Twenty-First Century Immersion Technologies in Health Professions Pedagogy

T

Catherine Hayes
University of Sunderland, UK

INTRODUCTION

"Life is not a problem to be solved, but a reality to be experienced."

Søren Kierkegaard (1813-1855)

The justification of pedagogy in the context of Extended Reality (XR), which encompasses Virtual Reality (VR), Augmented Reality (AR) and Mixed/Hybrid Reality (MR) has become an ongoing source of complex ambiguity over the last decade, that the COVID-19 pandemic has only served to exacerbate (van der Niet and Bleakley, 2021). Ensuring the validity and reliability of XR experiences within health professions education remains central to the potential to rule out technologies as adjuncts to optimal pedagogic practice as an authentic means of providing insight and illumination of medical contexts, scenarios, and disease processes (McGrath et al, 2018). For the purposes of this chapter there will be four fundamental operationally definitive terms of what the umbrella term XR encompasses, firstly VR refers to the use of computer technology in the creation of simulated learning environments. Secondly, AR pertains to the addition of computerised content as an overlay to reality, which means that learners can actively interact both with real world and augmentations of it at the same time. Mixed or hybrid reality refers to the transection of virtual worlds and actual worlds, where physical and computerised objects can interact and exist concurrently. XR encompasses all of these and as a collective they have revolutionised health and medical training, particularly in relation to the practise of risk management and professional role identity in life and death situations, for example obstetric emergencies, as reported by Hayes, Hinshaw and Petrie (2018).

Training for the strategic management of risk in healthcare practice in situated contexts of healthcare provision has been a key focus in the use of XR in practice (Hilty et al, 2020). Not only does it involve rational aspects of cognitive knowledge or the purist demonstration of psychomotor skills and affective domain learning (Zulkilfli, 2019). It also encompasses the intuitive, tacit and largely intangible intellectual instincts that develop with sustained experiential learning (Humpherys, Bakir and Babb, 2021). One of the key issues has been the challenge of assessing the last of these, what XR has enabled is the benchmarking of perceived levels of interprofessional and multi-disciplinary teamwork, where intuitive knowledge can be used to measure risk, regardless of the level of the organisational hierarchy within which personnel are employed (Goh and Sandars, 2020; Hayes, Hinshaw and Petrie, 2018). This chapter will explore the key epistemologies or ways of knowing, from a theoretical perspective, that can be used to ensure the level of authenticity necessary to highlight the pedagogical shifts in the application of

DOI: 10.4018/978-1-6684-7366-5.ch023

learning theory which now characterise responsive curriculum design and adaptation to accommodate XR in practice.

BACKGROUND

The ongoing pandemic, which on February 14th, 2023, had reached 755,703,002 confirmed cases and 6,836,825 million fatalities, has not only changed the world of education in its current form, but it has also likely altered its mechanism of delivery for the foreseeable future (WHO International Data, 2023). In practice the pandemic has seen universities close, a switch to hybrid models of learning and education, a social science, depleted in terms of its capacity to engage people in face-to-face meetings (Okoye et al, 2021). The plethora of academic articles surrounding online learning is phenomenal, but few address how a fundamental paradigm shift in Higher Education is implemented methodologically (Luctkar-Flude and Tyerman, 2021). What is usually described is a narrative description of the processual use of technological intervention, rather than any degree of alignment in terms of underpinning theoretical justification for implementation, or indeed the constructive alignment demonstrating best how processes of assessment can effectively be driven by complementary processes of teaching and learning (Moreira, 2020). The physicality of learning has also been altered beyond recognition, seeing people as upper torsos and faces has changed everyday interaction in the situated nature and context of learning, yet minimal evidence exists as to the long term impact of this on motivating, engaging and sustaining active processes of learning, teaching and assessment on an individual level (Park and Kim, 2020). By over reliance on the physicalism of the articulated voice and postural positions of the upper torso, executed in an atmosphere of scrutiny, learners have had to change their interaction so that their degree of interaction is heavily influenced and constrained (Obrad, 2020). Whilst predicting how global disease and inequality will influence the future of education, it is impossible to ignore potential challenges that lie ahead for Higher Education (Bevins et al, 2020). It is possible to inferentially predict that COVID-19 may be one of the first of a new generation of global pandemics that will need to be death with alongside dramatic changes in overall global warming, which will also ensure that populations which are densely populated suffer most severely (Negev et al, 2021). Alongside the issue of pandemic disease is the prospect of global catastrophes and natural disasters occurring far more frequently and necessitating support and address now. The progressive redevelopment of existing technology to accommodate this is more than apparent, so that learners can engage physically in medical and healthcare settings with less extensively sized equipment and a greater capacity to seamlessly integrated extended reality into all practice (Yigitcanlar et al, 2020). Geographically there are other issues at play, in terms of the accessibility of technology across global outcomes, with the result that some countries cannot be guaranteed adequate internet access, bandwidth or the cost of the technology products may simply be prohibitively expensive (Horton, 2021). Being cognisant of this necessitates ensuring both affordability and accessibility across the globe if the differential inequity between countries is to be addressed on an ongoing basis. Being able to standardise and regulate experience for learners is also of fundamental importance if equity and parity of experience are to be assured across these programmes (Crouch et al, 2021).

HEALTH PROFESSIONS PEDAGOGY AND CURRICULUM DESIGN

Pedagogical design and its address within the context of Higher Educational institutional curricula often places processes of curriculum justification and design under scrutiny (Annala et al, 2021). This is largely attributable to the complex ambiguity that curriculum designers have to contend with, in terms of the technical capacity of XR equipment and the accompanying resources they necessitate (Aebersold and Dunbar, 2021). A key example of this is the multi-disciplinary perspectives that designed scenarios must authentically represent within the context of health and medical education, where XR is implemented in practice (Antoniou et al, 2020). Because of this, the concept of experiential learning has become a focus for the opportunity of ensuring that XR is relevant to real world application in practice, with the introduction of its continuum's integral parts (AR, VR and MR). The published evidence to date demonstrates that XR training has been shown to improve learner performance skills across an array of learning domains (cognitive, affective, and psychomotor) within the context of instructional simulation (Tabatabei, 2020). Having moved firmly from proof-of-concept pilot studies, XR as an embedded part of health and medical curricula is being used across a wide variety of simulated contexts (Tang et al, 2020). In comparison to traditional didactic teaching methodologies the benefits are seen within the areas of student motivation, confidence and the capacity of learners to take measured risk within the context of a consequence free facilitative environment where constructive feedback on performance can inform reflexive praxis around complex ambiguity and clinical decision making. Acclimatisation to new contexts and settings, for military learners, for example is invaluable, where introduction to new unfamiliar climates and contexts is undertaken via constructivist experiential learning opportunity in interactive immersive scenarios, where the pace and timing of exposure can largely be controlled in line with learner need (Cobos, 2020). The addition of iteratively increasing levels of complex ambiguity as skill increases is another opportunity for the formal scaffolding of learning within customised immersive experiences (Orr et al, 2020). Depending on whether learning is about the magnification of micro- theoretical concepts such as, for example atomic level particles, blood corpuscles or synaptic junctions or whether learning is centred around macro social constructs such as social justice and equity in different contexts of culture or climate, immersive technology with XR has the potential to extend the reach within and between academic pedagogies and disciplines and as a direct consequence impact on the capacity and capability of multi-disciplinary and interdisciplinary professional working at the front line of patient care (Mitchell and Boyle, 2021). Confidence underpins learner motivation and in turn elevates levels of competence, which ensure this iterative cycle continues (Owens, 2021).

