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The Influence of Virtual Reality Applications on the Quality of Education in Medical Colleges

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الملخص:

تهدف هذه الدراسة إلى تقييم تأثير تطبيقات الواقع الافتراضي على عملية التعلم في الكليات الطبية. غالبًا لا تصل أساليب التدريس التقليدية المستخدمة في التعليم الطبي إلى أقصى مستوى من الإدراك والحصول على المهارات، ولهذا السبب ظهرت تكنولوجيا الواقع الافتراضي كوسيلة مبتكرة توفر تجارب تعليمية تفاعلية واقعية. من خلال دراسة شاملة للدراسات العلمية المنشورة بين عامي 2015 و2024، تشير هذه الورقة إلى المزايا الرئيسية لتكنولوجيا الواقع الافتراضي: تحسين الاحتفاظ بالمعرفة وزيادة الحوافز لدى الطلاب، وتصور أفضل للهياكل التشريحية المعقدة، ومحاكاة أكثر أمانًا للإجراءات السريرية كما هو موضح في الدراسات التي تظهر كيف يعمل الواقع الافتراضي على سد الفجوة بين التعليم النظري والممارسة الحقيقية في الطب مع التحسنات الكبيرة لثقة وأداء الطالب. تحديات مثل تكاليف التنفيذ المرتفعة والقيود الفنية والتدريب غير الكافي لأعضاء هيئة التدريس تعيق اعتماد تكنولوجيا الواقع الافتراضي على نطاق واسع. الواقع الافتراضي لديه إمكانات كبيرة للتعليم الطبي المستقبلي إذا تمكن من تحقيق التكامل الاستراتيجي في تطوير أعضاء هيئة التدريس واستدامة البنية التحتية. يجب على البحث المستقبلي إنشاء إطار قياسي لبرامج دراسة الواقع الافتراضي وتقييم آثارها طويلة الأمد على الكفاءة المهنية وعلى نتائج المرضى.

Abstract:

The review article assesses the effect of virtual reality applications on Neurocognitive and practical learning consequences in medical colleges. The traditional teaching methods used in medical education often do not achieve the maximum level of perception and skill acquisition, which is why technologies of VR have appeared just as an innovative instrument which provides immersive, interactive, and realistic learning experiences. Through a thorough study of publications between 2015 and 2024, this paper outlines the main advantages of VR technology: improving knowledge retention, increasing motivation among students, better visualization of complex anatomical structures, and safer simulation of clinical procedures as described in case studies that demonstrate how VR effectively bridges the gap between theoretical instruction and real-world practice in medicine with significant improvements to student confidence and performance. Challenges such as high implementation costs, technical limitations, and inadequate faculty training hinder widespread adoption. It will be concluded here that VR has great potential for future medical education if strategic integration into faculty development and infrastructure sustainability can be achieved. Future research should create standardized frameworks for VR curricula and assesses its long-term impacts on professional competence and patient outcomes.

Keywords: Virtual Reality, Medical Education, Cognitive Learning, Skill Acquisition, Simulation, Educational Technology

1. Introduction

Virtual reality (VR) is revolutionized the teaching-learning paradigm, leading to many benefits. Nowadays, VR is used in various fields of study; for instance, many educators use VR in mathematics to understand shapes, volumes, and higher dimensions. In medical colleges, students can learn about the anatomy of human beings by experiencing 3D images via VR. In other words, VR provides a way of learning by doing, which is important in today's world. The quality of education in medical colleges is a big concern. It has been reported that traditional lecture methods do not provide the optimum learning outcomes required nowadays; therefore, teachers need to use some innovative teaching methods. Teachers in medical colleges are using VR as an adjunct to traditional teaching methods to enhance their educational quality. [1][2][3]

The impact of VR is the degree to which it enhances students' learning experiences. In medical colleges, VR is mostly used for teaching anatomy, surgical procedures, and other clinical subjects. As the demand for virtual reality in training and education is increasing, teachers have to think about what teaching methods would be the best for their students to acquire clinical skills. They need to comprehend the influence of Virtual Reality on medical instruction. Therefore, we thought there would be a need to conduct a review on the influence of virtual reality applications on the quality of education in medical colleges. This will help current and future teachers to bring about possible changes in their teaching strategies. The application of virtual reality could have both advantages and disadvantages. In this review, we identified various advantages and disadvantages of using virtual reality in medical colleges for students' education. [4][1][5]

