

A REVIEW ON THE IMPACT OF VIRTUAL REALITY (VR) AND AUGMENTED REALITY (AR) IN PHARMACY**Satyajit Sahoo^{1*}, Sohan Patel¹, Rashmi Rajeghorpade¹, Archana Kaushik¹, Mehvish Diwan¹****Pioneer Pharmacy College, Vadodara, Gujarat, India - 390019***Corresponding Author's E mail: satyajitsahoo@rediffmail.com

Received 11 June. 2025; Revised 17 June. 2025; Accepted 1 July. 2025, Available online 10 July. 2025



Cite this article as: Sahoo S, Patel S, Rajeghorpade R, Kaushik A and Diwan M. A Review on the Impact of Virtual Reality (VR) and Augmented Reality (AR) in Pharmacy. Asian Journal of Pharmaceutical Education and Research. 2025; 14(3):104-126.

<https://dx.doi.org/10.38164/AJPER/14.3.2025.104-126>

ABSTRACT

The integration of Virtual Reality (VR) and Augmented Reality (AR) in pharmacy is transforming education, patient engagement and medication management. VR provides immersive simulations for pharmacy students, enhancing their understanding of complex concepts, drug interactions, and patient scenarios. This experiential learning approach fosters critical thinking and clinical skills. AR, on the other hand, offers real-time, interactive overlays of information, assisting pharmacists in visualizing medication data and patient history, thus improving accuracy in dispensing medications. Both technologies enhance patient education by allowing patients to visualize treatment effects and medication administration procedures. The potential for VR and AR to streamline workflows, reduce errors, and improve patient outcomes makes them invaluable tools in modern pharmacy practice.

Keywords: Virtual reality (VR), Augmented reality (AR), pharmacy education, patient engagement, clinical training, surgery.

INTRODUCTION

Advancement in the field of science and technology Virtual Reality (VR) and Augmented Reality (AR) came into existence. It is used to reshape educational methodologies, patient interactions and operational practices within the pharmacy sector¹.

VR immerses users in computer-generated environments, enabling them to engage in simulations that replicate real-world scenarios. It is beneficial for pharmacy students, allowing them to practice skills and make decisions in a safe and controlled setting. By experiencing complex patient interactions and medication management scenarios through VR, students can enhance their clinical competencies and critical thinking skills².

In contrast, AR overlays digital information on to the real world, providing pharmacists and patients with real-time insights and interactive data. This technology can enhance the medication dispensing process, improve patient education, and streamline workflows. For example, AR applications can visualize drug interactions or demonstrate proper medication administration techniques, fostering better understanding and adherence among patients^{3,4}.

Now-a-days computers, smart phone, televisions have become a part of life⁵. Virtual reality and augmented reality are two technologies changing the way we use screens creating new and exciting interactive experiences. Virtual reality uses a headset having a screen that displays a virtual environment^{6,7}.

AR delivers visual elements, sound and other sensory information to the user through a device like a smartphone, glasses or a headset. This information is overlaid onto the device to create an interwoven and immersive experience where digital information alters the user's perception of the physical world. The overlaid information can be added to an environment or mask part of the natural environment^{8,9}.

Surgeons are increasingly using virtual reality (VR) for training, surgical planning, and even in the operating room. VR provides a safe, cost-effective way to practice complex procedures, access 3D anatomical models, and enhance collaboration among surgical teams. AR focuses on augmenting the physical world with digital artifacts, images, videos, or experiences overlaid with computer-generated images (CGI) and 3D models. VR aims to create a virtual experience with headsets and tracking to place the user in a different world. Thus, it is widely applied in recent years^{10,11}.

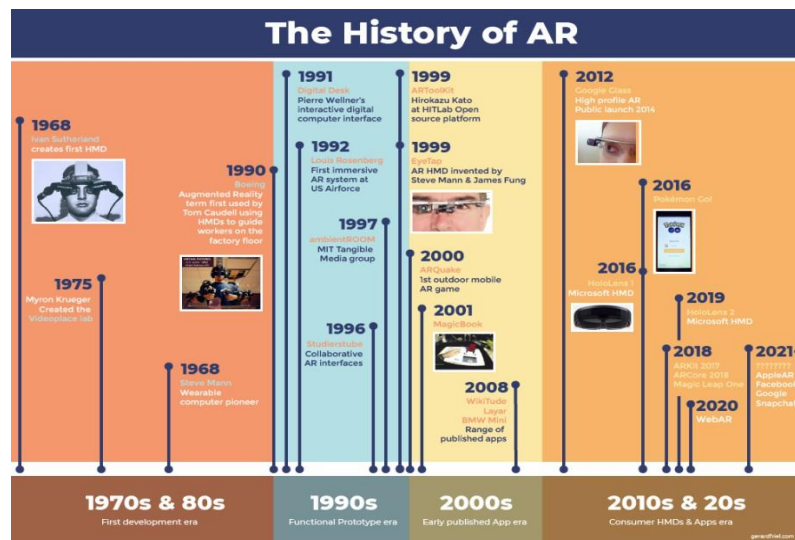


Fig. 1: History of AR

Applications of AR VR in Pharmacy^{12,13,14}

- **Simulation Training:** VR provides a risk-free environment for pharmacy profession allow them to engage in realistic pharmacy scenarios. These simulations cover various clinical situations, from managing a pharmacy to interacting with patients in a hospital setting. Reported that students using VR felt better prepared for real-life clinical situations, attributing this to hands-on practice without real-world consequences.
- **Interactive Learning Modules:** AR applications like Merge Cube and Google Expeditions provide interactive experiences. We can visualize pharmacokinetic processes and drug interactions in a 3D format. Also, it is helpful to understand complex pharmacological concepts compared to those using traditional textbooks.

Patient Counselling and Education

- **Visual Aids for Patients:** AR applications help pharmacists to explain the effectiveness of medicines to patient. For example, using AR, a pharmacist can show a patient a 3D model of their medication, highlighting how it works in the body.
- **Enhancing Medication Adherence:** VR can simulate real-life patient scenarios. It supports pharmacists practice counseling techniques. It allows pharmacists to refine their communication skills, which can lead to better patient adherence to medication regimens.