Roussin and Weinstock (2017) detailed the pedagogical challenges faced by educators and trainers leading simulation-based training in the context of healthcare and medical services. In relation to the theoretical underpinning of their work, they presented the complexities of managing programmes in relation to single and double- loop experiential learning and the impact of organising organisational hierarchies in relation to the need to gain experiential learning in practice. Whilst their work omits specific reference to the implicit value of tacit knowledge in crisis situations, the functional insight they provide in relation to situated learning is invaluable in relation to the overall administration of optimal multidisciplinary and interprofessional teamworking scenarios. Most significantly their research demonstrated the application of scaffolded learning to the point of autonomy, consistent with Vygotsky's Zone of Proximal Development (1978) but also Argyris' acknowledgement of the relevance of single and double loop learning and the need to challenge and reconcile assumptions relating to the acquisition of knowledge through experience. Both raise important issues in terms of the longitudinal provision in education with XR, in relation to the phasing and iterative presentation of learning outcomes, each serving to consolidate consequent stages of learning within and between cognitive, affective and psychomotor learning domains.

DRIVING AUTHENTIC LEARNING VIA PEDAGOGICAL JUSTIFICATION

Pedagogical design of the blurring of where reality and actuality co-exist within the context of digital immersion underpins the concept of validity in XR. While pedagogical research and applied praxis are still at the mercy of technology to a certain extent, as the virtual world becomes progressively more advanced, then so too will the capacity and capability for authenticity and validity within medical and healthcare education and training (Ligtart et al, 2021).

It is useful here, to consider the degree to which VR, AR and XR have been integrated across the health professions within differing signature pedagogies and the cognitive, psychomotor and affective learning domain skills necessitating address. It is here that some healthcare professions can be delineated in terms of their functional involvement in patient centred care. For example, dentistry and physiotherapy have relatively functional interventions, whilst the work of a podiatrist, due to the ergonomic positioning of a practitioner, entails more of an opportunity to engage psychosocially with patients during their appointments (King et al, 2018). Indeed academic debates have historically been posited about the functional basis of such healthcare professional roles as dentistry, since they are so functional in nature that people queried whether they could actually be regarded as a profession at all (Welie, 2004). The other implication is the stage of learning that medical and allied healthcare practitioners have reached in their career trajectories, where VR, AR and XR may be implemented most appropriately. The majority of published literature to date focuses on learning ‘in situ’ whereas the assessment of learning longitudinally in the context of real life praxis, is often evaluated with a degree of tokenism by those whose initiatives have introduced simulation in the first place.

The operationally definitive terms of VR, AR and XR are significant when considering the nature of the artificial environments that are created in the exploration of potentially risk filled scenarios, which emulate the real world (Alnagrat, Ismail and Idrus, 2021). This is primarily in relation to how artificial intelligence can be embedded within the context of virtual and simulated learning experiences, which also have to be optimally facilitated by staff skilled in the field of clinical simulation (Abbas, Kenth and Bruce, 2020). Central to progression in these aspects of a pedagogical paradigm shift, is the need for active dissemination and sharing of knowledge creation and acquisition that happens at the front line of medical and healthcare education where simulation in the context of XR are the expected and anticipated norms of undergraduate and postgraduate academic curricula across HEIs (Luo et al, 2021).

IMMERSION IN LEARNING EXPERIENCE

AR and VR enhance health professions education via immersion in learning experiences, positively influencing levels of engagement and motivation and by creating an atmosphere of interactive dialogue, which in terms of social inclusion can have a direct impact on the reduction of learner stress and anxiety (Brandon, Freiwirth and Hjersman, 2021). Encompassed by the umbrella term of XR, AR, MR and VR all bring a signature technological approach to applied praxis in the context of healthcare professions. In instances where different levels of sensorial intrusion are now widely used to extend the reach of pedagogic practice in medical and healthcare education and training, this has broad ramifications, not only on the practical delivery of emergent technology in practice but on their pedagogical theoretical justifications as well (Robert, 2021). In instances where the affordability and hence the extent of digital technology available determines accessibility in practice-based settings. In terms of a hierarchy of availability, AR is perhaps the most widely available and least invasive of all XR and can be easily accommodated by readily available display systems (Suryanti et al, 2020).

In instances where the need for the relevance of space and situatedness and context is of fundamental importance, then MR is the best platform for integration into available physical environments. In this sense MR fills the gap that VR leaves, in permitting users to physically interact with pre-identified physical spaces (Silén et al, 2008). Dimensionality is also of key importance in terms of whether the ability to facilitate visualisation in 3-D is something which can actively contribute to the acquisition of tacit knowledge and actively contribute to a more finely tuned intuitive response to any given scenario in medical and healthcare practice (Gerup, Soerensen and Dieckmann, 2020). MR effectively bridges the gap between AR and VR as a consequence of the development of the hardware capability of display screens and visualisation resources (Juraschek, 2018).

Research into XR pedagogical initiatives and methodological designs is usually characterised by relatively small-scale case studies, focused on the collection of qualitative data rather than tangible quantitative evidence about the impact of XR in practice (Hamilton, 2021). Those which have succeeded in this, tend to focus specifically on psychomotor skill or level of cognitive improvement rather than affective domain learning. The concept of tacit knowledge is also one which remains relatively underexplored and which remains almost a hidden bonus in developing the confidence of collective team hierarchies in clinical and medical practice. making generalisability of findings to other contexts and settings. Whilst this is a disadvantage, the potential for transferability of findings within and between similar situational contexts and settings across the global can be quite high in terms of overall content validity (Levitt, 2021).

The majority of XR technologies now extends the bridge between simulated environments and their polar opposites in physical reality. The rate of progressive developmental platforms has been amplified and magnified by the global COVID-19 pandemic, which has contributed to a paradigmatic shift in learners centred hybrid and hyflex learning and teaching opportunities across the medical and healthcare professions pedagogies (Acharya, 2021). As signature disciplines, these professions have maintained a certain degree of reticence to engage fully immersive technology within the context of clinical healthcare practice, since this completely detaches the clinician from their normal parameters of visual capacity. Whilst lenses are acceptable, they also permit and maintain human characteristics and gestures such as established eye contact and that degree of connection, which patients deserve and need (Jongerius et al, 2020). This has been particularly evidenced within the context of brain and cardiac surgery, both of which have optimally utilised these technological advances for the patients they serve.

