Erasmus Plus Strategic Partnerships

Project Title: “Co-creation of Virtual Reality reusable e-Resources for European Healthcare Education”

Project Number: 2018-1-UK01-KA203-048215

IO5: A set of recommendations for use of virtual reality reusable e-resources in healthcare curricula in terms of pedagogical aspects

Intellectual Output Type	Studies / analysis – Data collection / analysis
Deliverable Type	Text file / Internet
Dissemination level	Public
Delivery date	15th December 2021
Status	Final
Author(s)	*Matthew Pears (UoN), Panagiotis Antoniou (AUTH), Eirini Schiza(CYENS), Kleanthis Neokleous (CYENS), Constantinos S. Pattichis (CYENS), Panagiotis D. Bamidis (AUTH), Stathis Th. Konstantinidis (UoN)*

Table of Contents

1. Introduction

This document details the process involved in creating a set of recommendation guidelines for use of virtual reality reusable e-resources in healthcare curricula in terms of pedagogical aspects. This was based on IO1 (Curriculum Plan), IO3 (Best practices on co-creating virtual reality reusable e-resources) and IO4 (Feasibility and acceptance of virtual reality reusable e-resources in healthcare curricula) and using a modified Delphi process, that have been used in the past by UoN and AUTH.

Increased digitalisation of healthcare curricula by the provision of a set of recommendations for use of virtual reality reusable e-resources in terms of pedagogical aspects, is essential. These guidelines can enable clinical skills e-resources to match the existing immersive needs of the leaners and the needs of teachers and health professionals. Teaching staff have capacity to enhance their e-Learning co-creation competences and make use of co-creation best practices and recommendation for use. The CoViRR approach provided a concrete and easy to transfer solution to healthcare undergraduate, postgraduate or CPD curriculum, minimizing the cost of training and maximising the experience. With collation from the other Intellectual Outputs, CoViRR has provided a holistic, transferable approach of co-creating virtual reality reusable e-resources and creating an immersive experience of learners to other EU institutions. The set of recommendations for use of virtual reality reusable e-resources in healthcare curricula in terms of pedagogical aspects could also be used individual to incorporate existing VR reusable e-resources into the curriculum.

To provide more specific content into the needs for such recommendation:

VR has increased phenomenally in recent years however much development is through trial and error. There is little aid for the specific detail of the most appropriate methodologies behind creating and embedding effective immersive technology applications into practice. This work aimed to capture expert insight and formulate guidelines for use of virtual reality (VR) reusable e-resources for healthcare curricula in terms of pedagogical aspects. Once they were developed, these recommendations can now and have been disseminated to be impactful support for others. Further development of resources for VR reusable e-resources in healthcare curricula will benefit from these recommendations.

A summary of the Delphi Study is presented below:

The study was conducted online using a modified Delphi approach. Participants were recruited through partner networks in addition to searching Web of Science for authors of recent articles in pedagogy, innovative technology, and learning informatics. To be distinguished as a Subject Matter Expert, participants had obtained elevated levels of sociometric status, extended domain experience, and high-performance outputs. Selected participants were emailed, and the first round gained 75 participants after exclusion criteria. The data was analysed by two researchers and the most significant information was reformed after thematic analysis and continued into the second round of the study. Data analysis uncovered several themes including technical strategies, compatibility and safety, organisational strategies, impact/measurements/evaluation, educator strategies, and learner strategies. Round 2 detailed the ranking or exclusion of recommendations. Round 3 permitted participants to 'fine pick' the results to best capture their expertise for methods, theory, and practice. We proposed a novel set of recommendations use of VR reusable e-resources in healthcare curricula pedagogy. These can be used for guiding, benchmarking, and comparing best practice and are freely accessible to anyone. Future upscaling of healthcare curricula pedagogy by use of VR reusable e-resources can be improved by use of these recommendations.

The Delphi study has critical dependency on sourcing expert knowledge. This can be challenging if a subject area is new, a narrow field, and availability constraints are common. Regional, national, and internationally relevant individuals who show expertise can strengthen the validity of the findings towards successful reuse by others. Therefore, it was a strength for CoViRR that a plethora of high-profile and highly skilled individuals were able to collaborate in providing expertise in this report. The collaborators are shown in Tabel1 below.

Table 1: Main portion of high-profile collaborators of the Delphi study process. Those who were in Round 1 but did not continue to Round 2 are not included however we recognise their contribution to this study also.