Medication Management

- **Real-time Drug Interaction Visualization:** AR applications can overlay information on medication labels during the dispensing process. For example, using a smart phone or smart glasses, pharmacists can see alerts about potential drug interactions or allergies based on the patient's profile. This capability enhances safety and accuracy in medication management.
- **Streamlining Inventory Processes:** VR can facilitate virtual audits of pharmacy inventory, allowing pharmacists to conduct assessments without physically counting Items. It saves time and reduces discrepancies in inventory management.

Clinical Practice Enhancements

- **Telehealth and Remote Consultations:** VR can enhance telehealth experiences by creating virtual consultations where pharmacists and patients interact in a 3D space. This immersive environment can make remote interactions more engaging and personal, fostering better relationships.

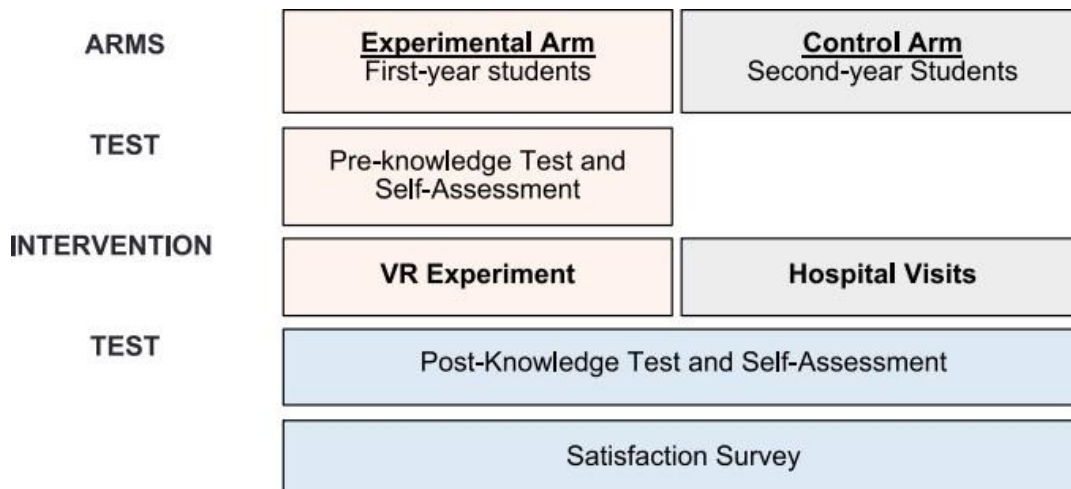
- **Research and Development:** AR and VR can assist researchers in drug development processes. It helps researchers to visualize molecular interactions in a 3D space.

METHODS

1. Study sample and design

A quasi-experimental study was conducted at King Saud University, College of Pharmacy, to assess the impact of using virtual reality technology. All first-year pharmacy students who are currently enrolled in the IPPE-1 course were considered to be experimental arm. Second- year pharmacy students who completed the traditional IPPE-1 course were identified as the control arm. During the traditional IPPE-1 course, students conducted a hospital visit to orient them to the different pharmacy settings. In contrast to the experiment, the VR technology was implemented prior to any hospital visits¹⁵.

Procedure



The VR experiment was conducted at the pharmacy simulation abusing VR headsets. A 360-technology camera was used to capture three different settings in King Saud University Medical City consisting of fifteen-hundred-bed. Three videos were filmed in settings including in patient pharmacy, out patient pharmacy and counselling clinic. Each video was 2 to 3 minutes long and narrated with a detailed description of each setting. For example, in the out patient pharmacy video, the narrator focused on the environment and the dispensing process. Headings were added to the video pointing to the narrated subjects, e.g., unit dose system¹⁶.



Figure 2: Pharmacy simulation experience

Questionnaire and knowledge test

A test containing a total of 10 questions was created to measure the students knowledge of different pharmacy settings and mapped to the IPPE-1 learning outcomes. First-year pharmacy students were expected to understand the roles, responsibilities and equipment in each training setting (out-patient, in-patient, and clinic). The test was administered before and after the experiment to ensure accuracy and validity and to measure first-year students knowledge gain. Additionally, a five-point like scale satisfaction survey was distributed following the experience among both arms to assess the students satisfaction with the time, approach, content and environment of the experience. A pilot was done prior to implementation to ensure the validity and reliability of the testing tools¹⁷.

Statistical analysis

All statistical analyses were performed using STATA 15.1 (Stata Corp LP, College Station, Texas, USA). A paired t-test was performed for numerical data to analyse pre- test vs post-test scores. Furthermore, an unpaired t-test and Chi-Square test for numerical and ordinal data were used to compare 1st year and 2nd-year satisfaction survey scores¹⁸.

AR and VR In Healthcare:4 Use Cases with Real-Life Examples

Use Case 1. AR for 3D Body Mapping

Performing surgery is always risky. Often, problems arise from not having a clear view of a patient's internal organs. MRIs and X-rays help doctors to navigate, but the picture only becomes clear during the surgery itself. Sometimes, this can lead to surgical errors and patients may die. Thus, surgeons have to face legal disputes, fines, and loss of reputation. So to avoid these scenario, AR and VR came into existence. First, the solution studies MRI scans. Then, it processes the information obtained from the scans and presents it in 3D body layers. Doctors can examine even the smallest 3D body section together with organs, veins, arteries and bones. They can also spot tumors, inflamed spots etc. These tools supports the doctor to perform accurate surgery ^{19,20}.

Real-Life Example: Reconstructing 3D Body Sections

Lowa Spencer Hospital wanted to make medical procedures safe and achieve greater accuracy in diagnostics and surgery. To achieve this, they tried an AR solution in their day-to-day treatment activities that was designed by a US startup. The AR tool is based on simultaneous localization and mapping (SLAM) technology. To see inner organs, doctors just need to direct the smart phone toward a specific area of the patient's body. They can virtually map the body, including its organs, veins, and any tumors. The resulting accurate body scans enable medical manipulations. These have helped increase biopsy success by 50% and aneurysm surgeries by 30% ²¹.

Use Case 2. AR for Maintenance in Medical Labs

Modern medical laboratories are equipped with advanced microscopes, cell counters, and other high-precision equipment. But, like all hi-tech equipment, lab tools are prone to breakdowns. This equipment is so complicated and tends to be so hard to fixed in labs have to call out third-party experts to mend it. This may take days or even weeks, costing a fortune.