TRADITIONS IN MEDICAL AND HEALTHCARE EDUCATION

Across the continuum of signature pedagogies that contribute directly to medical and allied health education, it is anatomy and mathematics which arguably transcend most disciplinary boundaries (Hayes and Capper, 2020). The visualisation techniques, which both permit and facilitate enhanced pedagogical teaching methodologies respectively appeared first in the context of simulation within the aviation industry at the beginning of the 20th Century. Their developmental progression over the last century and the early part of the 21st Century has ensured that levels of complex sensory and visual experience have now become a mainstay of medical and healthcare education and training programmes (Jentsch and Curtis, 2017). In the sense of providing students with the opportunity to undertake complex and risk inclined procedures, simulation is an invaluable resource. Within the context of safety, processes of experiential learning from practice can be fully exploited without there being any tangible, negative consequences in reality, so that unwanted outcomes can be illustrated and acknowledged without them actually ever having to come to fruition to do so.

Resources and student access to them have been a key issue during the pandemic, particularly for health and medical students for whom access to real- life anatomical models and cadavers may have been completely negated (Hilburg et al, 2020). For these students XR has ensured an opportunity for continued engagement with the discipline of anatomy and physiology across a range of contexts and settings. Since learning is extensive in relation to the need to develop a 3-D knowledge of bodily organs and systems, then the spatiality that XR offers also permits dynamic interaction, which otherwise would not be possible. In relation to the functional role of bodily organs and systems, XR has the added advantage that simulation of the dynamic motion of the body can be visualised as a learning resource, in contrast to cadavers, which are obviously non-functional (Ziker, Truman and Dodds, 2021). Within this simulation, it is also possible to identify, isolate and examine the individual functionality that specified aspects of these systems perform via repeated familiarisation. Ensuring learners iteratively progress from novice to expert within the use of XR of this nature, also ensures that learners can work in a risk free environment, which nevertheless serves to introduce them to the experiential learning which can form a solid foundation for their future professional careers in healthcare and medicine. In terms of pedagogic design and academic rigour the use of XR also provides an ideal opportunity to benchmark functional skills acquisition, alongside the real-time assessment of clinical practice and the opportunity for them to be exposed to sensory feedback from the situated learning they undertake (Kang et al, 2021).

BUILDING CAPABILITY FOR CLINICAL EDUCATORS WITH XR

The education and training of future medical and healthcare staff is not only dependent on disciplinary expertise but also the capacity to provide optimal learning experiences which in turn drive processes of assessment which are authentic and have real world validity and credibility (Voštinár et al, 2021). Future practitioners of all disciplines across the health and wellbeing continuum not only have to use evidence-based practice to discern clinical decision making, they also have to continually use scientific published evidence to iteratively update their continuing professional development in practice (Agha, 2021). As methodologies of pedagogic practice have become progressively more student there has been increasing emphasis on a move away from traditional rote learning to mechanisms of interactive, engaging processes of learning, which ensure deep rather than superficial learning across all aspects of education and training. Alongside this, is the recognition that learning driven purely by pressure to 'perform' within the context of examinations is futile in the truest sense of meaningful learning opportunity. In order to achieve this, XR can be regarded as a significant tool in the armoury of medical and healthcare educators who use this form of specialist resource to reinforce, motivate and enhance learning opportunities through authentically, strategically and constructively aligned academic curricula in Higher Education (Howell and Mikeska, 2021). Future practitioners also need the capacity to be educated in authentic situated learning contexts which are:

- Based on principles of diversity, equity and inclusion in terms of both optimal provision and optimal service to global, national, regional and local practice areas.

- Built on an ethos of compassion for all recipients and a respect for human life and wellbeing.
- Co-constructed with medical and healthcare service users and their families and carers.
- Designed on the basis of evidence-based healthcare practice and evidence-based processes of educational provision.
- Drivers of high quality multi-disciplinary and interprofessional patient centred teamworking.
- Effective in their capacity to drive education in relation to health and medical outcomes for patients at the front line of clinical care.
- Globally responsive and globally focussed
- Pedagogically designed and responsively designed on the basis of need and healthcare priorities in applied practice.
- Responsive in their capacity to dynamic and iterative change in healthcare landscapes.
- Specifically designed to value and promote autonomous learning, capacity for teamwork and proactive higher order critical thinking in relation to problem solving in health and medical care practice.

Within the context of XR integration, each pose individual challenges in relation to ensuring that digital technology is only ever seen as an adjunct to medical and healthcare education for the human race, not merely a functionalist or solely objective driver of it (Gandolfi, Kosko and Ferdig, 2021).

EXPERIENTIAL LEARNING THEORIES

The grander philosophical debates of perceived versus actual reality on an individual and collective basis are central to the processes of teaching and learning with XR. As a tool for the enhancement of understanding, meaning making and then critical reflection on practice, digital technology in invaluable as an adjunct to the human facilitation of knowledge, skills, attitudes and behaviours (Logeswaran et al 2021). The philosophical underpinning of experiential learning has its origins in constructivism, which is central to the acknowledgement of truth, either perceived or actual, and the capacity of all individuals to construct a perspective on truth based on their immersion in experience and the meaning they make of it (Koufidis et al, 2021). In this sense education is an entirely different experience for everyone who experiences the same phenomena and it is this individual experience and perspective meaning making, which lies at the heart of both collective and personal processes of transformation. The construction of a version of reality ensures that different perspective lenses can be applied to the same phenomena, so that scrutiny from several sources of triangulation can take place. Whether the experience differs collectively between adults and children in terms of capacity for meaning making through experiential learning was the source of seminal debate in the late 20th Century, with Knowles assertion that there was a distinction between andragogy, in terms of 'adult' ways of knowing and that of 'pedagogic' or child-based learning. What is arguable more relevant is the concept of lifelong learning, across which learning takes place from the cradle to the grave, as a temporal mechanism of integrating the prospective with the retrospective and making inference from it as part of the integral processes of reflection and reflexivity (Loeng, 2021).

THEORETICAL UNDERPINNINGS OF XR PEDAGOGY

Experiential learning has become a byword for the placement experiences that medical and healthcare students undertake as an integral part of their undergraduate studies with patients, whose consent, briskly acquired provides novice learners with an opportunity to build confidence and be guided by an ever vigilant and highly respected disciplinary expert observer. In instances of postgraduate study, it may conjure the image of a professional moving from competence to proficiency and consequent mastery of their specific field of disciplinary context (Mortimore et al 2021). Medical training to the uninitiated is instilled with the imagery of cadaveric dissection as a means of visualising what lies beneath the skin that is to be negotiated across a respected lifelong career. In contrast to practice-based experience at the front line of patient care in the context of care provision, though, the two are very different. It is here that whilst disciplinary knowledge and skill are invaluable to the expert educator, that skills of pedagogical praxis are equally important if the acquisition of knowledge which will underpin this lifelong career is to be assured and validated in practice. The theoretical underpinnings of learning and teaching have resonance in relation to the eventual capacity of medical and healthcare students not only to make meaning of experience but also to question that which cannot be taught, the tacit and reflexive response to intuition, which can only be derived from inner conscience and derived from processes of experiential learning in the psychomotor, cognitive and affective domains of learning, which can be tangible assessed and used to benchmark fundamental knowledge and skills acquisition (Birt et al, 2018). Similarly, the capacity to transfer knowledge from the context of learning to the real world with patients who have an immediate need for assessment, diagnosis and consequent management is highly relevant to the potential to scaffold knowledge as clinical learners each move from the state of disciplinary novice to expert (Durning & Artino 2011)

