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The Implementation of Interactive Learning Technologies in Medical Education: A Review

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Abstract
At present, interest in the use of innovative methods and technologies that depend on the Internet has increased to develop medical education skills further, so this article aimed to describe the activities of blended learning using Interactive Learning because of its great importance in increasing the area of teaching and learning, which is one of the most important requirements for blended education in Iraq, so the importance of Interactive Learning and the types and methods used in its use in the field of education for the students of the medical group were highlighted.

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1. Introduction

Medical education is slowly transitioning from traditional teaching to more technology-oriented and innovative pedagogical methods. There is a need to scaffold the best innovative educational methods in preparing healthcare professionals for the future. The education department has released a new curriculum for medical undergraduates, in which there are several learning outcomes for the development of traits essential for the current learning environment. Similarly, the vision and the comprehensive technical path of the Faculty of Medicine is to advance human education with educational technology. The interactive learning technologies have been in the field for decades, and many of them are innovative, but they are not used much in the medical education domain. The modern learning theories present the design and development of technology-enhanced learning environments, which are based on methods to improve personalization, creativity, and inclusion in the learning process. (Zarifsanaiey *et al*.2024, Gaur *et al*.2020) [91, 36].

Technology-enhanced education was introduced in the Middle Ages using static media. Over the past few decades, face-to-face teaching has gradually been replaced by the frequent use of semi-interactive learning technologies. Recently, interactive technology has become increasingly used in medical education by incorporating these technologies into undergraduate as well as postgraduate curricula. The use of interactive technology in medical education revolves around four principal goals: technology-enhanced learning can improve engagement, participation, or motivation; it can improve learning outcomes, knowledge, skills, or attitudes; it can improve the function of the learning environment, for example, making schedules, group activities, or feedback easier; or it can improve the efficiency of the learning process, for example, allowing the same quality of learning in a shorter period of time. The targeted use of innovative technology has an evidence-based tangible increase in learner participation and knowledge retention. (Tuma, 2021) (Van der Niet & Bleakley, 2021) (Binks *et al*.2021) [86, 88, 14].

1.1. Background and Rationale

Educational practices across time have been informed by learning theories, a period's social and economic conditions, professional organizations' opinions, political and contextual demands, and philosophical positions. Traditional medical training programs relied on carrying these historical precedents, concepts, and beliefs of educational paradigms; they incorporated unsystematic familiarization with a series of descriptions, prevailing practice experiences, and trial-and-error correction.

Although the last century has seen increasing educational methodology promotion, these remain primarily theoretically driven claims with unrealistic or doubtful reproducibility and low reliability. Traditional education focusing on teacher-centered direct teaching techniques resulted in student reluctance, shallow representational content conceptual memories, lower retention rates, a limited association between prior fragmented knowledge and real-world practice, and a labile experience of clinical problem solving. This deep-rooted tradition, its exploration of current trends, and potential barriers were succinctly reviewed. (Murphy *et al*.2021) (Abdulsamee *et al*., 2021) (Treve 2024) [64, 1, 85].

In contrast to the traditional educational practices, there have been renewed calls for incorporating methods addressing current pedagogical concepts in medical education, which mimic clinical contexts, bringing direct teaching technique researchers, educational technology entrepreneurs, and educators together. Learner-centered approaches capture the real-world need for training future physicians, addressing diverse learning styles, the values of reflection and meta-analyses, different developmental stages of medical students, constructivist learning principles, and learning environments where students can experience failure or partial success and take personal responsibilities. This review aims to report on worldwide medical students and teachers, with a special focus on the use, effectiveness, and evaluation methods for these technologies in attaining a higher performance of medical students regarding their clinical competencies and the transfer of new knowledge. (Lee *et al*.2022) (Roehrig *et al*.2021) (Roberts, 2021) [52, 73, 72].

1.2. Scope and Objectives

This comprehensive review specifically focuses on ILTs designed for medical education and seeks to address the following topics: - Technologies used as ILTs in longitudinal and block-based programs; - ILTs deployed in demographic and educational settings; - Pedagogical frameworks; and - The implementation challenges that faculty face and the recommendations to address these challenges. The aim of the review is to facilitate understanding of the contributions the review intended to make. The scope of the review presents a clear and narrow focus. In this review, we demarcated interactive learning from the ILTs that support the interactive delivery of learning, such as simulators or other digital media that students interact with. (Drenckpohl, 2024) (Ummihusna and Zairul 2022) (Andacoglu *et al*. 2023) [31, 87, 6].

1.2.1 Objectives

Considering the scarcity of review papers regarding ILTs and medical training, the scope of this review is comprehensive and forms a consolidated view of the need for such interactive tools in medical education. It presents the state-of-the-art research in ILTs in medical education, providing examples of and suggestions from various disciplines, with the main focus on trainee recruitment, longitudinal assessment processes, and other integrative courses. Due to the specialties and extensive areas of research and experience in medical education, studies surrounding ILTs for these programs may need to be addressed in separate reviews given the scope of this field review. The objectives of this review are: to review different technologies used in research to develop interactive learning tools (ILTs) that researchers in medicine, psychiatry, and surgery believe are essential for improving the quality of training in the area and/or to solve any identified major challenges. Given the challenges in medical education, a further objective was to review the results from studies about the positive impact on training and learning outcomes when ILTs have been employed. Very few studies have been written recently about the future of ILTs; hence, that is the main theme that resulted from this review. (Ryan *et al*.2022) (Tang *et al*.2022) (Barteit *et al*.2020) [75, 83, 10].