AR can help in-house lab technicians conduct maintenance and repair procedures quickly and autonomously. Using AR helmets and glasses, engineers can conduct live video streams with remote experts. Experts guide an engineer through the repair process, providing instructions that make it smooth and quick.

The technology can also help technicians to fix the equipment on their own using AR instructions. A technician would point an AR-based device at a broken piece of equipment so that it immediately

presents 3D visualizations of its inner structure. Then, it superimposes simple step-by-step maintenance and repair manuals. These help technicians fix equipment even without remote assistance.

Real-Life Example: Fixing Lab Equipment

AR remote assistance to fix and maintain their medical test equipment. Before, they had to rely on experts who came onsite to resolve problems. This is time consuming and expensive. Engineers can connect with remote experts via AR glasses and get the technical guidance they need. As a result, their on-site technicians can now fix almost any failure on their own, all in a matter of hours—not days. Moreover, the maintenance process has become easier and more productive. In 2022, the company saved approximately \$500K on maintenance activities ²².

Use Case 3. VR for Mental Health Treatment

Mental Health America rings the alarm : one-fifth of the adult American population suffers from some type of mental illness. About 60% receive no treatment or medication because they ignore their symptoms.

VR facilitates drug-free treatment. This has been proven to be effective, comfortable and convenient as patients may not even need to leave their homes. The technology enables meditation and breathing exercises in immersive environments. It also gives people the opportunity to confront their fears ²³.

For example, someone who has a phobia of spiders or big waves can process their fears in a virtual environment. They might ride those big waves or play with spiders. This adds an element of fun to a fearful situation while teaching stress-management techniques and coping mechanisms. There are also games people can use for distraction. These work well for anxiety management and relief. Overall, VR for mental health treatment offers a type of therapy that can ease anxiety, phobias and symptoms of depression. For instance, patients learn how to manage their symptoms in a simulation so that they can transfer that knowledge into the real world ²⁴.

Real-Life Example: Treating Cognitive and Behavioural Health Conditions

XR Health developed a virtual clinic that treats mental health disorders using VR therapy. The solution consists of VR headsets, a mobile application and a data analytics platform. The clinic is aimed to de-stress the nervous system and treat psychosis and depression. What's important is that patients get treatment from the comfort of their homes with guidance from a licensed therapist.

Last year, the company *XR Health* conducted research based on 470 patients. They found that 424 patients managed to fully overcome their fear and anxiety. Almost half of them previously had severe symptoms^{25,26}.

Use Case 4. VR for Pain Management

Pain killers don't just kill pain. Everyday about 40 people die from prescription opioid over doses in the US. which is more deaths than from heroin and cocaine combined.

VR serves as a drug-free pain management alternative to traditional aesthetic methods. The technology could reduce the use of harmful pain killers and save lives. To soothe pain, VR apps offer various interactive games that provide cognitive distraction.

In other words, using VR, patients are immersed in an entertaining virtual environment—perhaps an interactive gamified experience or realistic, relaxing surroundings. These experiences switch the focus of a patient's brain. The pain subsides and patients find relief²⁷.

Real-Life Example: Easing Pain

St. Jude Research Hospital offered their patients a drug-free method of coping with chronic pain. Their goal was to minimize the use of addictive opioids and help patients for whom sedation is contraindicated. To achieve this, they tried Ease VRx, a VR platform that uses goggles and headsets to create an immersive 3D world. The solution offers various programs, including pain distraction via immersive games and escapes in relaxing environments. The platform also provides patients with educational tools that teach them how to manage their pain. After six months, the hospital admitted that they had managed to reduce pain scores by 50%. They also saved \$200 Kon purchasing pain-relieving drugs every month²⁸.

Augmented Reality in Pharma Industry

The pharmaceutical industry is facing numerous challenges, including rising costs, increased competition and the need for better patient engagement. AR has the potential to overcome these issues. AR-powered medical devices and AR-assisted drug delivery are the two applications of AR^{29,30}.

Augmented Reality in the Pharmaceutical Industry

Augmented Reality (AR) refers to the overlaying of digital information includes it images, text, or sounds—onto the real world. Generally, it can be observed via a device like a smartphone, tablet, or

specialized AR glasses. AR allows users to interact with both the real world and virtual elements simultaneously.

Example of training lab technicians in the pharmaceutical labs. Let's take a one scenario- A pharmaceutical lab has recently adopted a new high- throughput screening machine for drug discovery. The machine is complex and needs to be operated carefully to ensure accurate results. Training is essential for lab technicians, but experts are not always available to provide in-person training ^{31,32,33}.

Selling and Marketing Pharmaceuticals with AR

VR and AR are emerging technologies and both are used by medical profession for sales, marketing and advertising. AR technology can help sales representatives to visualize the benefits of their products, literature to doctors. They can generate 3D presentations designed to educate healthcare professionals visually. Pharmaceutical companies are already using interactive animations to show the effects of their products. XR technology is enabling the use of animated sequences that involve 3D simulations

and moving images that show the effects of a particular medication. These AR applications give healthcare professionals deeper insights into the benefits these new products offer and thus help them to better explain to their patients how these treatments work.

It can also be used by professionals to “test-drive” larger medical equipment without having to physically bring it in. Not only does this make life easier for manufacturers in terms of shipping costs and training, but importantly, it allows medical professionals to gain a better hands-on feel for the product before committing to purchase ^{34,35}.

Patient Education and Care

XR technologies can be used to educate and ease the anxieties of apprehensive patients about procedures and treatments in an interactive and immersive way. Patients benefit from the technology in two ways: education and reassurance ³⁶.

Better Choices

Patient education is a particularly important aspect of AR's potential. AR helps in better understanding of diagnosis and treatment options. This knowledge will in turn empower them to take care of themselves and be more responsible toward their health and recovery³⁷.

In addition, being able to better understand medication is vital in deciding which medicine to buy. Patients can use augmented reality (AR) through their smart phones to learn more about drugs and treatments and their possible side effects. The best current implementation of this practice comes in the form of helping patients choose medicines based on specific pain areas. Some pharmaceutical uses AR applications to help patients regarding selection of the best product ³⁸.

Doctors can also use AR to demonstrate the proper usage of devices for their patients treatment and recovery. The knowledge of proper use of equipment for homecare patients, for example, improving the quality of life of patients such as their recovery from disease without the need for expensive hospital treatments³⁹.