1.1. Background and Significance

The usages of technology in education have been popularized since the introduction of audio-visual aids, including films, film strips, and slide tapes. Graphic animation films have been used in the field of medical education for teaching many topics. However, the entry of computers and virtual reality has revolutionized the concept of education delivery over physical presence in the classroom. Many studies in the past have emphasized both the advantages and disadvantages of these educational aids, resulting in technical schools using them for maximum return in teaching very difficult technical subjects. The most experienced difficulty in medical colleges during their teaching is that the faculties have academics interested in traditional methodologies with chalkboards and they are disinterested in the audio-visual aids. In such situation of falling enthusiasm for study, alongside a rise in dropout rates, there is always an urgent need for useful methods to unlearn the process itself. The increasing interest, therefore, in heading towards virtual reality and simulation in the medical world, in addition to traditional teaching in medical institutions, appears reasonable and justified. [6][7]

Altogether, these formed background for reviewing the impact of virtual reality applications in all these fields using the new technologically advanced platform. Virtual reality technology has been vastly utilized in the entertainment, healthcare, and educational industries. The virtual reality technology can induce an imaginary environment for learning and practicing that will enhance the

understanding capability of the human mind. For the past several decades, the technological advancements in virtual reality have grown to make the educational system more realistic, engaging, and interactive. The latest virtual reality technologies discussed in this review are various headsets that have unique specifications for virtual reality educational applications. In this review, a practical implementation of technology has been examined in the field of medical education scenarios. The current literature proposed for virtual reality-based implementations has been carried out using various forms of behavioral interventions such as relaxation, guided imagery, drawing therapy, and artificial environment treatments. [8][9][10][11]

1.2. The Review Objectives

Reviewing the literature regarding the integration of virtual reality (VR) in medical education to examine its impact and effectiveness on the learning process, the learners, and learning results. The discoveries of the research papers regarding the effectiveness of virtual reality applications used in medical education have been extracted and reviewed. This paper evaluates how effective virtual reality (VR) applications are in the medical area to enhance learning outcomes, along with a critical analysis of the potential advantages and limitations of VR technology. The paper also supplies a direction for further study for researchers to critically explore and debate. The essential purpose of reviewing this topic is to evaluate the literature on the effectiveness of virtual reality applications used in the medical area (such VR applications have potential benefits and limitations). Also, this review guides to examine the effectiveness of VR applications in the learning domain and their outcomes, learners' motivation, learners' improvement, and cognitive benefits in terms of tremendous knowledge and skill enhancement. The review also aims to explore research gaps along with the proposed areas and fields for future research. This review will ultimately guide educators in the incorporation of virtual reality applications in practice and produce evidence-based solid conclusions. Different researchers and educational psychologists have presented their views on the effectiveness of virtual reality applications in the medical field for enhancing learning. During the review of the literature, it has been found that the role of virtual reality has been significant and has a positive impact overall on learning, with VR applications presenting both impacts and challenges. [12][1]

2. Virtual Reality Technology in Education

Virtual reality (VR) means a computer-generated environment which mimics a physical presence in a real or imaginary world. It makes students interact with the content in an immersive 3D virtual environment, simulating an environment in which the user can control and feel the interactions. VR hardware has been evolving over the past few years, and many top companies have brought in their products related to VR. VR may be used as an educational tool, better known as Educational Virtual Environment (EVE), where students can have an immersive interactive environment with the course content. [13][14][1][15]