2. Interactive Learning Technologies in Medical Education

This topical collection addresses novel practices involving the application of information communication technology (ICT) in diverse stages of healthcare medical training. We specifically emphasize the use and/or potential benefits of ICT as a pivotal resource in medical training programs to support knowledge, develop skills, and teach attitudes. Knowledge in healthcare must be continuously connected with meaningful practice. The use of ICT-based learning tools and resources can be particularly useful to address different learning styles dictating the attitudes and preferences of new generations. Today, we experience a wide variety of educational technologies, encompassing all aspects of learning—cognitive, motivational, practical, and social. Online learning technologies can be categorized into different fields: association of content, simulation, calculative content, creating original content, or connection via social media, including tools and virtual worlds. Given the changes in scholarly practices offered by new web-based technologies, it is likely that in the coming years we will see a greater presence of user-generated content in medical education. Particularly, case creation and publication among communities of students, educators, and professionals will increase. A number of barriers and challenges must be addressed to evaluate implementation costs and assess adequate resource allocation. Both capabilities and challenges of new pedagogical technological tools must be respected and kept in balance in order to effectively engage teachers and learners. Focusing evaluations of these tools at both the macro and outcome-based levels will help generate those evaluations. In conclusion, the choice and the use of particular technologies should be shaped by an educational approach, which is the expected outcome. This paper presents a comprehensive review of interactive learning technologies in medical education, with the aim of improving communication among members of the medical field in the present and future. In addition, to create renewable resources in affirming training and medical education in general, where more is expected from educators and learners. This type of review is important as the exchange of ideas and knowledge, educational practices, influences in the learning process, and logical implications of the use of these new techniques will exert significant influence on medical training and healthcare, specifically regarding education in medical schools. The major aim of integration of these interactive learning technologies in the general context of the medical curricula is to crossover basic/imposed and optional/dependent types. It revolves around promoting curricular strategies that can cater to the intellectual capacity, preference, and satisfaction of each curriculum participant including the learner and the teacher. This will increase the use of ICT in education, especially in terms of medical education. In the field of medical education, total physical interaction versus basic electronic communication has gradually progressed to comprehensive electronic collaboration with advanced interactive learning tools and, finally, to blended medical education. This review will guide those interested in shifting from conventional to modern and advanced methods of acquiring knowledge and mediating the process of science. (Bhoir and Patil2021)(Gómez-Galán, 2020) (SHIMOJO *et al.* 2020) (SABER 2021) (Marín-Díaz 2020) [13, 38, 81, 76, 56].

2.1. Definition and Types of Interactive Learning Technologies

In the following, several definitions of interactive learning technologies are outlined in order to clarify and delimit the concept. The work differentiates between four types of interactive learning technologies: simulated and virtual interactive learning technologies, games and gamification, blended learning, and mobile learning/hybrid learning. All four types are described regarding their definition, context, functionalities, investment, and output, as well as their relevance for medical education. (Aveiro-Róbalo, 2022) (Krishnamurthy *et al.*2022) [9, 50].

Interactive learning technologies (ILT) are digital tools and products that users control to support, document, facilitate, and enhance the learning process. They are used to manipulate, explore, and test educational concepts and enable research into social and ethical aspects of the domain. A recent typology summarized the following ILT: collaborative environments, virtual reality, learning apps, special learning objects, and wet lab software. While blended/hybrid learning, games, and simulations/augmented reality are already established learning formats, there are new types of ILT that bring creative, interactive, and motivating elements into the learning process, such as 3D applications, mobile learning, and movies. Some earlier recommendations regarding these new types of interactive learning technologies should be complemented, since medical education is dynamic and always demands innovative approaches. In turn, the vitality of medical education depends on the successful implementation of cost-intensive and high-quality concepts such as case-based, problem-based, and inter professional learning. Educational institutions demand innovative educational technologies based on an e-learning platform, such as online examinations and learning management systems, too. (Tuma, 2021) (Haleem *et al.*2022) (Qureshi *et al.*, 2021) [86, 43, 70].

2.2. Benefits and Challenges

Interactive learning technologies implemented in medical education have led to substantial benefits. First, these tools can improve learners' involvement and lead to greater satisfaction, thus enhancing student engagement with the teaching material. Second, interactive technology can contribute to students' better performance and growth—positive significant correlations were reported between students' feedback via quiz questions and final exam scores. Last but not least, a higher retention rate of learned material was indicated. Simulation-based mental skills training improved job-related and professional attitudes for psychiatric residents in different doctoral-level training programs. Moreover, evidence demonstrated that an interactive e-module would have a useful role in medical education by simulating real-world encounters with clinical problems and offering feedback. Immediate feedback was beneficial in the study. Instructors found it useful, as immediate feedback allows them to delete existing confusion. (Krishnamurthy *et al.*2022) (Tuma, 2021) (Dhar *et al.*2021) [50, 86, 28].