MEANING MAKING IN HEALTHCARE PRACTICE

At the heart of capacity to learn and build on pre-existing experience is the theory of constructionist philosophy which when integrated alongside sociocultural perspectives from processes of active participation lies at the heart of all learning. The delineation between and linkage across theory and practice has become a fundamental goal of all involved in workplace education and training (Dennick, 2016). Since learning is both an individual and collective experience in the same sense as learning. What the Covid-19 pandemic detracted from was the fact that education is a social science, wholly reliant on interactivity and the derivation of meaning from multi-faceted and complex situational specificities, which when grouped as a collective constitute human experience. Being able to understand and frame the margin between knowledge and research entails a consideration of both the origin and consequent history of learning (Ten Cate and Billet, 2014). Alongside this, it is also necessary to consider how knowledge acquisition is gradually scaffolded through experience from novice to expert and to value those contributors to pedagogic practice who have acknowledged and formally recognised this (Graf et al, 2020). Whilst Kolb is often regarded as the seminal theorist of experiential learning, however there are several others of direct relevance to the pedagogical implementation of XR (Heong et al, 2020). Rooted in constructivist perspectives, Kolb's is of relevance since its focus lies in the translation of experience from external sources into epistemic cognition and meaning making on an individual basis. Kolb's theoretical perspectives are of importance when considering the processes of experiential learning, which in turn contribute to elements of subconscious bias that inevitably contribute to the professional identity of educators from specific signature pedagogies and disciplines. Social learning theory also plays a significant role in the development of experiential learning. It is a perspective upon which health and medicine have drawn heavily upon in the shaping and framing of new pedagogical perspectives. It frames learning outcomes in the context of their impact in applied praxis rather than in terms of their individual impact and acknowledges that these are often a natural by-product of distinctive social cultures and contexts. This also aligns with the concept of lifelong learning within which there is the acknowledgement that learning is dependent on levels of increasing experience (Hartman et al, 2020).

SCAFFOLDING LEARNING

XR provides an environment where the context of safety ensures that learners can iteratively be scaffolded through processes of knowledge acquisition and the basis of psychomotor skill competency and eventual mastery can be gained and evidenced in practice (Adefila et al, 2020).

One important aspect of the integration of XR though, is the degree to which it increases non-patient-based learning and the potential impact of this in relation to a lack of authentic human interaction across health and medical curricula. What this debate highlights are the significance of strategic curriculum design and justification across all programmes, where pedagogical constructive alignment is pivotal to outcomes-based assessment techniques and the credibility of their implementation. Similarly, where variations and combinations of XR are integrated across academic and clinical curricula then the technology selected ought to be aligned with the need for the acquisition of specific skills and techniques. The integration of XR and its components does ensure, however, that during the process of learning and the acquisition of new knowledge, skills and behaviours that ensure:

- Aims and objectives can be aligned with the opportunity for ongoing feedback and the opportunity to rehearse and develop new skill sets from novice to expert.
- Benchmarking of learner performance can be isolated into specific learning domains and assessed accordingly, with the potential of identifying individual learning need.
- Interruption and hence unnecessary and unwanted distraction, during the process of learning, can be avoided
- Patients can avoid any risk in terms of discomfort or the need to move regularly, as learners iteratively develop and refine new skills, where they can focus on domain specificity until a level of competency and eventual mastery is reached.
- That individual learning styles can be accommodated and encouraged by constructively aligning individual learning outcomes within each teaching session, where time permits.
- That psychomotor tasks can be repeated so that exposure, practical viability and accuracy can be iteratively increased.
- The opportunity for focused learner reflection on specific aspects of knowledge and skill acquisition and a reflexive approach for the address of individually recognised shortfalls.
- The theory-praxis gap can be gradually reduced by scaffolding learning and gradually increasing exposure to real life contexts where patients and their families are an integral part of authentic learning.

Non-technical skills such as interprofessional working and multi-disciplinary team working and the clinical attributes they necessitate in terms of optimal interpersonal communication and the management of the clinical environment characterise the skill sets necessary to ensure the achievement of holistic learning in proficient practice (Dehghani et al, 2021). Examples where this is now integrated in practice are in the skills and drills training, where it is also possible to integrate aspects of complex ambiguity and stress into situations, where a clear integration of psychomotor skill, affective and cognitive domain knowledge and application are necessary within any given scenario (DeMaria and Levine, 2013). It is these learning needs that high-fidelity clinical simulators address, so that once basic competence in a skill has been achieved then additional emotional stress and the need for instantaneous clinical decision making can be assessed. Whilst simulation is not an active replacement for the adrenaline rush faced, it does offer an insight within learner centred experiential learning of the potentially uncertain scenarios that health and medical professionals often face in the real world. The portability of simulators such as 'SimMan' and 'SimMom' also provides the opportunity for context specific training opportunities where situated learning ca become an integral part of strategic curriculum justification, design and delivery (Viglialoro, 2021).

SUPPORTING CHANGE IN GLOBAL HEALTHCARE WORKFORCE PROVISION

Despite being one of the most needed and often underacknowledged parts of the global workforce, healthcare workers have virtually all been exposed to traditionalist mechanisms of education, which in terms of educational delivery have remained pedagogically unaltered for the best part of half a century (Karunathilake and Samarasekera, 2021). XR, as an integral part of a new technological age has been embedded within existing educational infrastructures, where traditional instruction mechanisms have shaped its implementation in relation to the pre-existing array of subject areas and academic disciplines represented by HEIs across the world. Stemming from the traditionalist apprenticeship models of learning, these learning approaches have been shaken to the core by a global pandemic that despite being predicted, came as a complete shock to global academic communities where health and medical education had to continue, despite education as a social science being altered beyond recognition in a space of six months, when national lockdowns shaped altered approaches to educational affordance and opportunity to learn (Chan, 2021). Whilst medical publications have an average currency of five years, clinicians of health and medical practice work for an average of forty years on the foundational knowledge attained almost half a century before. It is perhaps no surprise to learn then, that medical errors have become a progressively iterative problem across global health and medical practice, in situations where technology has developed to such an extent that new interventions are often almost obsolete before their initial implementation at the front line of patient care (Melnyk et al, 2021). Whilst these issues are concerning, they also pose the greatest opportunity for processes of progressive change for health and medical students whose curricula will inform the complex and ambiguous territories of professionalism that they will need to negotiate over the forthcoming years. This is an opportunity not only to focus and stabilise the quality and optimal provision of education for the next generations of healthcare practice, but also to ensure that medical education becomes more accessible, cost effective and most importantly places patients at the heart of compassionate human care. Exponentially in response to these challenges there has been a progressive switch to Problem Based Learning pedagogical approaches to medical and healthcare curricula across the globe. The immediacy of feedback and impact of professional facilitation of learning is central to the success of this approach in practice and ensures that the mindset of a critical enquirer is entrenched in learners who one day will become the next generation of medical and healthcare providers.