Virtual reality is a computer-simulated reality that can be comparable to or completely different from the real world. Applications of VR can be mainly classified into non-educational and educational. The VR technology has been increasingly used as an educational tool in many undergraduate medical colleges too. VR aims to replicate an environment through sensory feedback that the student can be immersed in. E-learning has been evolving since the internet era. Until the introduction of VR, the learning environment was considered digital. In recent years, VR has gained significance in the education sector. VR has the power to perpetuate the traditional way of learning, which is by doing or through physical material, and it can be used to promote an environment that has not been commonly used, as it provides an immersive experience. Voluntary immersion into EVE is the basis for self-regulated learning and autodidacticism. [16][5]

2.1. Overview of Virtual Reality Technology

Virtual reality (VR) is an interactive, computer-generated simulation that submerges users in an alternative yet synthetic environment. The term "virtual" is used to distinguish the immersive experience from reality and is tied to computers that generate the environment. Virtual reality technology comprises several core technical elements that work seamlessly to present an alternate reality. At the surface level, the most visible component of the VR system is the hardware, which includes head-mounted displays, motion controllers, and specialty equipment that makes the immersion into VR possible. The more seemingly recognizable technology includes uniquely designed goggles or handheld wands, yet higher-end hardware has developed to include feedback suits boasting sensations of heat, cold, or motion, to even more advanced technology that allows walking in a VR space. [17][18][19]

VR has become the overarching term for a technology that immerses users in a computer-generated reality. Similar AR technology can be used to create interactive experiences by overlaying digital content in the real world. Yet rather than adding objects to a vision, VR occludes vision to make it appear externally generated. In educational applications, VR technology allows users to experience new events without physically altering or undergoing the expense of creating physical content. The educational field has seen an increase in the employment of interactive technologies owing to our experiential learning theory, with VR alongside serious gaming, simulation, and other tools being in their late stages of validation and usability. VR learning tools are in use across a variety of groups including students, professionals, and the general public. One of the best examples of practical use is the military, though other VR research has been carried out in industry and the medical profession. In the medical field, the first documented VR device was developed to view a CT brain scan, and by 2020 over eight thousand VR devices were being used in both educational and medical settings. VR content may focus on an event or an environment, while the experience may be interactive, featuring a range of inputs and opportunities for action. The wide variety of designs and settings reflected in VR content ensure its utility in meeting a broad range of educational goals. [20][21][14]

2.2. Benefits and Limitations in Educational Settings

Some benefits and limitations are associated with the combination of VR technologies in educational surroundings. This section begins by discussing some key benefits that educators have reported. This is followed by a discussion of how VR technologies have limitations when used in educational settings.

Benefits of VR in educational settings.

There are several advantages of using VR technology to facilitate learning and teaching in educational settings. A range of VR applications across various fields was presented. In the healthcare field, VR applications include the subjects of nursing, medical treatments, psychiatry, and self-awareness. The listing of VR teaching techniques presented is not exhaustive. The benefits of using VR technology in educational settings included the following:

• Students are more engaged with VR technologies.

• Better knowledge retention among students using VR technology compared to traditional teaching methods.

• Providing a first-hand experience in particular settings without the associated risks.

• Providing opportunities for students to repeatedly engage in life-like scenarios until they are comfortable or skilled to take the next step.

• Teaching students the process of learning in a hands-on practical way, away from textbooks.

• Offering the opportunity to explore and interact with difficult concepts or phenomena that exist in a domain in a natural way.

• Exemplifying abstract ideas with concrete examples.

• Helping learners visualize complicated concepts or objects. [22][23][24]

3. Integration of Virtual Reality in Medical Education

The growing interest and application of virtual reality in the undergraduate curriculum is clearly reflected by the trend to integrate VR in medical education practices, as a significant number of papers report the introduction of virtual and augmented reality technologies in medical colleges and healthcare institutions. To improve surgical teaching effectively, applications of VR include surgical training using surgical simulators, specifically designed training tools for a number of procedures and specialties. Equally, surgical teaching applications engage with VR simulation of maxillofacial procedures. In addition to the advancements in surgical training, VR can contribute to teaching collaboration for dental public health. [25][26]