Reassuring the Patient

Augmented reality can also help surgeons adequately prepare for potentially risky procedures. The technology can simulate a virtual rendering of the operating theatre that can help the doctor identify and anticipate potential challenges throughout the entire procedure.

This can give the healthcare professional the much-needed confidence to minimize potential risks. This helps to reassure the patient that they are safe in the hands of their surgeon ⁴⁰.

Efficient Equipment Manufacture and Operation

AR can be used in the manufacture of medical equipment, machinery and devices. It can be used to visualize three-dimensional schematics of a product in the design phase. Thus, it can help engineers understand how to improve a design and render it more effective. AR can also assure uniform production of the equipment. It can improve the safety of these products.

Pharmaceutical AR can reduce costs in research and development. It can simulate the reaction of components in bioreactors without having to run actual procedures and using resources on tests that could end up in flawed versions of the final product. It reduces potential flaws by simulating visual tests based on past data.

It can also help hospitals and clinics in training their personnel with the use of new equipment. Specialized equipment needs to be operated and maintained in specific ways and manufacturers—or even HR. It can use AR training technology to develop training programs that can teach staff the correct procedures in terms of operation and maintenance without touching the machinery. This can be done remotely, even before the equipment's arrival ^{41,42}.

Discussing the acceptance and potential of virtual reality in pharmacology

In 1992, Fleming and Mills suggested four modes of teaching/learning, namely visual, auditory, reading and kinesthetic, abbreviated as VARK.

Visual includes the depiction of info in the form of graphs, charts, diagrams, flowcharts, etc. Auditory modality comprises information heard or spoken. This includes live lectures or pre-recorded ones, podcasts and group discussions. There adding modality is a preference for info displayed in the form of words such as in essays, manuals, textbooks, and articles. The kinesthetic modality is learning via hands-on experience. This includes on-the- job training, internships, and simulation such as VR ^{43,44}.

Potential of AR/VR

Students can visualize the drugs from their ingestion to absorption to receptor level mechanism and interactions. Handling laboratory animals and pre-clinical testing can be practiced to improve technique. This technology also provides access to teaching material to students around the world, connecting them globally. The best teachers in the field can be accessed with the help of the right gadgets.

In pharmacology, animal experimentation is no longer approved for the sake of training undergraduate students. AR can help students in learning the different instruments used in drug screening. Google has already made AR accessible to the public where they can place 3- dimensional digital objects in one's own space directly from the Google search bar. The maps feature has also become immersive with directions popping up in the field of vision and space. This helps one understand concepts with better context and scale.

Another challenge is the lack of realism in VR and AR simulations. The quality of the display is an important element of the user experience. The better the graphics, the more real and immersive the experience becomes^{45,46}.

Strengths of the study

This is the first study that explores the utility of VR and AR in the subject of Pharmacology. The Oculus TM VR headset, a VR technology was used in the study ⁴⁷.

Short comings of the study

This study was conducted at a single teaching hospital, with 100 students. The results of this study may not be representative of the opinion of the actual student population⁴⁷.

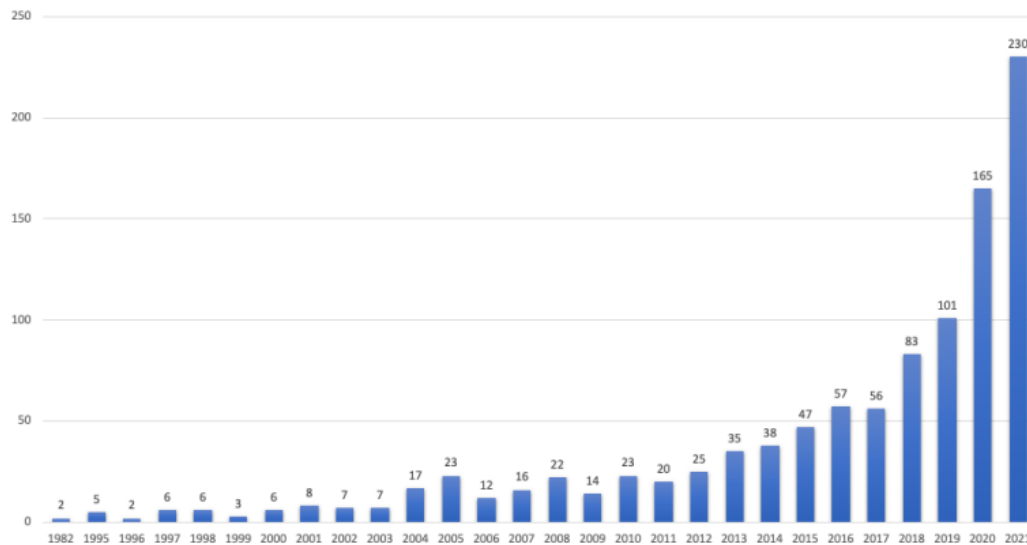


Fig. 3: Trend of Publications on Augmented Reality in Surgery over the Years

Oncology

AR application is frequent used in oncology such as osteosarcoma, mandibular kidney and prostate cancer, meningioma, urological cancer, intracranial, neuro- oncological, and cancer of the liver. AR ensures an accurate visualization of the tumor, identifying its edges and position during surgeries. The capability to visualize three anatomical structures, such as convolutions, grooves, blood vessels and nervous tracts, allows control during their section and permits surgeons to try to eradicate the tumor while removing as little of the surrounding healthy tissue as possible. It provides information of both bone and tumor which can lead to its successful removal. Moreover, AR can be applied in twin digital simulation technique that can be used as medical support tool. It can be helpful to predict cancer in patients by oncologists through the development of appropriate simulation models and the creation of appropriate data sets⁴⁸.

Spinal Surgeries

AR is often used in spinal surgeries. Spinal cord, nerve root or vascular injuries in spines can be predicted with the help of AR technology. Open methods and direct visualization supporting the placement of the instrumentation, such as pedicle screw, have historically characterized this type of surgery. Peuchot and his team developed a system for visualizing a vertebra during surgery in 1977. Minimally Invasive Surgery (MIS) has been under investigation for last two decades. Many articles

have targeted study of Minimally Invasive Surgery (MIS) over the past 20 years. This has led to the introduction of new approaches such as the in operative navigation. So, it helps in visualizing anatomy and precisely guiding surgeries. Furthermore, MIS ensures a higher level of accuracy, while minimizing possible damage to contiguous structures, providing access to deeper ones and improving dynamics and logistics in the operating room. The union of AR and MIS allows the surgeon to see more accurately inside the patient, possibly visualizing the pre-operative planned drilling trajectory over the display. Thus this technology ensures advantages in terms of accuracy, reduction of radiation exposure, blood loss and hospital stay. The drawbacks are mainly related to high costs and to the steepness of the learning curve, still too high ^{49,50}.