PATIENT CARER PUBLIC INVOLVEMENT IN CURRICULUM DELIVERY

The integration of patients and their families and carers, within the context of patient and carer public involvement (PCPI) initiatives is now an integral part of most health and medical school curricula (Ocloo et al, 2021). Whilst they are invaluable in relation to the development of affective domain learning and interpersonal and effective communication skills, the fact that these skills are inseparable from highly attuned cognitive and psychomotor skills in practice still exists. Where they are therefore of value is in the integration of these skills in conjunction with high fidelity simulation equipment, so that psychological fidelity can also be integrated into the acquisition of psychomotor technical skills training (Johnson et al, 2020; Hayes and Graham, 2020). This is of value in the transitioning between specifically designed learning environments, within which simulated learning takes place, and the eventual 'real life' praxis that students face. In terms of recreating learning environments which also reflect the multi-disciplinary and interprofessional working contexts within which health and medical staff find themselves daily, XR provides a useful mechanism of ensuring the psychological fidelity of scenarios used in learning. The origins of human factor analysis and historical emergence of XR training are well documented within the aviation industry, where contexts of flight simulation and the selective integration and conditions of flying can be reconstructed in terms of variability (Hawkins, 2017). One distinct variation in terms of the potential transferability of learning to 'real life' though, is the complex ambiguity and unpredictability of working with humans, whose predictability far outweighs anything an aeroplane, however complex can reflect. Unlike flying, therefore, those assessments regarded as 'high stake' in terms of potential outcome and risk, cannot be conducted with medical simulation equipment because of their relative potential variability in pathological and physiological status (Spurgeon et al, 2019).

Using teaching and learning to drive assessment is an acknowledged feature of student centred learning but we must never lose sight of the fact that XR, whilst being an adjunct and embedded part of health and medical curricula must never become the driver of learning in itself, lest the most important learning opportunities and factors may be lost to the prioritisation of technology over human need. Similarly, some higher education institutions aspire to owning the latest equipment, which is often declared obsolete before it can be pedagogically integrated with any degree of credibility across those academic curricula for which it was originally purchased. The focus of curriculum design and how teaching and learning ought to drive assessment rather than vice-versa must be advocated if the overall resultant levels of quality in patient care are to remain optimal (Burgess et al, 2020).

FUTURE RESEARCH DIRECTIONS

Within the context of the assessment of healthcare and medical students, formative assessment that is subject to the regulations of Professional and Statutory Regulatory Boards such as allied health and medicine programmes, there is also the opportunity to effectively moderate assessment within and between educational institutions in terms of the parity and equity of assessment mechanisms. Where clinical educators and academics must evidence the objectivity of processes of assessment, then XR will become an invaluable resource in terms of being able to standardise approaches to both formative and summative assessment techniques and their respective outcomes in educational practice (Wilson and Shankar, 2021). The COVID-19 pandemic has seen an exponential rise in the delivery of blended synchronous online and face to face teaching, which has been termed a hybrid learning approach. However, a newer term is the hyflex curricula which have permeated the educational marketplace, with tailored offers of individual flexibility in learning patterns, which can accommodate more diverse student cohorts. These curricula represent the future of research for these disciplinary fields of praxis. Instructional resources delivered by XR are often an integral part of these flexible offers and it can be an optimal way of managing learning time for those adult learners who have additional family or working commitments to fulfil (Gagnon et al, 2020). Operationally defined, hyflex models also adopt a hybrid approach but offer the opportunity to study flexibly rather than at a pre-set time. Delineating between models of actual attendance on campus is often indicated by the term hybrid, whereas the actual curriculum model is termed blended and provide a fundamental platform for future pedagogical research.

CONCLUSION

Progressive innovation across medical and healthcare professions is something which challenges traditional, conservative approaches to pedagogy, which ultimately contributes to the life and death decision making of clinicians at the front line of care. In this regard, it is important that technology is seen as a driver of pedagogic practice, rather than a methodology in itself. In this sense uptake of these new adjuncts is wholly dependent on medical and healthcare educators being open to change in approaches to education of subsequent generations of students and an acceptance that iterative and ongoing professional skills development is an integral part of adopting technology in practice. In practice this also necessitates the recruitment of staff with specialist technical skills who are responsible for the operationalisation of equipment, but who may not necessarily have specialist pedagogical skills in terms of curriculum design and implementation. So collaborative teamwork in the context of operational delivery of teaching sessions is pivotal. This investment, in terms of financial cost, collaborative working and mandatory iterative skills development for both academic and clinical educators, ensures that learning in a context safe from real-life risk with the potential for benchmarking the acquisition of knowledge and skills, is made possible in practice. The ongoing global COVID-19 pandemic has caused huge global disruption to traditional medical and healthcare education. Innovative responses in digital and technological tools have been quickly implemented with the aim of ensuring that learning can be maintained and sustained to ensure sufficient medical and healthcare graduates continue to qualify each year. Whilst change continues to ensure transformative approaches in those countries who can afford the fiscal implications of these developments, the gap between training providers globally also has the potential to widen in relation to optimal quality of medical and healthcare education. This is an obvious area for address if there is not to become a skills deficit in those countries where the affordance of digital technology as standard for learners and their academic and clinical teachers, is not yet possible. It is the acknowledgement and address of these key challenges which has the potential for a truly authentic paradigm shift in the application of XR in pedagogic design, scholarship, and implementation to be achieved.

REFERENCES

Abbas, J. R., Kenth, J. J., & Bruce, I. A. (2020). The role of virtual reality in the changing landscape of surgical training. *The Journal of Laryngology and Otology*, *134*(10), 863–866. doi:10.1017/S0022215120002078 PMID:33032666

Acharya, S., Bhatt, A. N., Chakrabarti, A., Delhi, V. S., Diehl, J. C., van Andel, E., & Subra, R. (2021). Problem-Based Learning (PBL) in Undergraduate Education: Design Thinking to Redesign Courses. In *Design for Tomorrow—Volume 2* (pp. 349–360). Springer. doi:10.1007/978-981-16-0119-4_28

Adefila, A., Opie, J., Ball, S., & Bluteau, P. (2020). Students' engagement and learning experiences using virtual patient simulation in a computer supported collaborative learning environment. *Innovations in Education and Teaching International*, *57*(1), 50–61.

Aebersold, M., & Dunbar, D. M. (2021). Virtual and Augmented Realities in Nursing Education: State of the Science. *Annual Review of Nursing Research*, *39*(1), 225–242. doi:10.1891/0739-6686.39.225 PMID:33431644

Agha, S. (2021). Aligning continuing professional development (CPD) with quality assurance (QA): A perspective of healthcare leadership. *Quality & Quantity*, 1–15.