Dr Rebecca Thompson	NHS, Oxford Medical Simulation, UK.
Mr James Tomlinson	Health Education England NE & Yorks, UK.
Dr Faisal Mushtaq	Associate Professor Associate Director, Centre for Immersive Technologies University of Leeds
Mr Shekhar Biyani	Consultant Urologist, MBBS, MS, FRCS, FRCS (Urol), FEBU, MSc (Medical Simulation)
Dr Sarah Markham	B.A. (Hons), M.A. (Cantab), Ph.D. Department of Biostatistics & Health Informatics Institute of Psychiatry, Psychology & Neuroscience (IoPPN) King's College London.
Professor Heather Wharrad	Professor of e-Learning and Health Informatics, Faculty of Medicine & Health Sciences, University of Nottingham, UK.
Assoc. Prof. Jennifer C. Reneker	Associate Professor and Assistant Dean of Scholarly Innovation School of Population Health University of Mississippi Medical Centre, U.S.A
Professor Trudie Roberts	Professor of Medical Education Medical School, University of Leeds
Professor Margaret Verkuyl	NP:PHC, MN, School of Community and Health Studies, Centennial College.
Professor DeBlieck	New Mexico State University College of Health, Education and Social Transformation - School of Nursing Las Cruces New Mexico (USA).
Mr Simon Flemming	Orthopaedic Registrar and PhD(c), Barts and The London, UK.
Dr. Gopal Nambi	Associate professor, Department of Health and rehabilitation sciences, College of applied medical sciences, Prince Sattam bin Abdulaziz University, Al kharj, Saudi Arabia
Professor Aslak Steinsbekk	Department of Public Health and Nursing, Norwegian University of Science and Technology, Norway.
Marina Yiasemidou	NIHR Academic Clinical Lecturer, University of Hull, ST7 colorectal surgery, Bradford Teaching Hospitals.
Dr Cho Lee Wong	The Nethersole School of Nursing, Faculty of Medicine, The Chinese University of Hong Kong.

Professor Debra Nestel	School of Clinical Sciences Monash University, Australia Department of Surgery (Austin Precinct) University of Melbourne, Australia.
Dr. Sebastian Rutkowski	Department of Physical Education and Physiotherapy, Opole University of Technology, PL.
Prof. Sonya Jakubec	RN, PhDm Professor, School of Nursing and Midwifery, Mount Royal University, Canada.
Ken Spearpoint	Principal Lecturer, Medical Simulation, School of Life and Medical Sciences, University of Hertfordshire, UK.
Dr Fabrizio Cutolo, PhD	Department of Information Engineering, University of Pisa, Italy.
Dr. Dalila Burin	Institute of Development, Aging and Cancer, Tohoku University (Sendai, Japan).
Mr James Henderson	Software Developer School of Health Sciences, University of Nottingham, UK.
Prof. Stefano Tamburin	University of Verona, Dept. of Neurosciences, Biomedicine & Movement Sciences P.le Scuro 10 - 37134 Verona – ITALY
Prof. Graeme McLeod	Consultant Anaesthetist & Honorary Professor
Dr Brennan Spiegel	Professor of Medicine and Public Health
Pascale PIOLINO	Head MC^2Lab, University Paris
Dr. Marc Lazarovici	Head of Simulation Centre
Prof. Matthias Weigl	Professor for Patient Safety
Michael Taylor	Senior Learning Technologist
Lars Ebert	Co-head 3D Center Zurich
Prof. Sharon Farra	Professor, Director of Research

2. **Background**

To understand how the CoViRR team should best approach this problem, a literature review on current issues and resources was performed, followed by a methodology and plan of data analysis:

Students are experiencing increasing absence of face-to-face training and accessible simulation. Web-based services have been popular and provide the healthcare workforce with 24/7 accessible training, such as the NHS e-Learning from home programme [1]. These learning solutions have numerous benefits, but ultimately preclude essential practical skills training with fidelity akin to real-world scenarios. This is where immersive material can improve learning outcomes- they have novel components that facilitate improvements in training. These technologies include fully computer-generated interactive 3D Virtual Reality environments (VR), or mobile based VR applications, and can include digital projections that link to real-world environments to create Augmented Reality (AR). As healthcare education comprises of a vast array of roles immersive technologies must be assessed, designed, developed, implemented, and evaluated to be effective tools for students, lecturers, practitioners, and patients.