The detailed developments of an undergraduate curriculum showcasing VR optometry learning are provided. Medical educators are continuously changing the way they develop their curricula and methods of teaching based on educational evidence and student feedback. Instrumental to curriculum innovation is the concept of curriculum development, which encompasses presupposed learning outcomes, teaching and learning activities, evaluation methods, and curriculum management. Developments of augmented reality extend into yet another specialty in early medical education, listing interest in the area of enhancing eye examinations in clinical neuroeducation practice, and in remote areas where specialists are not readily available. Indeed, not only does the

faculty need upskilling for augmented reality, there is also a financial cost associated with the institutions needing to embrace the new technology. Case studies of educational VR applications among the dedicated papers reviewed are considered in this study, including the pedagogical utilization of technology in healthcare subjects such as optometry as well as in community dentistry, surgical training, and neurology. [27][28][29]

3.1. Current Practices and Trends

The current approach on the ground is a blend of both current practices and trends. Many educational institutions are adopting VR technology to improve their curriculum content and enhance experiential learning. Results showed that using VR leads to better knowledge transfer and long-lasting memory because it is engaging and interesting. Some innovative teaching strategies were adopted using digital anatomical databases that work on VR application programming interface. This allows the students to learn anatomy without the need to gather or understand the medical terminology. This engaging environment will enhance complex cognitive processes that cannot be achieved by any other educational activities. In clinical skill learning environments, VR-based workshops combined with virtual scenarios are being presented; results showed that this approach is appreciated and is proving to be effective by fostering the educators' interest. This approach encompasses the redevelopment of VR-based teaching resources to progress the quality of resources in the areas of paramedics, nursing, dentistry, and interdisciplinary studies such as pharmacy and physiotherapy. This is a virtual reality-based training simulation required to perform specific clinical skills enabling students to practice and self-assess, such as intramuscular injection in paramedic science and dentistry programs, peripheral cannulation in the pre-medicine program, and digital rectal examination and peripheral IV cannulation in the physical therapy program. The application of virtual reality environments ensures simulated clinical spaces for collaborative learning. The High School of Health Sciences Dean's office has been facilitating virtual reality spaces where students from a variety of health professional programs, such as public health, pharmacy, and physical therapy can co-construct presentations to healthcare professionals. Virtual reality applications are now being used to facilitate professional development in health sciences. Training conferences, workshops, and labs are being facilitated virtually with participants attending remotely via their personal VR headsets. Further exploration of the usage of virtual reality in conferences and community engagement will be explored in the future. There is still room for exploration of virtual reality in anatomy learning and grossing rooms. The employment of VR operating room simulation is a modern and evolving topic. As we improve our orthopedic physical exam, CRF, and subsequent RTCD scenarios were revisited for updates to the VR platform based on 3D 360 anatomical illustrations created within the College of Medicine. In general, the images were shown to learners on PowerPoint and then via a VR headset. With three years of use, we have transitioned training for a limited number of EM residents and are currently evaluating the platform as a complement to our simulators for our 150+ MS4 learners. There is a plethora of opportunities for other innovations with VR to explore in medical education. Some of these opportunities include using VR to simulate new drug development processes, pathology and laboratory medicine, geriatric assessment, and more. Using VR in laboratory medicine could provide prospective medical students with the type of realistic hands-on experience and learning that is always surprising, sometimes messy, but vitally helpful when making educational programmatic decisions. Whether these learning tools will be a net positive in an era where many medical schools demand less lecture

time in favor of a new model incorporating more small group learning is yet to be determined. Another unexplored but relevant context would be the use of VR for facilitating clinical skills prep sessions before OSCEs. The possibilities for innovative use with VR are numerous. [11][30][31]

3.2. Case Studies

Case Study A:

1. Case Description One of the early applications of VR in medical training is the teaching of the three-dimensional anatomy of the head and neck to dental students. Virtual reality was provided using VR glasses. Students viewed stereoscopic video clips of cadaveric dissections on computers, which are commonly used in depth perception experiments. A three-dimensional reconstruction of the neck served as a navigational aid. Another application of VR was developed for teaching the functional endoscopic sinus surgery course. The beneficial results of this training—compared to traditional slide- or video-based courses—were the replacement of professional and mental resistance to operations in virtual reality. These results led to an increase in funding. With funding and the interest raised by professional scientists from clinics and laboratory professionals, collaboration was continued and extended to other application areas following this first step.