However, several problems related to the integration of interactive technologies need to be taken into account. Replacing traditional lecture time with interactive technology requires institutions to invest more in faculty time for development. The subjects murmured that writing quizzes could be a burden. Thus, many educators might prefer to create traditional lectures instead of using interactive tools. Other financial and technical barriers are also present. For example, these tools are not free, and because rookie medical students are more skilled and excited about technology, many institutions make new students use this platform only for online tests and research and treatment. Therefore, the adoption and integration of the technology should be supported at the level of the universities. Furthermore, learning technologies are considered to be tools with a means to an end, not ends in themselves. Institutional support and guidance will help assure that educational innovation trumps gimmickry and leads toward substantial implementation and outcomes of applications in practice. (Lu & Zheng, 2020) (Mbunge 2020) (Bereczki & Kárpáti, 2021) [54, 60, 12].

3. Pedagogical Frameworks for Interactive Learning

Educational software has gradually been evolving as technology has advanced. While interactive learning technologies have increased, their integration into both classroom and clinical teaching in medical education is not uniform. It becomes fundamental to link educational technology to well-established educational principles and theory to maximize its potential to enhance learning experiences. This section explores the educational theories and their offshoots that may justify the use of and inform the application of interactive learning technologies in medical education, and be underpinned by informed application towards work on educational technologies. (Emanuel, 2020)(Grafton-Clarke *et al.*2022) [33, 39].

Constructivist Learning Theory: An educational theory popular among medical education circles is that of Constructivist Learning Theory. This approach emphasizes the importance of acquiring and applying knowledge through practical experience and argues in favor of promoting a student's advancement through the different levels of competence at their own pace. Key components of Constructivist Learning Theory include the facilitation of active learning, encouraging students to think critically and solve their own problems, as well as to encourage connections between new and old information. As the conceptual framework guides learning away from memorization towards constructed knowledge, students develop a deeper understanding of the material rather than just surface learning. This educational theory involves technology furthering these goals. (Dong *et al.*, 2021) (Mohammed and Kınyo 2020) [29, 62].

Social Learning Theory: Social Learning Theory is argued to be closely connected with the principles of social constructivism and involves an emphasis on the role of a social context in learning. Learning occurs in so-called social systems which enable and encourage collaborative learning. This collaboration includes revealing standards, resources, and knowledge, and giving students opportunities to develop. Cooperative learning has been shown to facilitate observational learning among group members. These ideas are consistent with the data indicating that students who have been helped substantially by a group member are more likely to help someone else in the group adjust to group pressures. Sharing common goals increases group cohesiveness, and observational learning encourages individuals to learn from one another. While a collaborative, interactive approach to learning is both perceived as beneficial and practical within medical education, it is the pedagogical theories that should inform the conceptualization and implementation of educational technologies rather than vice versa. (Krishnamurthy *et al*.2022) (Saiyad *et al*.2020) [50, 77].

3.1. Constructivist Learning Theory

Constructivist learning theory can be defined as a view of knowledge that is based on the idea that learners are not passive recipients and reproducers of knowledge, but should be considered as creators of knowledge. Knowledge construction occurs through experience and reflection; the process occurs when new knowledge is related and layered onto the old. Therefore, constructivist learning theory utilizes experiential learning and active engagement in the learning process as tools to increase higher cognitive thinking. According to constructivist learning theory, if learners are put in situations where they have hands-on, real-life experiences with theoretical concepts, they are more likely to retain these concepts long term, as they have been able to apply the learned theory to a practical experience. Because constructivism heavily supports the notion that individuals learn and grow from their interactions with others, collaborative activities and classroom discussions are the main method of transferring knowledge in constructivist classes. (Matriano, 2020) (Bell and Bell 2020) [58, 11].

In contradistinction to traditional pedagogy—a teacher-directed, fact-oriented approach—one of the main themes in constructivist learning theory is purposeful and motivated learning that ensues since learners are actively participating in the road to knowledge construction. It is widely believed that learners will be more inclined to take ownership of and responsibility for their own education when they are faced with learning that is of genuine interest and relevance to them. As such, constructivist learning theory encompasses the principles that diverse student needs should be addressed and their prior knowledge should be used as a foundation of new knowledge. If educators choose to integrate constructivist learning theories into their courses, it is of the utmost importance that some sense of fairness and equity is established. (Mohammed and Kınyo2020)(Chuang, 2021) [62, 21].

3.2. Social Learning Theory

Social Learning Theory, an expanded and revised framework of behaviorism, is of particular relevance to the use of video-based debriefing and educational games as interactive learning technologies in medical education. Social Learning Theory contends that individuals learn by observing and modeling the behavior of others through the use of attention, retention, reproduction, and motivation. According to this theory, human learning does not merely occur by means of internal drives or impulses or by external stimuli and responses to one's behavior but by the consequences of expressed or observed behavior. Therefore, Social Learning Theory holds that learning is affected by the social context in which the behavior was modeled, its intrinsic reinforcement, the degree to which the behavior is transformed, the observed consequences, as well as the effect on the learner. (Zhang, 2020) (Tejos *et al*.2021) [90, 84].