Before the pandemic, the Joint Information Systems Committee (JISC) published a report in Q4 of 2019 regarding limitations identified in Augmented Reality (AR), Virtual Reality (VR) and teaching practice [2]. This involved 101 responses from 51 organisations in Higher Education (HE) (78%) and further education/other (22%). Respondents were learning technologists (52%), academics (24%), and research/IT/other (24%). JISC supplied several key points which were a concern for the utilisation of VR in pedagogy. They stated that immersive technology is embedded in pockets rather than widespread use, and that costs remain one of the largest challenges. Additionally, higher education institutions stated they had a lack of specialist support and skills, in parallel they had limited understanding on potential uses of VR/AR. Around 96% of HE institutions indicated that in their current state, the advice and guidance of VR and AR development would be especially useful to them. Unfortunately, this guidance does not exist in a singular source that is expert-based, includes both organizational and educator levels, and specific for pedagogical application in healthcare. Responses suggested a need for advice around how to implement the technology, how to use it effectively for learning and teaching, the benefits of use, and guidance around the pros/cons of available equipment and software.

There are a small number of companies attempting to provide educational platforms that can support a global audience. Some companies provide pedagogical platforms to provide students with VR materials to examine, diagnose, communicate with, and prescribe treatment for digital patients. Growing numbers of training scenarios allow students to practice in a variety of virtual clinical settings [3]. Personalized software can adapt to user's actions to provide scaffolding of needs towards the desired learning outcome. This has premise to the real-life dynamics of incoming information in training. Indeed, emerging start-up companies who include academic rigor in parallel to product development have become more common. For example, applications exist that include content only accredited by the respective medical council in the domain intended for. The Royal College of Surgeons and the American Academy of Orthopaedic Surgeons have collaborated with immersive reality technologists to create continuous professional development and continual medical education content [4]. Scientific advisory board can also maintain an elevated level quality, relevance, and standardization [5]. Access to these resources is limited and costly, with the creation processes not documented for replication from private companies, and stakeholder inclusion is undervalued.

Furthermore, in early 2020 the COVID-19 pandemic effected global educational delivery systems in higher education and accelerated accessibility issues on a global scale. Adaptations for using immersive technologies have been sporadic in nature- partially due to the rapid timescale of effects from COVID-19, but also due to the development and implementation problems. Indeed, the authors perceive the pandemic will continue to affect HE and other domains including business and tourism throughout 2022 and likely 2023 with emergence of variants.

Current Limitations in healthcare pedagogy

The processes involved in VR-based resource production are crucial in allowing other institutions to follow experience-based and research-driven guidelines to produce their own immersive reusable VR resources. The transparency of how successful companies and research institutions have developed resources needs improvement. As educational products for medical and surgical learners increase, their efficacy and acceptance by students will be problematic if creation processes are not facilitative for end-users. This will restrict incorporation into hospitals, universities, and private practices. To combat this, a recent collaboration of over 100+ professionals in healthcare including nurses, surgeons, doctors, learning technologists, academics, software developers, and leads in agencies such as Health Education England created a set of recommendations to inform best practice in these areas [6]. They included priority towards stakeholder engagement, increased planning stages, and continuing feedback and evaluation as described by a previous adapted implementation model [7]. One finding was that 'challenges exist in the design, development, implementation, and understanding of immersive training environments and must be overcome if these technologies must realise their potential.' .'though informative, this document targeted a higher macro level in healthcare, that may be too abstract for healthcare professionals and educators to follow when developing and embedding their own resources.

There are still limitations in the current landscape of immersive technology pedagogy. There is a need to expand upon and remedy the undervalue and underutilisation of co-creation processes. The main goal of the present study was to formulate a series of statements via a modified Delphi study that can be used internationally as best practice recommendations regarding usage of models, frameworks, and implementation strategies for VR pedagogy in healthcare.

3. Method

As best practice recommendations in healthcare pedagogy change with user and technology needs, the creation of a consensus of recommendations using the Delphi method is presented that support the need for such flexibility. The Delphi method permits a panel of experts to form consensus by adaptive facilitation of decision-making and prioritisation, achieving the desired guidelines [8]. It is a systematic method that cannot foresee the specific outputs, but typically produces identifications of quality indicators, review criteria, or defines methods specific to the topic at hand. This knowledge synthesis from experts is performed by the research group between each subsequent round [9].