Alnagrat, A. J. A., Ismail, R. C., & Idrus, S. Z. S. (2021, May). Extended Reality (XR) in Virtual Laboratories: A Review of Challenges and Future Training Directions. *Journal of Physics: Conference Series*, *1874*(1), 012031. doi:10.1088/1742-6596/1874/1/012031

Annala, J., Lindén, J., Mäkinen, M., & Henriksson, J. (2021). Understanding academic agency in curriculum change in higher education. *Teaching in Higher Education*, 1–18. doi:10.1080/13562517.2021.1881772

Antoniou, P., Arfaras, G., Pandria, N., Ntakakis, G., Bambatsikos, E., & Athanasiou, A. (2020). Real-time affective measurements in medical education, using virtual and mixed reality. In *International Conference on Brain Function Assessment in Learning* (pp. 87-95). Springer. 10.1007/978-3-030-60735-7_9

Argyris, C. (1991). Teaching smart people how to learn. *Harvard Business Review*, *69*(3).

Bevins, F., Bryant, J., Krishnan, C., & Law, J. (2020). Coronavirus: How should US higher education plan for an uncertain future. *McKinsey. Recuperado el, 22*.

Birt, J., Stromberga, Z., Cowling, M., & Moro, C. (2018). Mobile mixed reality for experiential learning and simulation in medical and health sciences education. *Information (Basel)*, *9*(2), 31. doi:10.3390/info9020031

Brandon, E., Freiwirth, R., & Hjersman, J. (2021, May). Special Session—Student Engagement with Reduced Bias in a Virtual Classroom Environment. In *2021 7th International Conference of the Immersive Learning Research Network (iLRN)* (pp. 1-3). IEEE.

Burgess, A., van Diggele, C., Roberts, C., & Mellis, C. (2020). Key tips for teaching in the clinical setting. *BMC Medical Education*, *20*(2), 1–7. doi:10.118612909-020-02283-2 PMID:33272257

Chan, S. (2021). *Digitally Enabling 'Learning by Doing' in Vocational Education: Enhancing 'Learning as Becoming' Processes*. Springer Nature. doi:10.1007/978-981-16-3405-5

Crouch, L., Rolleston, C., & Gustafsson, M. (2021). Eliminating global learning poverty: The importance of equalities and equity. *International Journal of Educational Development*, *82*, 102250. doi:10.1016/j.ijedudev.2020.102250

Dehghani, M., Acikgoz, F., Mashatan, A., & Lee, S. H. (2021). A holistic analysis towards understanding consumer perceptions of virtual reality devices in the post-adoption phase. *Behaviour & Information Technology*, 1–19.

DeMaria, S., & Levine, A. I. (2013). The use of stress to enrich the simulated environment. In *The comprehensive textbook of healthcare simulation* (pp. 65–72). Springer. doi:10.1007/978-1-4614-5993-4_5

Dennick, R. (2016). Constructivism: Reflections on twenty-five years teaching the constructivist approach in medical education. *International Journal of Medical Education*, *7*, 200–205. doi:10.5116/ijme.5763.de11 PMID:27344115

Durning, S. J., & Artino, A. R. (2011). Situativity theory: a perspective on how participants and the environment can interact: AMEE Guide no. 52. *Medical Teacher*, *33*(3), 188–199. doi:10.3109/0142159X.2011.550965 PMID:21345059

Gagnon, K., Young, B., Bachman, T., Longbottom, T., Severin, R., & Walker, M. J. (2020). Doctor of physical therapy education in a hybrid learning environment: Reimagining the possibilities and navigating a "new normal". *Physical Therapy*, *100*(8), 1268–1277. doi:10.1093/ptj/pzaa096 PMID:32424417

Gandolfi, E., Kosko, K. W., & Ferdig, R. E. (2021). Situating presence within extended reality for teacher training: Validation of the extended Reality Presence Scale (XRPS) in preservice teacher use of immersive 360 video. *British Journal of Educational Technology*, *52*(2), 824–841. doi:10.1111/bjet.13058

Gerup, J., Soerensen, C. B., & Dieckmann, P. (2020). Augmented reality and mixed reality for healthcare education beyond surgery: An integrative review. *International Journal of Medical Education*, *11*, 1–18. doi:10.5116/ijme.5e01.eb1a PMID:31955150

Goh, P. S., & Sandars, J. (2020). A vision of the use of technology in medical education after the COVID-19 pandemic. *MedEdPublish*, 9.

Graf, A. C., Jacob, E., Twigg, D., & Nattabi, B. (2020). Contemporary nursing graduates' transition to practice: A critical review of transition models. *Journal of Clinical Nursing*, *29*(15-16), 3097–3107. doi:10.1111/jocn.15234 PMID:32129522

Hamilton, D., McKechnie, J., Edgerton, E., & Wilson, C. (2021). Immersive virtual reality as a pedagogical tool in education: A systematic literature review of quantitative learning outcomes and experimental design. *Journal of Computers in Education*, *8*(1), 1–32. doi:10.100740692-020-00169-2

Hartman, E., Reynolds, N. P., Ferrarini, C., Messmore, N., Evans, S., Al-Ebrahim, B., & Brown, J. M. (2020). Coloniality-decoloniality and critical global citizenship: Identity, belonging, and education abroad. *Frontiers: The Interdisciplinary Journal of Study Abroad*, *32*(1), 33–59. doi:10.36366/frontiers.v32i1.433

Hawkins, F. H. (2017). *Human factors in flight*. Routledge. doi:10.4324/9781351218580

Hayes, C., & Capper, S. (2020). Illustrating the transcendence of disciplinarity. In *Beyond Disciplinarity* (pp. 40–49). Routledge. doi:10.4324/9781315108377-4

Hayes, C., & Graham, Y. (2020). *Designing a Benchmarking Tool for Testing Posttest Confidence Levels in Emergency Obstetrics Training*. SAGE Publications. doi:10.4135/9781529709285

Hayes, C., Hinshaw, K., & Petrie, K. (2019). Reconceptualizing medical curriculum design in strategic clinical leadership training for the 21st century physician. In *Preparing Physicians to Lead in the 21st Century* (pp. 147–163). IGI Global. doi:10.4018/978-1-5225-7576-4.ch009

Heong, Y. M., Ping, K. H., Hamdan, N., Ching, K. B., Yunos, J. M., Mohamad, M. M., ... Azid, N. (2020). Integration of Learning Styles and Higher Order Thinking Skills among Technical Students. *Journal of Technical Education and Training*, *12*(3), 171–179.

Hilburg, R., Patel, N., Ambruso, S., Biewald, M. A., & Farouk, S. S. (2020). Medical education during the coronavirus disease-2019 pandemic: Learning from a distance. *Advances in Chronic Kidney Disease*, *27*(5), 412–417. doi:10.1053/j.ackd.2020.05.017 PMID:33308507

Hilty, D. M., Parish, M. B., Chan, S., Torous, J., Xiong, G., & Yellowlees, P. M. (2020). A comparison of in-person, synchronous and asynchronous telepsychiatry: Skills/competencies, teamwork, and administrative workflow. *Journal of Technology in Behavioral Science*, *5*(3), 273–288. doi:10.100741347-020-00137-8

Horton, S. (2021). Empathy Cannot Sustain Action in Technology Accessibility. *Frontiers of Computer Science*, *3*, 31.

