers have proposed a blockchain and machine learning-based drug supply-chain management and recommendation system (DSCMR) to combat counterfeit drugs. First, we must distinguish between the two complementary components of this system — the drug supply management system and the recommendation system. In the drug management system, users can track the drug at every step, make orders, update orders, and more. The recommendation system works to recommend the best medicine to pharmaceutical company customers through the use of the Ngram and LightGBM machine learning-based modules.

The Drug Management System

With the drug supply-chain management system, users can perform various transactions such as checking drug information, tracking and tracing orders, updating records, etc. The system's users can include patients, doctors, manufacturers, distributors, pharmacies, and hospitals, and more. Data related to the various users are stored within the blockchain system.

Each user is provided with a web application where they can perform their transaction and communicate with the blockchain network, and each user can track the status of drug delivery. Furthermore, all users must receive permission to check the complete details of drugs. They will use the client application to log in and perform their respective transactions. This works to increase the levels of security along the pharmaceutical supply chain.

To submit a transaction proposal, users must submit a request using their credential. The request, if valid, is sent to peer nodes in the system to be reviewed and approved. These peer nodes work to examine the proposal and give approval if it is valid and fulfills the smart contract criteria. They also work to validate the results of the transactions and record them in the ledger. Once this has been complete, the ledger updates all data for everyone to see.

The Drug Recommendation System

The drug recommendation system, which was created with both natural language processing and machine learning techniques, works to recommend the best medicine to pharmaceutical company customers through the use of the Ngram and LightGBM machine learning-based modules.

A public drug review dataset based on the reviews of drug users was used to train the models of this system and to predict the best and most effective drugs in the pharmaceutical industry. The review data include information about any side effects, benefits, and comments from customers received in the client application mentioned earlier.

The use of smart contracts is also implemented to limit the number of individuals involved in a certain transaction. A smart contract aims to provide the parties involved a way to exchange information, property, or even money without the use of a third-party agent or broker. It is typically lines of computer code that enforce the agreement made without using a middleman. In the proposed network, Java and Node.JS were used to write smart contracts. These smart contracts are stored in the distributed ledger of the blockchain network, where they are protected from tampering or possible deletion (Adikwu, 2022).

Big Data in Pharmacy Education

With the large amount of available data and data sources known as "big data," modern technologies enable teachers and students to access knowledge from around the world (Ma et al., 2015). Students and researchers also have more data sources to make better research and enhance their learning. These data are all obtained through online courses or other learning systems that rely on technology thus making learning more personal. In this instance, data analysis can help students learn more effectively and direct them toward outcomes that are more effective than those of traditional education (Khan & Alqahtani, 2020).

Pharmacy schools can have access to big data resources from the digitalization of pharmacy recruitment, admissions, and educational program performance and outcome information that can help direct recruitment and selection of the most suitable candidates for admission based on pooled student performance data (Baldwin et al., 2015).

Big data obtained from employers, graduates, pharmacists, preceptors, other health professionals, and the general public could promote a more clearly defined standard for professionalism and help pharmacy students and college advisors make career focus and pathway decision (Baldwin et al., 2015). Additionally, big data analysis has a significant impact on how colleges evaluate curricula and student outcomes, as well as how successful researchers are produced in graduate research programs (Khan & Alqahtani, 2020).

Three-Dimensional (3D) Printing in Pharmacy Practice

Three-dimensional (3D) printing, also known as additive manufacturing, which employs a computerized model to guide the layer-by-layer production of a 3D object, is one technique that might

meet the need for personalized therapeutics. The pharmaceutical industry could be significantly disrupted by 3D printing technologies because they could enable the on-demand production of products with individualized dosages, drug combinations, geometries, and release characteristics (Jamróz et al., 2018). These capabilities are not currently available from traditional manufacturing techniques like tableting and encapsulation. Since the US Food and Drug Administration (FDA) authorized the first 3D-printed drug, Spritam® (a levetiracetam tablet), in July 2015, the number of articles explaining the 3D printing of drugs has grown over time. There are now a number of examples of 3D-printed medical products available on the market, ranging from polypills like guaifenesin and the multi-active combination of nifedipine, captopril, and glipizide to drug delivery devices for progesterone and pseudoephedrine (Jamróz et al., 2018).