This theory can have major implications for the field of medical education. The clinical learning environment is multifaceted and an area where social interaction and collaboration are critical. The learning framework where medical students contribute to one another's learning is gaining importance because of its practicable implications and its compatibility with Social Learning Theory. More educational institutions identify the need to consolidate the lessons learned from real-life experiences with relevant theoretical inputs on professional and ethical issues. Partially guided by Social Learning Theory, more medical institutions have increasingly been experimenting with games, simulations, small workgroups, and interactive case studies to facilitate collaborative work where the students can share diverse perspectives, reflections, and knowledge and engage in community building and development of interpersonal and teamwork skills. Such learning experiences also permit a bridge between undergraduate and postgraduate expectations and allow students to integrate and internalize prior learning. These strategies capitalize on a basic assumption of the social cognitive framework that individuals are more likely to adopt change if they are actively involved in formulating that change. Therefore, reflection, described as both an introspective process in addition to 'looking-back' as in a reflective eye, is a significant feature of these cases. Reflection at an individual and group level is crucial as it can promote the development of the sense of 'situational awareness.' With this learning framework in mind, facilitators can use their small workgroups to converge as well as diverge opportunities in a safe practice environment. (Krishnamurthy *et al*.2022) (Guckian *et al*., 2020) (Campos *et al*. 2020) [50, 42, 17].

Opportunities in course material and processes also present a different role for faculty in comparison to informational styles of delivery. The main role of faculty in the transformative learning framework is to set a tone and stage for group dynamics, articulate rationales, encourage diverse perspectives, facilitate interpersonal understanding, evoke emotional responses, and challenge constructs. They function as stewards of learners, learning, and learning organizations. The creation of a socially constructed and shared understanding that is the basis for the negotiated nature of curriculum, evaluation, and instruction and encourages group dynamics is in line with the principles of Social Learning Theory. By designing opportunities for social learning, educators can in effect foster a supportive learning community that encourages the development of competence and mastery. (Cox, 2021) (Grocott, 2022) [23, 41].

4. Case Studies and Examples

The case studies and examples described in this section provide an examination of the practical applications of the technologies and concepts discussed. Each case study focuses on specific technologies, detailing their implementation in a real educational context, and showcases their effectiveness in achieving teaching goals. By demonstrating the application of interactive learning technologies in various educational settings, we establish that not only are the tools versatile and can be employed across different fields, but that they truly have been used to transform teaching practice. Each case study examines the situation, challenges, processes, solutions, and evaluations of their implementations. Detailed descriptions of teaching outcomes provide evidence supporting the effectiveness of these tools. Furthermore, the case studies examine how the technologies have been employed to meet educational aims, and the effect they have had on teaching practices. (Alamri *et al*., 2021) (Criollo-C *et al*.2021) (Bond *et al*.2020) [4, 24, 15].

The lessons learned from these case studies are paramount to the success of future implementations, providing the necessary background research for continued work to improve the learner experience through technology. The 'pain points' highlighted will demonstrate to higher education institutions, policymakers, educational developers, and medical academics the difficulty of embedding technology and principles of interactive learning. The case studies and examples presented in this section concentrate on specific implementations of technologies, which provide evidence of the technologies used and the strategies in place to improve students' experiences of medical education, in turn leading to a positive impact on learning that raises the caliber of newly qualified health professionals. The implementations detailed focus on how interactive learning technologies have been used in medical education teaching to help students develop real-world skills, and to help them learn to evidence their understanding of ethical, social, and inter professional issues, and also to develop teamwork strategies. These examples also show how these technologies have been used in formative assessment and teaching spaces. The real-world examples aim to show how these interactive learning technologies have created learning experiences that align with real life, to improve students' employability. The use of these technologies helps students develop graduate competencies and fosters positive attitudes toward lifelong learning as digital citizens. It is essential that graduates who have studied in university courses where medical concepts are taught can evidence differing views and present them publicly. Best practice illustrates that students need international, national, and local context skills to develop their knowledge, insight, and research into the portfolios later instigated. Each short section concludes with an examination of the teaching outcomes and effectiveness of the technology implemented. These cases illustrate theory in practice to a fuller potential, showing the importance and impact of these technologies on learning. (Grainger *et al*., 2021)(Ryan *et al*.2022)(Aveiro-Róbalo, 2022)(Barteit *et al*.2020) [75, 10, 9].

4.1. Virtual Patient Simulations

Virtual patient simulations offer learners an opportunity to experience real-life patient scenarios without risk. Both clinical and ethical decision-making can be practiced in such patient scenarios. This risk-free environment denoted by virtual patients replicates real-life scenarios, makes practical training more time-effective and lower cost, and increases training safety; hence, its implementation in medical education has recently soared. Simulators in medical education predominantly target procedural and decision-making clinical skills, as well as patient-doctor communication. A wide range of platforms powered by various technologies are used to integrate virtual patient simulation into medical curricula. Environmental visualizations with varying degrees of immersion can be shown from the desktop and the screen to full-body immersive holographic simulation. (Lee *et al*.2020)(Elendu *et al*.2024)(Plackett *et al*.2022) [53, 32, 68].