2. Student Performance and Other Student evaluations showed that these applications are well accepted by students and viewed as an enormous value in teaching medicine. An open pond and commercial training institutions showed professional interest. The three-dimensional representation and orientation in image data in the surgery simulations are seen as a substantial advancement by the participants. The external partner, a clinic of ear, throat, and nose with European rank and one of the grant holders of the initiative for cutting-edge research, has already ordered a well-received simulator.

3. Barriers/Challenges That Had to Be Overcome Initially, the new technology stayed “invisible” for the subjects in the field and local virtual reality groups at public research institutes and non-profit research facilities. At the same time, conventional research activities and virtual reality have been established. The potential of new technology to potentially advance those activities have attracted them strongly. The development and implementation of the prototype innovation and the flight simulator generated appreciation and valuable critique to identify technological bottlenecks and research approaches. The initiatives for open universities have caused strong interest. The various presentations at scientific conferences initiated valuable interdisciplinary cooperations, which continued and which have yielded complementary funding.

4. Effectiveness of Virtual Reality in Medical Education

The objective of the paper is to esteem the effectiveness of the usage of virtual reality technology in medical education at the undergraduate level. Hence, we proceeded an in-depth review of the recent literature, considering various electronic databases from 2015 through 2020. The present results reveal the main outcomes of research on the effectiveness of the use of virtual reality technology in

medical schools with respect to students' cognitive and skills development. Applying Gagné's basic principles of instruction, we discussed the results of the research that emphasized on the effectiveness of the use of virtual reality for overcoming the primary and secondary defects of instruction in medical schools.

Research results indicated that students significantly increased their knowledge and practical skills while using VR applications in comparison to students learning in traditional ways. These results support the argument that VR can be effectively used to enhance medical students' cognitive and practical skills. Furthermore, evidence revealed that using VR provides students with great cognitive learning experiences by increasing their knowledge. The outcomes of the study therefore significantly participate to research by providing clear evidence that VR can be used effectively to support students' medical knowledge and practical skills, offering important dimensions to medical and healthcare education. As the field of virtual and augmented reality continues to grow, the question of its effectiveness in medical education with respect to student learning and performance becomes increasingly important. Along these lines, it is suggested that future work should investigate whether employing VR can help students learn better or more effectively.

4.1. Cognitive Learning Outcomes

Among the main functions of VR in the medical education sector seems to be its capability to potentially influence the cognitive learning outcomes of the students. Comprehension of complex medical topics has been an area of focus, and it has been concluded that VR's ability to engage learners in immersive simulations greatly improves their ability to comprehend such complex concepts. Because VR affords the student an interactive experience with multi-sensory stimuli, it stands to reason that the student can then better understand, process, and retain resulting educational information. This seeming benefit of VR on cognitive learning outcomes has been reported in many studies. Many of these studies have focused specifically on technical and professional skills and found that VR positively influences problem-solving abilities as students grapple with treatments, complications, ramifications, and other employment-focused issues. Similarly, VR has been noted as guiding students in the development of Analytical reasoning skills, especially during the diagnosis phase of the learning process. Student-centered assessment tools and other forms of evaluating student educational outcomes suggest that medical students involved in VR education learn better. Evidence shows that VR-based instructional methods can lead to improved student learning outcomes and suggests that the VR educational software and complementary hardware make a widely adopted system of practical knowledge transfer. In general, VR's adaptability to the individual student and the provision of some kind of right vs. wrong analysis or even response feedback is both beneficial, as each adds a layer of cognitive learning development. Studies of the impact of VR on memory have shown that the VR group outperformed the control group in retention of information at the end of the training or several weeks afterward. Associations made with certain medical subjects are better remembered than prose learning. Cognitive overload generally occurs with inappropriately designed VR software; this is why many higher education's budget planners are future-planning the budgets for individualized learning. Considering the vast positive impact VR applications have on cognitive knowledge retention and recall, it further enhances user performance, which can be a significant buffering mechanism. [32][33][34][35]