Howell, H., & Mikeska, J. N. (2021). Approximations of practice as a framework for understanding authenticity in simulations of teaching. *Journal of Research on Technology in Education*, *53*(1), 8–20. doi:10.1080/15391523.2020.1809033

Humpherys, S. L., Bakir, N., & Babb, J. (2021). Experiential learning to foster tacit knowledge through a role play, business simulation. *Journal of Education for Business*, 1–7.

Jentsch, F., & Curtis, M. (2017). *Simulation in aviation training*. Routledge. doi:10.4324/9781315243092

Johnson, C. E., Kimble, L. P., Gunby, S. S., & Davis, A. H. (2020). Using deliberate practice and simulation for psychomotor skill competency acquisition and retention: A mixed-methods study. *Nurse Educator*, *45*(3), 150–154. doi:10.1097/NNE.0000000000000713 PMID:31246693

Jongerius, C., Hessels, R. S., Romijn, J. A., Smets, E. M., & Hillen, M. A. (2020). The measurement of eye contact in human interactions: A scoping review. *Journal of Nonverbal Behavior*, *44*(3), 1–27. doi:10.100710919-020-00333-3

Juraschek, M., Büth, L., Posselt, G., & Herrmann, C. (2018). Mixed reality in learning factories. *Procedia Manufacturing*, *23*, 153–158. doi:10.1016/j.promfg.2018.04.009

Kang, J., Diederich, M., Lindgren, R., & Junokas, M. (2021). Gesture patterns and learning in an embodied XR science simulation. *Journal of Educational Technology & Society*, *24*(2), 77–92.

Karunathilake, I. M., & Samarasekera, D. D. (2021). Learning In The 21st Century— 'What's All the Fuss about Change?'. In Educate, Train and Transform: Toolkit on Medical and Health Professions Education (pp. 1-14). Routledge.

Kierkegaard, S. (2013). Kierkegaard's Writings, II, Volume 2: The Concept of Irony, with Continual Reference to Socrates/Notes of Schelling's Berlin Lectures. Princeton University Press.

King, O., Borthwick, A., Nancarrow, S., & Grace, S. (2018). Sociology of the professions: What it means for podiatry. *Journal of Foot and Ankle Research*, *11*(1), 1–8. doi:10.118613047-018-0275-0 PMID:29942353

Koufidis, C., Manninen, K., Nieminen, J., Wohlin, M., & Silén, C. (2021). Unravelling the polyphony in clinical reasoning research in medical education. *Journal of Evaluation in Clinical Practice*, *27*(2), 438–450. doi:10.1111/jep.13432 PMID:32573080

Levitt, H. M. (2021). Qualitative generalization, not to the population but to the phenomenon: Reconceptualizing variation in qualitative research. *Qualitative Psychology*, *8*(1), 95–110. doi:10.1037/qup0000184

Loeng, S. (2018). Various ways of understanding the concept of andragogy. *Cogent Education*, *5*(1), 1496643. doi:10.1080/2331186X.2018.1496643

Logeswaran, A., Munsch, C., Chong, Y. J., Ralph, N., & McCrossnan, J. (2021). The role of extended reality technology in healthcare education: Towards a learner-centred approach. *Future Healthcare Journal*, *8*(1), e79–e84. doi:10.7861/fhj.2020-0112 PMID:33791482

Luctkar-Flude, M., & Tyerman, J. (2021). The Rise of Virtual Simulation: Pandemic Response or Enduring Pedagogy? *Clinical Simulation in Nursing*, *57*, 1–2. doi:10.1016/j.ecns.2021.06.008

Luo, C., Lan, Y., Luo, X. R., & Li, H. (2021). The effect of commitment on knowledge sharing: An empirical study of virtual communities. *Technological Forecasting and Social Change*, *163*, 120438. doi:10.1016/j.techfore.2020.120438

Mathew, P. S., & Pillai, A. S. (2020). Role of Immersive (XR) Technologies in Improving Healthcare Competencies: A Review. *Virtual and Augmented Reality in Education, Art, and Museums*, 23-46.

McGrath, J. L., Taekman, J. M., Dev, P., Danforth, D. R., Mohan, D., Kman, N., ... Won, K. (2018). Using virtual reality simulation environments to assess competence for emergency medicine learners. *Academic Emergency Medicine*, *25*(2), 186–195. doi:10.1111/acem.13308 PMID:28888070

Melnyk, B. M., Tan, A., Hsieh, A. P., Gawlik, K., Arslanian-Engoren, C., Braun, L. T., Dunbar, S., Dunbar-Jacob, J., Lewis, L. M., Millan, A., Orsolini, L., Robbins, L. B., Russell, C. L., Tucker, S., & Wilbur, J. (2021). Critical care nurses' physical and mental health, worksite wellness support, and medical errors. *American Journal of Critical Care*, *30*(3), 176–184. doi:10.4037/ajcc2021301 PMID:34161980

Mitchell, R., & Boyle, B. (2021). Understanding the role of profession in multidisciplinary team innovation: Professional identity, minority dissent and team innovation. *British Journal of Management*, *32*(2), 512–528. doi:10.1111/1467-8551.12419

Moreira, D. (2020). Virtual networks and asynchronous communities: methodological reflections on the digital. In *Ethnography in Higher Education* (pp. 177–196). Springer VS. doi:10.1007/978-3-658-30381-5_11

Mortimore, G., Reynolds, J., Forman, D., Brannigan, C., & Mitchell, K. (2021). From expert to advanced clinical practitioner and beyond. *British Journal of Nursing (Mark Allen Publishing)*, *30*(11), 656–659. doi:10.12968/bjon.2021.30.11.656 PMID:34109817

Negev, M., Dahdal, Y., Khreis, H., Hochman, A., Shaheen, M., Jaghbir, M. T., Alpert, P., Levine, H., & Davidovitch, N. (2021). Regional lessons from the COVID-19 outbreak in the Middle East: From infectious diseases to climate change adaptation. *The Science of the Total Environment*, *768*, 144434. doi:10.1016/j.scitotenv.2020.144434 PMID:33444865

Obrad, C. (2020). Constraints and consequences of online teaching. *Sustainability*, *12*(17), 6982. doi:10.3390u12176982

Ocloo, J., Garfield, S., Franklin, B. D., & Dawson, S. (2021). Exploring the theory, barriers and enablers for patient and public involvement across health, social care and patient safety: A systematic review of reviews. *Health Research Policy and Systems*, *19*(1), 1–21. doi:10.118612961-020-00644-3 PMID:33472647

Okoye, K., Rodriguez-Tort, J. A., Escamilla, J., & Hosseini, S. (2021). Technology-mediated teaching and learning process: A conceptual study of educators' response amidst the Covid-19 pandemic. *Education and Information Technologies*, *26*(6), 1–33. doi:10.100710639-021-10527-x PMID:34025205

Orr, N., Matthews, B., See, Z. S., Burrell, A., Day, J., & Seengal, D. (2021). Transdisciplinarity in extended reality (XR) research design: Technological transformation and social good (co-creation session at XR+ Creativity Symposium, University of Newcastle, 2020). *Virtual Creativity, 11*(1), 163-179.