Virtual patient learning environments have been found to be well received by students. It has been shown that the level of engagement of students in an audition, firm, and OSCE testing using standard teaching methods and those using online virtual patients has been engaged, providing positive feedback. This evidence elucidates the undeniable potential of virtual patients in increasing interactivity and establishes their use in learning approaches in medical education. However, it must be made obvious to the students that the virtual patient learning experience is of lesser diagnostic accuracy than studying the real patient or even using paper-based scenarios. Some students expect standardized answers rather than appreciating the complexities of patient safety learning through online history taking. A number of research papers have shown encouraging results, such as the fact that early learners were significantly more satisfied with the virtual patient simulation module and perceived it as a better learning environment than their conventional teaching. Other studies have shown significant gains in student approaches to learning results with virtual patient simulations, encouraging the practice to be part of the undergraduate curriculum. Results from a study on the use of virtual patients in learning clinical reasoning revealed that students were more confident and competent after web-based learning using virtual patients. The study suggests that learning objectives can be well achieved through the use of virtual patients. Virtual patient learning experiences are being constantly developed to incorporate advancements in technology, offer consistent quality enhancement in existing content, generate detailed scenarios and levels of difficulty, and provide increasing opportunities for feedback. Such continuous progression will move virtual patient learning from a mere stand-alone learning activity to one that extends beyond degree qualifications to be useful in extra-curricular learning for constituents, including doctors, to remain updated with rapid advances in medical treatments. (Adefila *et al*.2020)(Lee *et al*.2020) (Caprara & Caprara, 2022) [3, 53, 18].

4.2. Augmented Reality in Anatomy Education

The increasing implementation of AR in anatomy education signifies a promising phase and has become a headway in using technology in medical education. AR technology overlays simple visualizations, 3D models, or even 2D images or videos composed of a mix of virtual and real-world actions on a particular mobile device or desktop. The application of AR in anatomy education provides an immersive experience, allowing students to observe three-dimensional complex anatomical structures in a complete context. The spatial elements of anatomy can significantly stimulate student enthusiasm for exploring and learning independent anatomy, thereby increasing the understanding and memorization of anatomical knowledge. Research shows that students' understanding and retention of anatomical knowledge can be increased by applying AR without distracting them from their learning goals. The implementation of the activity is compatible as a blended learning teaching technique based on AR because it can be expected to align with face-to-face lectures and seminars or combined with other methods. Students can choose by themselves with prompt, mobile, rapid, and personalized or adaptive types of learning activities and assess their willingness to participate in the educational session. In relevance to these findings, implementations of AR anatomy educational applications are reviewed. (Chytas *et al*.2020) (Patra *et al*.2022) [22, 66].

In a study, it is seen to have the potential to supplement traditional teaching. The app has been received positively and could become an invaluable aide-memoire when practicing clinical skills. It is acknowledged that the most significant issues will likely arise in the implementation of AR, which will need a dedicated staff member to manage the system and the library. The infrastructure challenge remains repetitive to treatment outcomes and learning benefits, with the cost of the development and translation process that can be extensive. Another substantial problem involved in the application of AR is the need for access to personal desktop computers or the latest smartphones capable of executing AR. In an interesting study, it is suggested that facilities should be provided to students to ensure that they have the personal technology for educational purposes. (Marks & Thomas, 2022) (Haleem *et al*.2022) [57, 43].

5. Best Practices for Implementation

Planning for the implementation of any new resource in any curriculum requires a great deal of careful thought and planning. Full institutional support is essential for conducting a successful transition. Identifying enthusiastic early adopters is important as well, as these faculty members can be natural leaders and champions for the use of interactive learning technologies. A multi-tiered faculty training and support plan can help smooth the introduction of these technologies. Finally, in order to measure the effectiveness of any of these tools, a concerted effort to develop assessment strategies and specific outcomes that allow for meaningful evaluation must be part of the plan from the beginning. (Schreiner *et al*., 2020) (Mazzotti *et al*. 2021) [80, 59].

Assessment strategies for measuring the usefulness of any educational technology are an essential part of the implementation of that technology. For learning tools such as these, measuring the effectiveness of the tools themselves would be the only way to determine if incorporating technology into a particular pedagogical approach is advantageous, and to this end, the validity of those measurements becomes an essential question. The tools and the techniques that are used to make them should be interconnected to create a feedback loop. This process stitches the technical side of the learning exercise with the more pedagogically focused side of the exercise. The aim of the process is to have collaboration between educators and programmers to create a user experience that is efficient and optimized for performance on relevant learning objectives. (Vlachogianni and Tselios2022) (Kubiszyn & Borich, 2024) [84, 51]

Since we have been using technology in the process of teaching and learning, we can provide some recommendations as to how some of the challenges can be addressed along the way: • LDs and Software i. Keep in mind who is developing the LDs and realizing the software. ii. Establish clear purposes of the LD before developers get to work. iii. Foster communication (it should be bidirectional) among involved parties. • Work with developers i. In order for a successful relationship with developers, educators must make sure that the expectations are managed at the earliest stages. ii. Ensure that developers act as tools to execute LDs and not just as a technical team. • New Educational Technologies' Integration i. Interpret each technology's affordances and constraints. ii. Incorporate assessment from the very first stages. • As an assessment approach, focus groups with students should take place as they can help identify how technologies are impacting learning. • Efficiency is augmented when both groups involved design LDs and technologies. (Powell & Leary, 2021) (Pinna *et al*.2023) (BUDOMO *et al*., 2023) [69, 97, 16].