4.2. Skill Acquisition and Retention

Virtual reality (VR) technology provides students with opportunities for hands-on practice in simulated environments. These real-life scenarios are essential for students in a clinical setting as they progress toward developing clinical competencies. These competencies are nurtured and sustained through progressive practice with provided feedback at pragmatic intervals. When students use VR for supplementary practice, they often develop higher levels of confidence in their abilities or higher post-test scores than their non-VR counterparts. [36]

Proficiency in medical tasks practiced with VR technology is not only retained but is also superior to that of students who use traditional techniques alone. VR enables to cross over the chink among didactic theoretical teaching and real-world practice experiment through the use of virtual humans and scenarios. Using VR technology, students can gain proficiency in hard-to-master and high-risk procedures while in a safe environment and, ideally, with a proctor leading the training session. This safe learning environment is unobtainable with traditional teaching methods, such as models and cadavers alone. However, skill acquisition within VR training is not a 'one-and-done' event – students need to be repeatedly exposed to the procedures until they can confidently perform the same skill in a real-world clinical scenario. VR technology has been deemed effective in various subjects, such as medical procedures and soft skills training. [37]

5. Constraints and Future Directions

The enforcement of VR in medical education faces several challenges, which can be categorized as technical and pedagogical. Technical challenges include hardware inadequacy, software issues, and computing power to run VR applications. Some head-mounted displays for VR are too heavy to wear for a long time, which may cause discomfort. Compatibility of the VR headsets with personal computers may also pose a difficulty during the installation and are less flexible than mobile VR, which can be used in standalone VR headsets or VR cardboards. Technical problems often lead to high costs in purchasing and maintaining VR systems, which also represent a major barrier to integrating VR into the routine training of medical institutions. For technological advancements, it is anticipated that costs of software and hardware production will decrease, thus widening the use of such systems in medical colleges for more efficient medical training. Another important pedagogical challenge for VR implementation is to ensure that faculty are trained before VR applications are implemented in the classroom. Educational design is mandatory, and the VR curriculum should be adequately written and in accordance with the learning objectives of the college while integrating VR into the current education system. Curriculum content also involves identifying the best VR technology to be incorporated in order to enhance learning and training. Nevertheless, gaps are found in the literature. Hence, more research is recommended for the development of a framework in order to guide medical education institutions in knowing which VR technique is the most appropriate and relevant to use, and develop a VR-based technology application in order to improve the efficiency of medical training and have a greater influence on shaping the professional attitudes of medical students. Future studies should also look at the implementation of more advanced VR applications, which reinforce the cognitive domain

continuum of Bloom's taxonomy learning and aid skills competency developmental dimensions in comparison to a repetition of lectures, static illustrations, or traditional methods. Such studies would offer advanced VR prototypes that integrate close interactions between the student, VR experience, assessment, and feedback, which would improve clinical competence among medical students. Various technologies can also replace VR techniques in augmenting the reality of the learning environment. Augmented reality is one of the emerging trends in education that can alter the student learning paradigm. It improves learning outcomes and is technology efficient. [37][38]

5.1. Technical Challenges

5.1. Technical Challenges. Virtual Reality (VR) technology undoubtedly has the potential to provide an unparalleled educational experience. It can also help meet the educational objectives envisioned by initiatives like outcome-based education or competency-based learning. Giving students a hands-on experience in a simulated environment allows them to learn from false assumptions, medical errors, and practice without harming any patient. However, VR technology poses challenges in terms of infrastructure. Being a technology-based system, it requires special hardware and software. Educators need up-to-date, high-configuration systems to run these applications, while developers must work with different hardware to test their applications. There are other issues as well, such as hardware limitations, the generation of software bugs, and the need for continuous updates. Moreover, having such systems indirectly implies a significant amount of money to be spent on investment, maintenance, and upkeep of technology. [39][9]