Orthopedics

The application of AR in orthopedics came into existence in the beginning of the 2000s. The purpose of applying AR to orthopedic computer systems for computer-assisted surgery (CAS) has been increased due to its accuracy during surgeries, improving the possible outcomes and at the same time decreasing procedure-related complications. AR application can also contribute to the reduction of both surgery time and radiographic doses for both patients and surgery teams. AR avoids the use of X-rays to see through the patients, reducing their exposure time ⁵¹.

Neurosurgery

AR is frequently used in neurosurgery. It is applied in neuro navigation. It can help surgeons in reducing the consequences of the treatment, improving the quality of the surgery and reducing the operation time. The first neuro navigation system (NNS) was introduced in 1986. The advantage offered by AR associated to NSS consists in the mapping of the preoperative images directly onto the patient's visible surface, thus showing its anatomy on it ⁵².

Surgical Training and Medical Education

AR technology is being introduced in surgical training and medical education. Its introduction results in providing students with a better anatomic conceptualization and allows surgical simulations to improve their performances. AR ensures the possibility to practice surgeries without risks for the patient, saving the need of a supervisor and consequently reducing costs for the structures. It also provides an increasing acquisition of skills such as speed, ability to multitask, accuracy, hand-eye coordination and bimanual operation. The evolution of this system has led to the use of tele monitoring,

where experienced surgeons can train students remotely and also to take part in consultations among experts located in different countries⁵³.

Distribution of VR and AR throughout year of publication

Virtual reality (VR) and augmented reality (AR) technology are applied in multi-disciplinary department. So, learning or education of different subjects virtual and augmented reality can be used. The most dominant areas included computer science social sciences, engineering and medicine respectively⁵⁴.

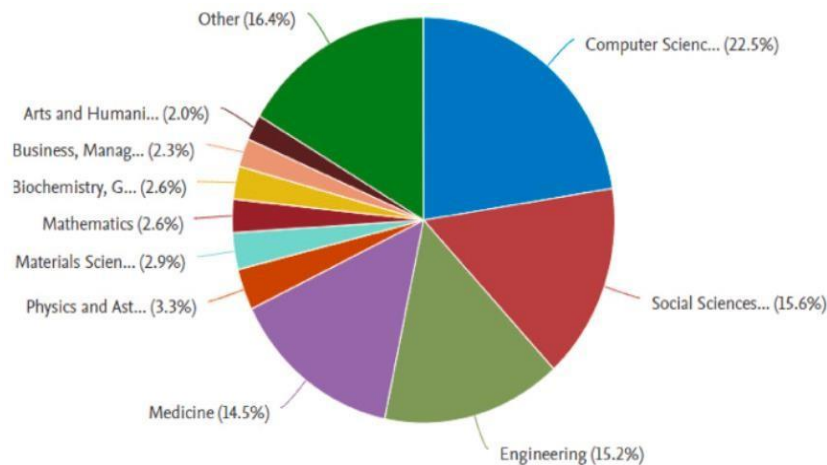


Fig. 4: Distribution of VR and AR throughout year of publication

Study of Augmented Reality Based Manufacturing for Further Integration of Quality Control:

Besides cost, time and flexibility, quality is one crucial dimension of manufacturing attributes in terms of products and processes. Its objective is to assure that the service or final product meets the specifications and satisfies the customers' requirements.

Total quality management (TQM) is the current highest level of quality in an organization context, which holistically considers internal and external customers' needs, cost of quality and system development to organize and assist quality improvement. Quality control (QC) is a part of TQM, playing an essential role in fulfilling technical specifications with inspection applying techniques such as statistical process control (SPS), which is statistical sampling to manage the in-line quality on the shop-floor manufacturing level. Contrastingly, Quality assurance (QA) concentrates more on the pre-manufacturing phases, such as planning, design, prototyping, etc., to ensure the achievement of quality requirements for manufacturing products. The international standard ISO 9001:2015 describes the specific standards of the quality management system. Many organizations have employed various

methods and approaches to improve quality performance such as TQM, Lean Six-Sigma, Failure mode and effect analysis (FMEA), quality function deployment (QFD) and benchmarking. Furthermore, certain behaviours in the factories, such as process management, customer focus, involvement in the quality of supply and small group activity, are required for the successful application of quality management.

Industry 4.0 is a new industrial digitization paradigm that may be seen at all levels of modern industry. Quality 4.0 can be considered an integral part of Industry 4.0 when the status of quality and industry 4.0 are combined. It is the digitalization of TQM or the application of Industry 4.0 technology to improve quality. The value propositions for Quality 4.0 include the augmentation or improvement of human intelligence; the enhancement of productivity and quality for decision-making; the improvement of transparency and traceability; human-centered learning; change prediction and management.

In a holistic view of a smart factory, Big Data, in conjunction with CPS, can be applied to manage the data understanding. Big data analytics play a critical role in supporting early failure detection during the manufacturing process, providing valuable insight into factory management such as productivity enhancement. IoT provides a superior global vision for the industrial network (including intelligent sensors and humans) as well as the ability to take real-time actions based on data comprehension. Then it comes to AI, which is currently used to perform visual inspections of products towards quality control evaluation. One of the most critical issues in manufacturing is the ability to visually assess product quality. AI methods (Machine learning techniques) proved their advancement in assisting inspections based on data analysis. This latter is frequently taken as images collected from sensors/cameras in side manufacturing environments. Finally, AR technologies can be applied to facilitate the inspection process with an immersive experience by superimposing digital information onto the working environment.

At the time of conducting this study, most enabling technologies of Industry 4.0, especially AR technology, have reached a mature point that could enhance the transformation of quality 4.0. This means that a systematic literature review about AR applied in the quality sector is essential and crucial not only for the digital transformation in quality 4.0 but also for the long-term integration of AR technology in quality sector. All relevant AR-assisted quality control solutions in the manufacturing context are considered for this SLR to observe how the cutting edge AR technology has been applied and evolved in quality sector. The findings of this SLR then can be used

as references for further improvement and implementation of AR in quality 4.0 to save costs and resources, as well as to improve productivity, accuracy and autonomy^{55,56}.