Conclusions In summary, we addressed (a) the rationale for implementing new practices into medical education, (b) the TELs that educators are currently using in their environments to transform their practice and the barriers and enablers when implementing them, (c) the best practices when implementing TELs. For future research, we encourage users to test notions of the conduct trial to see if there is an exploration of the penumbras and emanations from the use of each specific TEL. This will specify how users have implemented the TELs that they are using in the classroom and highlight the characteristics of teachers and students involved in catalyzing the change brought about by these technological experiences. This could then be coupled with research that interviews staff members to capture their perspectives and assist in exploring the penumbras of policy and potential legal implications that sometimes come out of practice. (Saiyad *et al*.2020) [77].

5.1. Faculty Training and Support

The successful implementation of interactive learning systems must include faculty who are trained to use the technology effectively to enhance teaching methods. Educational technologies should have a pedagogy that weaves interactive learning strategies into the fabric of a course to capitalize on the engagement of the student with the content, faculty member, and peers. To achieve these ends, instructors need to have adequate time and effort to learn to use these technologies. Faculty proficiency is deeply tied to the depth of training and reality of support. While many educators are aware of and embrace new technologies, not every academic has access to the support, knowledge, or resources that can lead to success in implementing new methods. A five-step process for successful implementation includes changing attitudes, providing the needed training, beginning the new effort gradually, networking across the institution, and giving the early technical enthusiasts multiple opportunities to develop their projects. There are a number of strategies for promoting a positive faculty attitude toward new technology, including providing adequate training in the use of new technologies and giving faculty time to learn to use it correctly and effectively. (Doran, 2020) (Scherer *et al*., 2020) (Nychkalo *et al*.2022) [30, 79, 65].

While faculty are excited by the prospect of innovative and engaging pedagogy, they are also concerned about the expansion of responsibilities imposed by the online revolution, the time-consuming nature of developing and changing courses for the online environment, and the need for training in technology. Resistance to the adoption of new educational technologies has been well-documented. This resistance is pervasive and may be manifested in a myriad of ways or strategies. The benefits to faculty development translate to an improvement in teaching, an increase in student engagement, a supportive student learning environment, improved satisfaction of alumni and employers, and possibly improved student attitudes and achievement of learning objectives. A related factor is faculty endorsement: with a commitment that includes efforts for the training and orientation of faculty, the possibility of implementing educational technology increases. (Antwı-boampong, 2021) (Kimball *et al*.2022) (Andrews *et al*.2020) [8, 48, 7].

5.2. Assessment Strategies

The advancement of technologies requires the development of updated assessments that accurately measure knowledge and skills important for the learner. Development of assessments in parallel with rapid technology advancements helps to ensure the validity of learning measures. Formative assessments, which can include in-class polling to monitor student progress, may help to inform educational programming, identify students in need of additional support, and help students gauge their own learning progress. As interactive learning technologies, item banks are being developed through collaboration with a wide variety of instructors, and data collection is underway to judge the fairness of and student response to these assessments. Educators must also be cautious in using high-stakes assessments in a new fashion so as not to perpetuate systemic bias resulting from existing educational disparities. Innovative approaches to student evaluations may include having students evaluate each other, known as peer evaluation, although care must be taken to ensure fairness in the distribution of learner ratings. Several systems are available for peer evaluation, with some designed to foster improvement in learners' metacognition based on reflection about their learning experience when completing peer evaluations. One challenge associated with assessment strategies, either involving peer or self-evaluation, includes potential legal implications of sharing unfavorable assessments, such as fear of lawsuits from learners or a decrease in the value of programs associated with poor ratings. In order to realize continued cognitive growth, it is important to ensure that detailed feedback is communicated to the learner in a timely fashion. For this reason, several systems are available to facilitate immediate feedback, although the use of these instant-feedback strategies is still rare in medical education. Additionally, learners who participate in a computer-based system are less likely to realize the role of a human faculty member in a computerized assessment and may face issues receiving social information between themselves and the faculty member related to the assessment inquiries. Should it persist, this may present a categorical issue in their educational experience. In order to facilitate learner self-assessment, faculty can also engage students in reflection, which is when students compare their learning with predetermined, clearly articulated learning objectives. A learner-centered pedagogical approach that emphasizes self-assessment can be beneficial to students, as they develop a greater sense of responsibility for their own learning and gain a clearer assessment of their own skills and knowledge. Therefore, it is suggested that educators use strategies that offer immediate feedback to students and allow for self-assessment through the use of detailed, timely points of immediate feedback. This ensures that students are able to correct their misunderstandings before they advance in their studies. (Kreitzer & Sweet-Cushman, 2021) (Meijer *et al*.2020) (Hill & West, 2020) (Carpenter *et al*.2020) (Gao *et al*., 2020) [49, 61, 46, 19, 35].