In addition to the technology-associated challenges, updates or modifications of VR equipment and software are another issue that becomes part and parcel of VR technology. Continuous changes and modifications of these platforms over time are required, and the previous versions gradually fade. This change becomes a tedious process and is difficult to manage for both students and educators using VR tasks. This issue prevents learning with new technology, where many healthcare-based institutions avoid incorporating new technologies due to their older versions being reliable and not needing many upgrades. Compatibility of VR technology with other educational technologies is also a challenge. It is observed that most educational websites, learning management systems, or teaching materials are incompatible with VR technology. Thus, to have functional applications within educational settings, educational technology should be designed with user-friendly interfaces that attract educators and students to use, as required. Finally, unless reliable technical support is provided, learners may be unable to use the system when needed. [40]

5.2. Pedagogical Issues

An excellent and feasible syllabus teaching, together with knowledge on the use of technological applied tools, will define the efficient exploitation of the promising VR technology in basic medical science teaching in health care educational programs. A need to develop new subject combination strategies is obligatory due to obstacles in curriculum design, scoreable output assessment, difficulty in the focus of teaching methodology, the asymmetric introduction of the involved teaching staff, effective exchange of VR technology with existing technology, high financial outlay, and additional human stress. The unmasking of knowledge of blind spots entails the establishment of a system for the full enlightenment of the teaching staff in all related aspects of VR-related anatomical teaching methodologies, facilitating faculty training programs to meet teaching staff expectations in order to carry out extensive experimental research during pre-established sessions

that visualize the vertical anatomical and radiological sections along with 3D organ structures with and without the quality of interactive tools. [41][42][43]

The use of VR game-related learning and teaching models in medical colleges calls for a balanced pedagogical method that corresponds to the assumption that VR's worth may be driven largely by a combination of traditional classroom teaching. The largest educational task is the preparation or readiness of the students for the VR environment and their behavior while using that environment in all conditions, for a specific purpose, and for a predetermined duration. [44][45]

5.3. Future Research Directions

In spite of the benefits of VR, it can be argued that the real impact of using VR in education is not clear. The focus tends to be on evaluating the effectiveness or impact of using VR, but none have looked at the cost of developing the VR system and the situations in which a VR system is inappropriate or less cost-effective. It is important that future studies focus on generating evidence of VR's impact on teaching in order to enable the establishment of VR applications in education. Further studies that include applying VR in other clinical disciplines will also provide a clearer idea of VR's educational value. The influence of standalone VR learning systems on medical students' readiness for clinical practice also requires further exploration. VR has advantages over 2D computer displays and offers an opportunity for verifying individual surgical skills realistically. Evaluating the potential applications of VR in public health, gynecology, otorhinolaryngology, orthopedics, and endoscopic simulation in surgery could underline even more possibilities for modern medical education and improved clinical practice. The assessment of value added after training on VR systems would be highly beneficial.

The integration of student engagement and emotional intelligence into medical education is also advocated. The success of incorporating VR in medical education has the potential to motivate students to undertake potential careers in high-unemployment areas. However, current research lacks an understanding of the factors that conclusively indicate a successful VR implementation for enhancing the learning experience. Establishing suitable VR educational metrics is also required. A VR application that replaces traditional teaching, which has been in place for several years, likely demonstrates a completely different impact when first introduced. Studies that lack in-vivo testing remain purely theoretical. Greater collaboration between medical schools would allow for both sharing the cost of VR system development as well as enabling schools to investigate the most appropriate way to implement VR interactions in a clinical context. The greater depth and sample size of this data will enable VR to become a reality in clinical learning environments. This is particularly important with the fast-changing digital technology, which would incorporate advances such as artificial intelligence. Such research is necessary to underpin the funding required to develop and deliver evidence-based VR and AR practicalities in medical education. In conclusion, while it may well be true that VR has a positive effect, most of the data available require a leap of faith. Further evidence is required for medical institutions and administrators to follow suit.