Creativity, Motivation and Acceptance:

Motivation is generally understood as a personal drive to accomplish. Motivation can be intrinsic or extrinsic. Intrinsic motivation is defined as doing something for one's own satisfaction and extrinsic motivation is defined as "the motivation to work on something primarily because it is a means to an end".

Researchers have studied the connection between intrinsic motivation and creativity as well as motivation and creativity in the context of design and found that when motivation is less, creative output decreases and stated that "creative potential is not fulfilled unless the individual is motivated to do so, and creative solutions are not found unless the individual is motivated to apply his or her skills."

Research has shown that extrinsic motivation for using assistive technology is captured by the PU construct in the TAM. Furthermore, Venkatesh, (2000) stated that intrinsic motivation is related to PEU. Because technology acceptance is affected by perceived ease of use and perceived ease of use is affected by intrinsic motivation, intrinsic motivation would appear to affect technology acceptance⁵⁷.

Effect of motivation on the technology acceptance model (TAM)

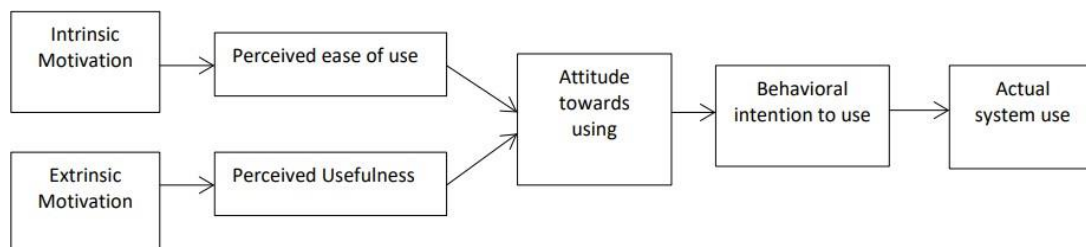


Fig. 5: Flowchart of Effect of motivation on the technology acceptance model

Perceived ease of use is a predictor of intrinsic motivation and intrinsic motivation enhances creativity. Through this link I examine whether perceived ease of use is related to creativity. Anasol, Ferreyra-Olivares and Alejandra (2013) proposed that the learning experience of kinesthetic learners could be enhanced through the tangibility of user interfaces. They further stated that virtual environments can be used as extensions of traditional physical classrooms, motivating visual or aural learners. Therefore, they suggest that user preference would affect the use of VR and AR interfaces in design and thereby affect the creative design process⁵⁸.

Results

VR a modern and innovative technology applied in the healthcare and pharma industry. It offers simulated models for drug kinetics, production of innovative medicines, etc. AR offers 3D image of organs and bones which helps surgeon during performing surgery in their patients. Also, Virtual reality (VR) and augmented reality (AR) are significantly impacting pharmacy and medicine, enhancing training, improving patient care and streamlining drug development. Thus, this can revolutionize in the field of medical professionals during training, understanding and managing the health of patients. This paper includes a comprehensive review regarding the applications of Virtual reality (VR) and Augmented reality (AR) ^{59,60}.

CONCLUSION

VR and AR technology is widely applied in the field of surgery. It offers although an accurate visualization of the anatomical structures and a good control of the activities performed during surgical resections. Also it is used in the field of orthopedics and oncology⁶¹. Neuro navigation system, XR technology have been used. Advancement in the field of technology, Microsoft HoloLens Viewer is the most used method. Likewise, the marker-based system combined with rigid registration is the most common solution for tracking and registration. The need for high accuracy of registration and tracking systems, as well as VOs misalignment problems and the possible vergence– accommodation conflict are important limitations. The latter can hinder the use of AR in surgery. The results of this study, as well as presenting the technological solutions used, show that AR can be applied in different fields of surgery. All of this can Favor The realization of further studies aimed at overcoming the current limitations on AR the clinical setting as well as promoting its application⁶².

Considering the significant role that AR can play within the treatment of a large numbers of patients, further studies are needed to better define all possible fields of application of AR and the best technological solutions to be used.

REFERENCES

1. Coyne L, Merritt TA, Parmentier BL, Sharpton RA and Takemoto JK. The Past, Present, and Future of Virtual Reality in Pharmacy Education. *Am J Pharm Educ.* 2019;83(3):7456. doi: 10.5688/ajpe7456.
2. Ventola CL. Virtual Reality in Pharmacy: Opportunities for Clinical, Research, and Educational Applications. *P T.* 2019;44(5):267-276.

3. Javaid M, Haleem A and RP Singh. Health informatics to enhance the healthcare industry's culture: An extensive analysis of its features, contributions, applications and limitations, *Informatics and Health*, 2024; 1(2):123-148. <https://doi.org/10.1016/j.infoh.2024.05.001>.
4. Alsoweih HA, Fageehi AA, Hadadi JH, Sharahili IM, Alsubhi FA and Aljabry IS. The impact of digital health technologies on pharmacy services and patient care. *Int J Community Med Public Health* 2024;11:2059-64. <https://doi.org/10.18203/2394-6040.ijcmph20240954>
5. Iqbal AI, Aamir A, Hammad A, Hafsa H, Basit A, Oduoye MO, Anis MW, Ahmed S, Younus MI and Jabeen S. Immersive Technologies in Healthcare: An In-Depth Exploration of Virtual Reality and Augmented Reality in Enhancing Patient Care, Medical Education, and Training Paradigms. *J Prim Care Community Health*. 2024; 15:21501319241293311. doi: <https://doi.org/10.1177/21501319241293311>.
6. Tene T, Vique López DF, Valverde Aguirre PE, Orna Puente LM and Vacacela GC. Virtual reality and augmented reality in medical education: an umbrella review. *Front Digit Health*. 2024;6:1365345.
7. Abbas JR, O'Connor A, Ganapathy E, Isba R, Payton A, McGrath B, Tolley N and Bruce IA. What is Virtual Reality? A healthcare-focused systematic review of definitions, *Health Policy and Technology*. 2023;12(2):100741.
8. Mendoza-Ramírez CE, Tudon-Martinez JC, Félix-Herrán LC, Lozoya-Santos JdJ, Vargas-Martínez A. Augmented Reality: Survey. *Applied Sciences*. 2023; 13(18):10491. <https://doi.org/10.3390/app131810491>
9. Syed TA, Siddiqui MS, Abdullah HB, Jan S, Namoun A, Alzahrani A, Nadeem A and Alkhodre AB. In-Depth Review of Augmented Reality: Tracking Technologies, Development Tools, AR Displays, Collaborative AR, and Security Concerns. *Sensors*. 2023; 23(1):146.
10. Ntakakis G, Plomariti C, Frantzidis C, Antoniou PE, Bamidis PD and Tsoulfas G. Exploring the use of virtual reality in surgical education. *World J Transplant*. 2023;13(2):36-43.
11. Laspro M, Groysman L, Verzella AN, Kimberly LL and Flores RL. The Use of Virtual Reality in Surgical Training: Implications for Education, Patient Safety, and Global Health Equity. *Surgeries*. 2023; 4(4):635-646.