6. Future Trends and Emerging Technologies

Advances in technology represent an inflection point in the development of medical education and are expected to transform medicine. The emerging trend of artificial intelligence includes deep machine learning, which enables users to create new functionalities as opposed to strictly following the manual input of programmers. Large databases have already been created for medical data and these databases will be employed to train predictive models. In the future, medical monitoring and management will track natural biological variation as well as the effectiveness of therapy. Another technological advancement involves simulated environments to not just replicate a field but to improve it by avoiding constraints and shortcomings. Virtual reality is a mature technology that can empower medical education and skills demonstration by creating realistic 3D interactive, immersive, and manipulatable scenarios. Virtual reality has found an excellent niche in the acquisition of procedural skills through instrumentation. The integration of AI and virtual reality technologies, known as virtual characters or agents, will be able to provide personal and specific responses that simulate main actors, thus favoring a major shift in the improvement of training in medical communication and skills. As more data is collected, virtual reality offers the potential for personalized medical applications and will revolutionize the way medical education is delivered. (Goh & Sandars, 2020) (Emanuel, 2020) (Gaur *et al*.2020) [36, 33].

Despite these evident advantages, the successful integration of new technologies into any educational curriculum, such as in the medical field, is challenging. In an era of consensus on the value of 'Education 4.0,' the question arises about how educators should equip themselves to correctly interpret and navigate these future trends. It is suggested that, since there is no substantial literature on the application and effects of virtual reality in medical education, it is essential for educators to investigate trends, applications in education, areas of interest, and newly emerging technologies for the best possible educational implementation. As 'Education 4.0' continues to evolve, it calls for continuous and collaborative research and development between educators and their educational systems. The social implications of new technologies, from development to provider, must be considered and made palpable. The expectations of the individuals involved are an essential criterion for defining the right pedagogical approach. New teaching and learning approaches are already emerging, such as flipped classroom, which inevitably relies heavily on these technologies. (Abich IV *et al*., 2021) (Hamilton *et al*.2021) (Fan *et al*., 2022) [2, 44, 34].

6.1. Artificial Intelligence in Medical Education

6.1.1. Introduction Artificial Intelligence (AI) has been proposed to revolutionize medical education by enabling a more personalized learning experience to cater to different student learning preferences and levels in real time. AI can provide instant feedback, optimize teaching material, and evaluate students' performance in selected domains, behaviors, and attitudes according to case-based training. Although AI can change traditional teaching patterns, transforming it into a more limited, simplistic, and technologically driven approach—the final migration into professional practice—cannot be guaranteed. This is especially true in the current period, in which areas such as the application of modern technologies, their adaptation, and transfer to education and training have revealed that they are 5 to 10 years ahead of the necessary internal and external adjustments. However, AI should still be used in accordance with general good practices and general biological education principles. (Maghsudi *et al*.2021) (Alowais *et al*.2023) [55, 5].

6.1.2. AI-Enriched Curricula Today, various universities use innovative AI solutions to guide the development of simulated patient interactions for healthcare students. A spectrum of AI-driven applications manifests real-time conversation between a healthcare student and an AVE, taking the interaction to unexpected or unexplored areas of physician–patient communication. Some of these AI applications can also record the conversational flows that occurred between the AI system and a given student and then implement auto-evaluation mechanisms to provide feedback on the points required by the intended learning outcomes, as assigned by teaching staff. The need for such an AI-enhanced approach arose from the problem associated with assigning the best user group according to authentic VMs for at least all high-fidelity groups. Exposing UoA students to cases shared with other groups led to a more comparable future CMHL group residency progress compared with the case-no-case curriculum. (Harmon *et al*., 2021) (Reed & Dodson, 2024) [45, 71].

6.2. Virtual Reality and Simulation

6.2.1. Virtual Reality and Simulation

Virtual reality (VR) is a rapidly expanding technology that, due to its immersive capabilities, is being investigated in medical education applications. Unlike traditional simulation approaches, VR simulations better replicate a clinical scenario. They provide learners with realistic scenarios, which enhance engagement and motivation while maintaining the repeatability and low-risk environment of the simulation. One of the key benefits is that VR simulation is equally as effective as, or more effective than, traditional training approaches for simulating skill acquisition and improving skill retention. Within health education, VR and augmented reality (AR) technologies are being developed across a variety of medical disciplines and at all levels of clinical experience, simulating clinical environments from operating rooms to patients' houses. (Rourke, 2020) [74].

Healthcare professionals must be prepared for real-world challenges; therefore, simulation fidelity is considered when making choices in relation to access to healthcare. VR is often more expensive to implement than other modalities, and although this access barrier is likely to lessen over time as the technology becomes more widespread and affordable, it currently exists. VR training has been used successfully in pharmacy for interpersonal communication skills and conversing with patients. Beyond undergraduate training, simulations using VR have been designed to teach advanced surgical skills, such as laparoscopic surgery, which has been tested with first-year surgical trainees. The feasibility and acceptability of using VR surgery simulation have been explored, with early results showing a positive response from trainees. A case study highlighted the lack of haptics in traditional VR surgery simulation tools and presented a practical way to implement a low-cost haptic feedback system, showing the potential for advances within this field. (Shorey *et al*., 2020) (Ilardo and Speciale 2020) [82, 47].