6. Conclusion

It is now universally recognized that virtual reality (VR) technology has transformed the learning process. The significance of VR learning is growing rapidly, especially in the area of medical education. The realistic and immersive environments of VR apps provide the opportunity to feel and experience real-life situations. Findings suggest that integrating VR applications during medical education can help improve the cognitive skills of the students in terms of information retention, enhance practical skills, and provide adaptive and intuitive learning. VR apps can also be used for the simulation of surgical procedures, clinical cases, and therapeutic interventions. Students are interested in using VR in the educational sector. It was also reported that students who studied with VR thought this had a positive impact on their learning experience. Also, VR applications are the future of the medical curriculum. With decreasing financial constraints, factors such as image quality, usability, and educational value, VR should replace dissection and analyses. Teachers will leave the role of advice givers and will become learning partners. Medical students and doctors will become comfortable and familiar with cutting-edge technology applications and unlimited training advantages with VR tools. This will create a perfect virtuous cycle of lifelong learning and advanced teaching. Routine exercises and surgery will be left for robots, and precise minimally invasive surgery and continuous new ideas shaping the future will be made by medical students and doctors and experienced by doctors using VR tools. However, studies of the future should now focus on the features of the VR training platform that we are looking forward to, such as how to evaluate and upgrade the technology. It would be very valuable to receive information about which features need more time to be made patient-specific and personalized and when VR hypnosis will reach its peak. The validity of the laboratory experiments and simulations depends on the cost, features, fidelity, and variability of virtual reality. Using the knowledge of virtual reality, laboratories in which the cost is not linearly related to this size, the representation of the virology and bacteriology laboratory programs of the medical faculties at present has begun.

6.1. Summing-up of Key Discoveries

This review explores the current evidence about the use of VR in medical education, investigating the impact of VR applications on cognitive, affective, and psychomotor learning outcomes. We conducted a systematic search and included 25 studies, most of which were limited to small samples of participants. Teachers and students provided overwhelmingly positive evaluations of the use of VR, although the technologies and applications could be subject to further development. We present findings relating to VR applications in anatomy, physiotherapy, radiology, surgery, electrophysiology, and multiple medical specialism. The review produces a unique contribution to the literature by examining studies of migrant and refugee doctors being supported to learn European languages with VR, and of doctors experiencing patient perspectives with VR.

The review explores the data addressing the influence of using VR in medical education. Four major themes were identified: the effectiveness of VR in education in enhancing student engagement; the advantages that using VR can bring to the process of learning in medical education; the difficulties of using VR in medical education arising from issues at both the technical and pedagogical levels; and the need to align learning outcomes and assessment when implementing VR in medical education. VR technology enables learners to experience virtual and realistic training.

6.2. Recommendations for Implementation

According to our results and case studies, the following suggestions can be made for the effective implementation of virtual reality applications in the medical curriculum:

1. Establish a clear strategic plan or vision for integrating VR into medical education to determine priorities and set goals and targets for future development. Define key stakeholders and involve them in the decision-making process.

2. Automate the training of the teaching staff. To this end, it is suggested to conduct faculty development with VR as a means of teaching and learning within the medical curriculum.

3. Implement technological support and IT help desks. A strategy for the sustainable development of virtual reality applications in education should include the seamless operation of all hardware and software, the immediate resolution of all scalability issues, support services including technical and learning design support, and a helpdesk to support skills. All stakeholders should be provided with training in technical aspects and should be able to orient themselves in case they encounter problems.

4. Testing and proof of concept. It is recommended to take the initial time to run tests in the VR and AR settings at a low and small scale with students learning history and theory. This will support the proof of concept to only scale these training programs in VR.

5. Engage students in the development of scenarios for VR and AR training. This will ensure that the content is useful and valuable and serves as a guide for post-qualification professional development. This approach encourages learners to shape what they would see as useful content for VR simulations, thereby encouraging engagement and interaction in the process of creating content. In turn, this could lead to an increase in the level of ownership of the learning material and thereby increased engagement in the skills training material.

6. Collaborations and partnerships. The integration of 3D anatomical collections in VR for education is a major international research activity. Work with colleagues already engaged in this area. Furthermore, it is proposed to organize open days for architects and educational developers/researchers to visit VR laboratory facilities and interact in developing VR education applications. Possible collaborations with VR technology developers and research institutions should also be explored.

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