12. Mason J. et al. Virtual Reality in Pharmacy Education: A Review of Current Applications." Pharmacy Education. 2021; 21(1), 40-47.
13. Huang, K., et al. The Role of Augmented Reality in Pharmacy Education. American Journal of Pharmaceutical Education. 2020; 84(4):735-743. doi: 10.62951/icistech.v4i1.139.
14. Bishop M. et al. Augmented Reality for Patient Education: A Systematic Review. Journal of Pharmacy Practice. 2022; 35(1): 15-23.
15. Alkhudair N, Alrayes F, Alsehli D and AlRayes S. Virtual reality in experiential pharmacy education: A quasi-experimental study. Saudi Pharm J. 2024; 32(5): 102028. doi: 10.1016/j.jsps.2024.102028.
16. Proceedings of the Saudi Health Simulation Conference 2018. Adv Simul (Lond). 2018;3(1):6. <https://doi.org/10.1186/s41077-018-0065-6>
17. Bareišytė L, Slatman S, Austin J, Rosema M, Sintemaartensdijk IV, Watson S and Bode C. Questionnaires for evaluating virtual reality: A systematic scoping review, Computers in Human Behavior Reports. 2024;16:100505.
18. Tabish N, *et al.* Treating terminal t-cell toxicity: plasma exchange for life threatening checkpoint inhibitor-induced hepatitis. Journal of Clinical Apheresis. 2023;38(3):321-322. doi: 10.1093/immadv/ltac012.
19. Luis A, Paulo M and Jorge D. On-Line 3D Body Modelling for Augmented Reality. 2012; 2: 26.
20. Balasubramanian M and Sheykhmaleki P. Emerging Roles of 3D Body Scanning in Human-Centric Applications. Technologies. 2025; 13(3): 126.
21. Correia HA and Brito JH. 3D reconstruction of human bodies from single-view and multi-view images: A systematic review, Computer Methods and Programs in Biomedicine, 2023; 239: 107620. <https://doi.org/10.1016/j.cmpb.2023.107620>
22. Beacco A, Gallego J and Slater M. 3D objects reconstruction from frontal images: an example with guitars. Vis Comput. 2023; 39(11): 5421-5436.
23. Hasan M. Virtual reality in telepsychiatry is a new horizon for immersive mental health therapy. Middle East Curr Psychiatry. 2024; 31: 76.

24. Selaskowski B, Wiebe A, Kannen K. *et al.* Clinical adoption of virtual reality in mental health is challenged by lack of high-quality research. *npj Mental Health Res.* 2024; 3: 24. <https://doi.org/10.1038/s44184-024-00069-8>.
25. Nakao M, Shiotsuki K and Sugaya N. Cognitive-behavioral therapy for management of mental health and stress-related disorders: Recent advances in techniques and technologies. *Biopsychosoc Med.* 2021;15(1):16.
26. Pretat T, Koller C and Hügler T. Virtual reality as a treatment for chronic musculoskeletal pain syndromes. *Joint Bone Spine.* 2025;92(1):105769
27. Matamala-Gomez M, Donegan T and Świdrak J. VR for Pain Relief. *Curr Top Behav Neuro sci.* 2023; 65:309-336.
28. Ganesh B and Suhass S. Digital marketing in pharmaceutical sector. *international journal of pharmaceutical science and health care.* 2020;2(1): 1-7.
29. Oyekunle D, Matthew UO, Waliu AO and Fatai LO. Healthcare applications of Augmented Reality (AR) and Virtual Reality (VR) simulation in clinical education. *J Clin Images Med Case Rep.* 2024; 5(6): 3141. <https://doi.org/10.52768/2766-7820/3141>.
30. Kapp K, Sivén M, Laurén P, Virtanen S, Katajavuori N and Södervik I. Design and Usability Testing of an Augmented Reality (AR) Environment in Pharmacy Education—Presenting a Pilot Study on Comparison between AR Smart Glasses and a Mobile Device in a Laboratory Course. *Education Sciences.* 2022; 12(12):854.
31. Mahajan I. Augmented Reality – Current Use and Future Influence in Healthcare. *International Journal of Innovative Science and Research Technology.* 2021;6(12):676-681.
32. Sadiku MNO, Adekunle PA and Sadiku JO. Extended Reality in the Pharmaceutical Industry. Published in *International Journal of Trend in Scientific Research and Development (IJTSRD).* 2024; 8(6): 10801089.
33. Bernardo F, Rodrigues J, Maria R, Susana V and João S. Augmented Reality Technology in a Pharmaceutical Industry Prototype. 2023; 23-24. <https://doi.org/10.1109/exp.at2358782.2023.10545757>.
34. Kumar H, Jwalapuram A, Kumar S, Sravan. Marketing strategies in the pharmaceutical industry. *The Scientific Temper.* 2023;14. 1526-1530. <https://doi.org/10.55248/gengpi.6.0425.1388>.