There are five main methods currently employed in the 3d printing of these pharmaceuticals which are (Cui et al., 2021):

1. Extrusion molding printing (EMP)
2. Drop on powder printing (DOP)
3. Selective laser sintering (SLS)
4. Stereolithography (SLA)
5. Electrohydrodynamic 3D printing (EHD)

One of the most used methods is EMP, which is further separated into semisolid extrusion molding technology (SSE) and fused deposition modelling (FDM) (Cui et al., 2021). SSE also known as pressure-assisted micro syringe extrusion technology (PAM) uses pressure to force a paste through a print head that is attached to a syringe and deposit material on the printing platform while FDM involves heating drug-loaded polymers to a semifluid state, extruding them through a printing nozzle, and letting them solidify on the printing platform to produce the desired output. Binder jetting, also known as DOP printing, employs droplets of a binding agent to bind powder that has been layered on the build platform into the final product (Cui et al., 2021). SLS is a different type of powder-based 3D printing method that uses a CO_2 laser to selectively sinter (heat to form solid material) certain areas of layers of powders (Cui et al., 2021; Jamróz et al., 2018). When performing SLA, a form of vat photopolymerization1, UV lasers are used to repeatedly layer-polymerize photosensitive resins until the required dosage form is produced. Using digitally controlled material deposition to pattern fibrous materials and create medicinal products, EHD is a new technology. It allows for fibre engineering on a micro- to nanoscale, enabling the creation of complex structures with specific geometries and well-ordered patterns (Cui et al., 2021).

The competitive advantage 3-D printing has over other methods of dosage form preparations is that it allows the preparation of orally disintegrating formulations, compound formulations, drug loading formulations, tailored dose formulation and personalized and innovative oral delivery devices (Cui et al., 2021) and creating tablet formulations with multiple active ingredients with varied characteristics and dissolution profiles (Jamróz et al., 2018).

Quantum Computing in Pharmacy Practice

A paradigm of computation called quantum computing uses quantum systems to process information. Quantum bits (qubits) are two-level quantum systems that are typically used to encode information in this situation (Pyrkov et al., 2023). Existing quantum algorithms have applications in biology and drug research; they can analyse linear systems and ground-state computations more quickly and offer opportunities for more precise predictions of drug-receptor interactions and protein folding (Pyrkov et al., 2023). Calculating the computational cost of a quantum algorithm is the most crucial metric for its development. These projections outline the resources (qubits and run-time) needed for a particular problem to be solved using quantum computing (Kyoseva et al., 2023). Additionally, rapid advancements in quantum machine learning (QML) techniques can strengthen traditional AI strategies for generative chemistry for example the Chemistry 42 Platform by in silico medicine (Pyrkov et al., 2023). Generative chemistry relies on generative modelling and leverages machine learning and cheminformatics tools as its foundation, to speed up the drug development process. (Pyrkov et al., 2023)

Algorithms for quantum simulations, algorithms for optimization, and the theoretical capacity of quantum computers to process big data and run machine learning algorithms significantly more quickly than their classical equivalents could advance various fields ranging from protein structure prediction to network analysis (Pyrkov et al., 2023). Researchers may be able to compute the wave functions of several groups of molecules when powerful quantum computers become accessible and then apply quantum machine learning algorithms to these wave functions. Pharmacokinetic properties could be predicted by using quantum machine learning methods on the findings of quantum computations (Kyoseva et al., 2023).

Challenges Facing the Adoption of these Disruptive Technologies in Pharmacy Education and Practice

As the pharmacy industry leverages enabling technology more and more, pharmacists may find themselves at a career crossroads: either increase the scope and value of their position or run the risk of being replaced. In the not-too-distant future, algorithms may handle most clinical changes, 3D printers may produce combination medicines, and robots will likely administer patients' drugs. Lower-skilled workers like pharmacy technicians will be able to perform simple tasks like visual verification with the help of augmented reality (AR) technologies, such as smart contact lenses (Antwerp et al., 2018).

The employment of digital technology in various nations is now hampered by the availability of energy and the Internet. As a result, those who are socially and economically marginalized, especially in developing nations, may not be able to access health services using digital technologies (Oliveira et al., 2022). There is also the issue of digital inequality which is the gap in the knowledge and the capacity to use digital and information technology among people. Digital inequality can be caused by low levels of literacy, access issues to digital technologies, or a lack of active engagement in the digital society. As a result of the digital inequality that exists across different demographics, the adoption of technologies in pharmacy practice will happen at varying "speeds" across the globe (Oliveira et al., 2022).

For some of these disruptive technologies like Augmented Reality, Quantum Computing and Artificial Intelligence, there is the issue of poor validation of clinical efficacy, and these technologies are expensive and not easily accessible especially in the developing countries. There are very few pharmacists who have gained knowledge on the use of some of the available technologies like artificial intelligence while many still battle with its acceptance (Lee Ventola, 2019). The common challenges associated with three-dimensional printing of pharmaceutical dosage forms are the lack of availability of excipients and the poor development of printing software and equipment (Mohapatra et al., 2022). Insufficient government support is a major challenge faced by many pharmacists especially in developing countries (Anklam et al., 2022; Liang et al., 2022; Mohapatra et al., 2022).