Owens, K. P. (2021, July). Competency-Based Experiential-Expertise and Future Adaptive Learning Systems. In *International Conference on Human-Computer Interaction* (pp. 93-109). Springer. 10.1007/978-3-030-77873-6_7

Park, C., & Kim, D. G. (2020). Exploring the roles of social presence and gender difference in online learning. *Decision Sciences Journal of Innovative Education*, *18*(2), 291–312. doi:10.1111/dsji.12207

Robert, I. V. (2021). Formation and development of digital transformation of domestic education on the basis of systemic convergence of pedagogical science and technology. In *SHS Web of Conferences* (Vol. 101, p. 03017). EDP Sciences. 10.1051hsconf/202110103017

Roussin, C. J., & Weinstock, P. (2017). SimZones: An organizational innovation for simulation programs and centers. *Academic Medicine*, *92*(8), 1114–1120. doi:10.1097/ACM.0000000000001746 PMID:28562455

Silén, C., Wirell, S., Kvist, J., Nylander, E., & Smedby, Ö. (2008). Advanced 3D visualization in student-centred medical education. *Medical Teacher*, *30*(5), e115–e124. doi:10.1080/01421590801932228 PMID:18576181

Suryanti, S., Sutaji, D., Arifani, Y., Muyasaroh, M., & Zamzamy, M. (2020). Improved learning accessibility and professionalism of teachers in remote areas through mentoring development of teaching materials based on Augmented Reality. *Kontribusia*, *3*(1), 224–232. doi:10.30587/kontribusia.v3i1.1032

Tabatabai, S. (2020). COVID-19 impact and virtual medical education. *Journal of Advances in Medical Education & Professionalism*, *8*(3), 140–143. PMID:32802908

Tang, K. S., Cheng, D. L., Mi, E., & Greenberg, P. B. (2020). Augmented reality in medical education: A systematic review. *Canadian Medical Education Journal*, *11*(1), e81. PMID:32215146

Ten Cate, O., & Billett, S. (2014). Competency-based medical education: Origins, perspectives and potentialities. *Medical Education*, *48*(3), 325–332. doi:10.1111/medu.12355 PMID:24528467

van der Niet, A. G., & Bleakley, A. (2021). Where medical education meets artificial intelligence: 'Does technology care?'. *Medical Education*, *55*(1), 30–36. doi:10.1111/medu.14131 PMID:32078175

Viglialoro, R. M., Condino, S., Turini, G., Carbone, M., Ferrari, V., & Gesi, M. (2021). Augmented Reality, Mixed Reality, and Hybrid Approach in Healthcare Simulation: A Systematic Review. *Applied Sciences (Basel, Switzerland)*, *11*(5), 2338. doi:10.3390/app11052338

Voštinár, P., Horváthová, D., Mitter, M., & Bako, M. (2021). The look at the various uses of VR. *Open Computer Science*, *11*(1), 241–250. doi:10.1515/comp-2020-0123

Vygotsky, L. S. (1978). Zone of proximal development: A new approach. *Mind in society: The development of higher psychological processes*, 84-91.

Welie, J. V. (2004). Is dentistry a profession? Part 3. Future challenges. *Journal - Canadian Dental Association*, *70*(10), 675–678. PMID:15530264

Wilson, I., & Shankar, P. R. (2021). The COVID-19 pandemic and undergraduate medical student teaching/learning and assessment. *MedEdPublish*, *10*(1), 10. doi:10.15694/mep.2021.000044.1

World Health Organisation. (2023). *International Data Online Updates*. https://www.who.int/data

Yigitcanlar, T., Butler, L., Windle, E., Desouza, K. C., Mehmood, R., & Corchado, J. M. (2020). Can building "artificially intelligent cities" safeguard humanity from natural disasters, pandemics, and other catastrophes? An urban scholar's perspective. *Sensors (Basel)*, *20*(10), 2988. doi:10.339020102988 PMID:32466175

Zulkifli, A. F. (2019). Student-centered approach and alternative assessments to improve students' learning domains during health education sessions. *Biomedical Human Kinetics*, *11*(1), 80–86. doi:10.2478/bhk-2019-0010

ADDITIONAL READING

Cranmer, K., Brehmer, J., & Louppe, G. (2020). The frontier of simulation-based inference. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(48), 30055–30062. doi:10.1073/pnas.1912789117 PMID:32471948

Hong, T., Langevin, J., & Sun, K. (2018, October). Building simulation: Ten challenges. *Building Simulation*, *11*(5), 871–898. doi:10.100712273-018-0444-x

Jeffries, P. (2020). *Simulation in nursing education: From conceptualization to evaluation*. Lippincott Williams & Wilkins.

Kadian, A., Truong, J., Gokaslan, A., Clegg, A., Wijmans, E., Lee, S., Savva, M., Chernova, S., & Batra, D. (2020). Sim2Real predictivity: Does evaluation in simulation predict real-world performance? *IEEE Robotics and Automation Letters*, *5*(4), 6670–6677. doi:10.1109/LRA.2020.3013848

Satin, A. J. (2018). Simulation in obstetrics. *Obstetrics and Gynecology*, *132*(1), 199–209. doi:10.1097/AOG.0000000000002682 PMID:29889745

KEY TERMS AND DEFINITIONS

Augmented Reality (AR): Is a technology capable of superimposing or overlaying a computer-generated image across a visual projection of the real world, providing a composite view of the two.

Extended Reality (XR): Is the term given to all real-and-virtual combined environments and human-machine interactions, which are functionally digitally generated by technology and wearable accessories.

Health Professions: Is the term used for workers who have been formally trained in the application of medical and healthcare principles underpinned by the core principles of care, compassion and evidence-based approaches to the care of people whose health necessitates assessment, diagnosis, or management.

Hybrid Curriculum: Is the term used to describe how online learning is integrated with traditional face to face learning and teaching.

Hyflex Curriculum: Is an adaptation of hybrid learning where each class session and learning activity is offered in-person, synchronously online, and asynchronously online. With this approach learners make the decision of how they will participate with the learning opportunities afforded to them.

Immersion Technology: Is the digital equipment which provides the perception of being present in a created and non-physical world.

Mixed Reality (MR): Is the merging of virtual and actual reality to provide new mechanisms of visualizing given scenarios. The physical objects and digital objects can interact with each other in real time.

Paradigm: A set of concepts or thought patterns, incorporating specific theories, designated research methods, hypotheses, and typical standards of what is a legitimate claim to contribution to a specific field of theory or practice.

Pedagogy: Is the methodological process and study of applied teaching and learning within specific subjects and academic disciplines.

Sensory: Relates to the experience of sensation via the physical senses in terms of either perception or transmission.

Simulation: Is the integrated use of a computer model, which imitates reality in the context of study, where risk can be eliminated as part of initial scaffolded learning.

Virtual Reality (VR): Is the digitally generated simulation of a 3-D image or situated context or learning environment, within which a learner can be placed and with which they can interact by wearing electronic accessories such as eye goggles or gloves with sensors.