35. Patil DG, Pore AV, Dongare GD and Bais SK. A Review on Pharmaceutical Sales and Marketing. *International Journal of Pharmacy and Herbal Technology*. 2024;2(4):3040-3051.
36. Logeswaran A, Munsch C, Chong YJ, Ralph N and McCrossnan J. The role of extended reality technology in healthcare education: Towards a learner-centred approach. *Future Healthc J*. 2021; 8(1): e79-e84.
37. Lastrucci A, Wandael Y, Barra A, Ricci R, Maccioni G, Pirrera A and Giansanti D. Exploring Augmented Reality Integration in Diagnostic Imaging: Myth or Reality? *Diagnostics (Basel)*. 2024;14(13):1333.
38. Peng Y, Wang H, Fang Q, Xie L, Shu L, Sun W and Liu Q. Effectiveness of Mobile Applications on Medication Adherence in Adults with Chronic Diseases: A Systematic Review and Meta-Analysis. *J Manag Care Spec Pharm*. 2020;26(4):550-561. <https://doi.org/10.18553/jmcp.2020.26.4.550>.
39. Haleem A, Javaid M, Singh RP and Suman R. Telemedicine for healthcare: Capabilities, features, barriers, and applications. *Sens Int*. 2021; 2: 100117.
40. Penzien DB and Rains JC. Reassuring patients about normal test results. *BMJ*. 2007;334(7589):325.
41. Xiao Y, Zhou J, Wang R, Zhu X and Zhang H. Energy-Saving and Efficient Equipment Selection for Machining Process Based on Business Compass Model. *Processes*. 2022; 10(9):1846.
42. Chikwendu OC, Chima AS and Edith MC. The optimization of overall equipment effectiveness factors in a pharmaceutical company. *Heliyon*. 2020; 6(4): e03796. <https://doi.org/10.1016/j.heliyon.2020.e03796>.
43. Sharan S, Bodepalli, D and Sharmila S. Virtual reality-The future of medical education or just another gimmick? Discussing the acceptance and potential of virtual reality in pharmacology. *Journal of Education Technology in Health Sciences*. 2023; 10: 17-20.
44. Kim K, Xie N, Hammersmith L, Berrocal Y and Roni MA. Impact of Virtual Reality on Pharmacology Education: A Pilot Study. *Cureus*. 2023; 13;15(8):e43411. <https://doi.org/10.7759/cureus.43411>.
45. Al-Ansi AM, Jaboob M, Garad A, Al-Ansi A. Analyzing augmented reality (AR) and virtual reality (VR) recent development in education, Social Sciences & Humanities Open. 2023; 8(1):100532.

46. Onma E, Omotoyosi O, Olusegun A, Emmanuel I, Akan I. Effect of Augmented Reality (AR) and Virtual Reality (VR) experiences on customer engagement and purchase behavior in retail stores. *Magna Scientia Advanced Research and Reviews*. 2024; 11: 132-150.
47. AlGerafi MAM, Zhou Y, Oubibi M, Wijaya TT. Unlocking the Potential: A Comprehensive Evaluation of Augmented Reality and Virtual Reality in Education. *Electronics*. 2023; 12(18):3953.
48. Schweizer MT and Yu EY. AR-Signaling in Human Malignancies: Prostate Cancer and Beyond. *Cancers (Basel)*. 2017; 11;9(1):7.
49. Yuk FJ, Maragkos GA, Sato K and Steinberger J. Current innovation in virtual and augmented reality in spine surgery. *Ann Transl Med*. 2021; 9(1):94. <https://doi.org/10.21037/atm-20-1132>.
50. Chen Q, Brahimaj BC, Khanna R, Kerolus MG, Tan LA, David BT and Fessler RG. Posterior atlantoaxial fusion: a comprehensive review of surgical techniques and relevant vascular anomalies. *J Spine Surg*. 2020;6(1):164-180.
51. Li T, Badre A, Alambeigi F and Tavakoli M. Robotic Systems and Navigation Techniques in Orthopedics: A Historical Review. *Applied Sciences*. 2023; 13(17):9768. <https://doi.org/10.3390/app13179768>
52. Barcali E, Iadanza E, Manetti L, Francia P, Nardi C and Bocchi L. Augmented Reality in Surgery: A Scoping Review. *Applied Sciences*. 2022; 12(14):6890.
53. Li X, Elnagar D, Song G and Ghannam R. Advancing Medical Education Using Virtual and Augmented Reality in Low- and Middle-Income Countries: A Systematic and Critical Review. *Virtual Worlds*. 2024; 3(3):384-403. <https://doi.org/10.3390/virtualworlds3030021>
54. Eckert M, Volmerg JS and Friedrich CM. Augmented Reality in Medicine: Systematic and Bibliographic Review. *JMIR Mhealth Uhealth*. 2019;7(4):e10967. <https://doi.org/10.2196/10967>
55. Karcher A, Arnold D and Kuhlenkötter B. Quality methods in virtual and augmented reality with a focus on education: a systematic literature review. *Manag Rev Q*. 2025; 75: 1111–1142.
56. Thao H, Jose A, José YF and Jorge S. Preliminary study of Augmented Reality based manufacturing for further integration of Quality Control 4.0 supported by metrology. *IOP Conference Series Materials Science and Engineering*. 2021; 1193: 012105.

57. Al-Adwan AS, Li N, Al-Adwan A. *et al.* Extending the Technology Acceptance Model (TAM) to Predict University Students' Intentions to Use Metaverse-Based Learning Platforms. *Educ Inf Technol.* 2023; 28: 15381–15413.
58. Oyetola O and Olayemi O. Perceived Usefulness and Ease of Use of GPT Technology in Enhancing Staff and Students Creativity in Management and Social Science. *International Journal of Scientific Research and Management (IJSRM).* 2024; 12. <https://doi.org/10.18535/ijssrm/v12i07.em14>.
59. Bateni H, Carruthers J, Mohan R and Pishva S. Use of Virtual Reality in Physical Therapy as an Intervention and Diagnostic Tool. *Rehabil Res Pract.* 2024 Jan 25; 2024:1122286. doi: 10.1155/2024/1122286.
60. Dhar P, Rocks T, Samarasinghe RM, Stephenson G and Smith C. Augmented reality in medical education: students' experiences and learning outcomes. *Med Educ Online.* 2021; 26(1): 1953953. <https://doi.org/10.1080/10872981.2021.1953953>
61. Osama H, Shidin B, Sarada D and Nassir N. Virtual and Augmented Reality in Surgery. 2020;7:257-285.
62. Sadeghi AH, Mathari S, Abjigitova D and Maat A. Current and Future Applications of Virtual, Augmented, and Mixed Reality in Cardiothoracic Surgery, *The Annals of Thoracic Surgery*, 2022;113(2):681-691. <https://doi.org/10.1016/j.athoracsur.2020.11.030>