Professional factors that act as a challenge to the adoption of these disruptive technologies include (Alsharif, 2019):

1. Insufficient education and training
2. A lack of collaboration between academia and industry or with healthcare organizations
3. Strict accreditation requirements or regulations that does not make room for innovation
4. Opposition from other healthcare organizations and professionals
5. The perception among stakeholders that pharmacists only dispense medicine

Other barriers include the lack of appreciation for the role of present practitioners, time and financial constraints and the absence of incentives for those who try to engage in pharmacy practice using the available disruptive technologies (Alsharif, 2019).

Current Happenings in Some African Countries

In various African countries, there are lots that are currently happening. In South Africa's pharmacy schools are now integrating digital health in their curriculum (Mosiane et al, 2022). Similarly, there is a great progress in Egypt's in pharmacy digitalization (Egypt Healthcare Authority, 2024). The focus of the changes was to introduce computational algorithms into the Pharmacy curriculum. These

initiatives include the automation of pharmacies, digital integration, and the implementation of green pharmacy practices across all facilities within the universal health insurance system governorates. Additionally, the roadmap emphasizes the expansion of drug information centres, which will contribute to the preparation of a drug compendium, as well as regular training programs aimed at developing pharmacists' skills in evidence-based practices and emerging therapies. When these digitisations are full implemented across many African countries it will help in the battle against counterfeit and spurious medicines such as the chronic cases of drug faking in Nigeria. The African Union (AU) has taken the interest in digitisation further by making pronouncements on Science, Technology and Innovation Strategy for Africa (STISA), (2024). On the Wings of Innovation, the AU STISA-2024 places science, technology and innovation at the epicentre of Africa's socio-economic development and growth. All these changes will enhance the digitisation of African education be it in Pharmacy, Engineering and other fields of study. Thus, making the need for retooling the curriculum more imperative.

Conclusion

Over the last few decades, technology has undergone a tremendous amount of change, which has transformed our lives and allowed us to advance alongside it. A disruptive technology is one that has fundamentally changed how organizations, customers, and entire industries function. Disruptive technologies including quantum computing, artificial intelligence, Internet of Things, augmented reality, virtual reality, Nanotechnology, 3D printing, 5G interconnectivity and big data have made various impacts in different fields. The pharmaceutical industry is not exempted from the impact of these disruptive technologies.

Disruptive technology has its role to play both in pharmacy education and in pharmacy practice. Recent advancements in pharmacy education requires the training of educators who are adept at adapting their lesson plans to the digital age and educational procedures suitable for embracing and promoting the effective use of disruptive technologies. In pharmacy practice, Pharmacists are anticipated to provide better and more sophisticated healthcare services as disruptive technologies are continuously being integrated into pharmacy practice.

Disruptive technologies have found great applications in both pharmacy education and practice. The use of smart classrooms (involving Internet of Things, Artificial Intelligence, Virtual Reality and Augmented Reality) to enhance educational activities and personalized student learning and the use of Internet of Things and big data for better organizational processes are some major applications of disruptive technology in pharmacy education.

In pharmacy practice, the use of disruptive technology has spread across the different aspects of pharmacy practice including pharmaceutical manufacturing, pharmaceutical supply chain, community and hospital pharmacy and pharmaceutical research and development. In pharmaceutical manufacturing, disruptive technologies such as artificial intelligence, Internet of Things, Extended reality (Augmented reality, virtual reality and mixed reality), quantum computing, 3D printing and nanotechnology are employed. These technologies play important roles in reducing errors in production, advancing the manufacturing environment, ensuring ease of production processes, making complex computations easy and advancing drug delivery systems.

In pharmaceutical supply chain, blockchain technology coupled with artificial intelligence and Internet of Things has found immense application in tracking pharmaceutical supplies and detecting fake products. In pharmaceutical research and development, the use of quantum computing, artificial intelligence and big data has made it easier to discover new drug molecules and modify existing drug molecules. This has stepped up the rate at which cure for various diseases and disorders can be found by decreasing the time spent in pharmaceutical research process.

Artificial intelligence (involving algorithms and robotics), augmented and virtual reality, 3D printing, nanotechnology, big data, quantum computing, internet of things and 5G interconnectivity have made community and hospital pharmacy practices move towards delivering better patient cantered care. This is achieved through the use of these disruptive technologies in improving patient adherence to medications, dispense personalized medications, use targeted drug therapies, improve patient health education, enhance service delivery and improve clinical decisions.

In conclusion, the opportunities offered by disruptive technologies in pharmacy education and practice have led to significant transformations in the pharmaceutical sector. Despite the challenges associated with these technologies, the impact of disruptive technology both in pharmacy education and pharmacy practice is expected to become even better in the future. Thus, the students need to be better prepared while in school to be able to deal positively with these challenges.

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