7. Conclusion

Interactive learning technologies in educational improvement, especially in the field of medical education, seem inevitable in view of what has been outlined in the comprehensive review. Our review of the published literature has shown that interactive learning technologies provide transformative learning experiences in medical education. The increasing access to technology, broadband internet, and online tools, which is a global trend, increases the acceptance of this method among medical students. Institutions and educators must continue to strive for research and to increase the implementation of more innovative technological advancements in medical curricula. Interactive learning technology facilitates the active contribution of learners in the learning processes and has the following properties: (1) it is responsive and adaptive to the types of questions that students need to answer, and (2) it provides feedback to students. Assisting learners with problem-solving, simulation methods together with feedback strategies, and patient follow-up scenarios demonstrate that simulated environments are useful for the development of clinical reasoning skills and are acceptable to medical students. This finding is confined by the limited number of studies identified in this area, the diversity of the assessment tools used, and the sophistication of the simulation technology, which currently poses challenges in terms of broader implementation at a curricular level. The design of future research in this area needs to address these issues. Implementing interactive learning technologies brings significant changes to medical curricula and teaching methodologies. Future challenges will be the embedding of these technologies in structured curricula, setting constructive assessments of student learning and technologies, and planning strategic for technology that will be replaced by new emerging technologies. The paradigm shift in medical education is inevitable, and interactive learning interventions are important in curriculum development. The curiosity for further research will usher in a new era to understand how and what implications arise in terms of the role of faculties and teaching hospitals. Nevertheless, a transformative digital pedagogy requires faculty capable of designing and delivering interactive content, and institutions must invest in national and institutional initiatives targeting this particular need.

7.1. Summary of Key Findings

In an overarching review of various technologies, we concluded that interactive methods can help engage medical students and yield better learning outcomes. A robust evidence base supported the advantages of interactive learning, although anomalies exist, generally without empirical validation. Nonetheless, a myriad of challenges were noted in interactive learning technology implementations, suggestive of several student- and faculty-driven issues. Most pertinent to our discussion in this review, we found that faculty development and support in the application of these approaches was somewhat lacking. Finally, perhaps more research needs to be conducted in which the use of these tools can be underpinned by specific learning theories. This review indicates that greater incorporation of interactive learning technologies is needed in medical education. Accordingly, a number of practical examples were provided, aiming to elucidate the implementation of these methods. Several learning technologies are discussed, accompanied by practical examples used in medical education. It is very essential in the modern era to incorporate socially interactive methods and technologies in the pedagogical settings. However, considering the diversity of students and their needs, it is recommended to incorporate a variety of techniques to blend learning. The same principle can be applied to our attempts at using technology, which should also cater to the diverse learning needs of our students. It can therefore be hoped that by using interactive teaching methods, we can shape a new generation of more effective health professionals. (Krishnamurthy *et al*.2022)(Challa *et al*., 2021) [50].

7.2. Implications for Medical Education

The review has advanced an understanding of the literature by discussing and further elaborating multiple ways in which interactive educational technologies can be implemented into the curriculum to provide a high-quality learning experience for future healthcare professionals. The implications extend beyond the level of medical and health professions curricula as it also targets other levels of higher, professional, and vocational education where the learning objectives are predicated on socially appropriate practical performances. The discussion prompts educational policymakers to acknowledge the unequivocal need for the integration of educational technologies in producing work-ready graduates with capabilities that professionals of the 21st century are required to possess. The findings also provide some guidelines and strategies for those devising and implementing policy, curricular, and professional development. In summary, the review calls upon educators to readily embrace the richness that educational technologies can add to designing modern society's professionals. Investing in the human capacity to be innovative in translating theory into practice is as important as the management and administrative structures expending funds on information and communications technologies. (Tuma, 2021) (Moro *et al*.2023) (Ryan *et al*.2022) [86, 75, 63].

For institutions to explore the use of educational technologies to ease the documentation burden and enhance educational experiences, they need to consider how to best create cultures that support and mentor faculty and course coordinators in such endeavors that, in turn, foster continuous improvement practices within the organization. It is also valuable to promote regional, national, and international collaboration to facilitate the customization and dissemination of evidence in a not-for-profit manner. This is seen as being facilitated if there are, for example, isolated 'centres of excellence' along with expert groups from several institutions who pursue continuous research and development into the improvement of educational technologies. Communication and partnership with commercial providers to extend criteria is also likely to increase the effectiveness and relevance of the use of educational technologies. The review recognizes the consensus from the forum and broader evidence to continue research that leads to improved educational strategies in addition to creating ways to explore the effects of adoption and diffusion on educational and economic outcomes. However, it points out the situation is rapidly changing, suggesting an urgent need to constantly re-evaluate current evidence. Funders and researchers are thus advised to invest in strategies rather than specific technologies for these reasons. (Womack *et al*.2020) (Davis *et al*.2022) [90, 25].

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