3.1. Panel of Experts Composition

Subject Matter Experts were recruited via email. As the participants of this Delphi study were not able to be interviewed in-depth for expertise, their position and years of experience were used as correlative indicators of expertise. However, an individual's rank, years of service, or leadership status can be misinterpreted as expertise. This is problematic- as a long length of time can only aid in expertise if it contains improvements to knowledge or skill. From a cognitive perspective, an expert has obtained richer mental models of a system, increased tacit knowledge, and can anticipate future states that most colleagues would miss [10]. When filtering the participants in this study, more complex measures were considered, these were surrounding sociometric analysis (being social status), extended domain experience (time in a subject area), performance analysis (e.g., research outputs, achievements etc), and education/career analysis [11]– [15]. Eight exclusions were made due to years of experience being low (between 1-6) or stating early-career roles.

A mix of healthcare and technology professionals were included as this has been suggested to enrich the Delphi method results [10]. Five examples of healthcare-based expertise indicators were: Chief Medical Officer and founder for an internationally leading Healthcare Simulation company; Professor of Medical Simulation (previous President of the Association for Medical Education in Europe); Professor of Simulation Education in Healthcare (leads national programs for simulation educators); Principal Lecturer in Medical Simulation; and a Senior Director, Educational Development and Research/CPD Evaluation and Assessment Specialist. Indicators of technology-based expertise were- Software Engineer with 15+ years' experience (co-head of a world leading VR research institute); Senior research engineer with 20+ years' experience (specialist in medical software in academic skills); Learning Technologist with 20+ years' experience (health E-Learning and media specialist); and a Software Research Developer with 10+ years' experience (specialist healthcare material development for pedagogy, including VR).

3.2. *Delphi Survey Usage*

Participants were given a link to a questionnaire using JISC online surveys [17], via email. All experts participated using an e-questionnaire therefore adhered to COVID-19 related social distance restrictions at the time of data collection. The participants read the information sheet and signed the online consent form to agree to take part. Subsequently, they completed the demographic data form and the questionnaire.

3.3. *Delphi Rounds*

Three rounds were carried out between July and November 2021. Round 1: Three open-ended questions were presented to collect information about the topic in general and were created to capture a large array of responses [18], see Table 1.

Table 1: Round 1 statements and the aspects addressed, based on a previous literature overview

Aspect Addressed	Questions
Sociodemographic factors	Full Name, Consent, Role, Job Title, Years in current profession
Practical and experience-driven information	Please list as many pedagogical recommendations as you can for the use of VR resources into educational practice. These are based on your experiences towards successful formation and implementation of VR resources
Evidence of contextual deployment and efficacy, or expertise on deployment and efficacy	Can you describe a scenario of how a VR resource can be, or was, used in Health Sciences/ Medical Education? This is based on your perspectives of how VR resources can be, or has been, utilized
Supporting research/information to concur in parallel with expertise, and/or suggested sources that facilitate the processes involved	Please identify any educational theories or frameworks that you consider can be applied in aiding towards the creation and use of VR resources, into Health Sciences/ Medical education

Round 2: After Thematic Analysis of round 1 results, a link to round 2 was sent to all participants consisting of 75 key items. The response rate after exclusion criteria was 44% from round 1 (86>31) however this number is still above the suggested amount for expert consensus and concurs with similar Delphi study frequency [19]. A Likert scale was used- 1 (strongly agree with the inclusion) to 5 (strongly disagree with this being included), along with '*not relevant'* and '*unsure*' options to leave comments in case data interpretation from round 1 was incorrect or information was unclear. Means, modes, and rank scores were used to determine the cut-off criteria for each statement, see Table 2. These central tendencies can represent most of the data therefore the collective of the participants. Round 2 results provided details for generating modification to statements in preparation for round 3 and the finalization of recommendations that gained consensus.

Round 3: The revised survey was sent to experts and a more definitive finalisation was presented by options for 'include', 'include after modification', or 'do not include'. The participants had the opportunity to suggest modifications to the grammar, syntax, or minor changes in context of each recommendation. The final round had 26 participants.

3.4. Data Analysis

A thematic analysis of each participant's open-ended responses was performed and cross referenced by two researchers to maintain inter-rater reliability, as data was allocated into emerging themes. The goal was to represent the participants' perceptions and comprehensions of the landscape by selecting phrases, coding them, and identifying core elements that were able to be used in round 2, with no added interpretation by the researchers. In round 2 quantitative data was the main data type via 5-point Likert scale, and the criteria used for determining consensus of inclusion were- High consensus: the median and mode responses were equal to or greater than 2 (agree) with at least 70% of the experts scoring the element proposed as positive (1 or 2). Low consensus: the median and mode responses were equal to or greater than 3 with at least 50% of the experts scoring the element proposed as positive (1 or 2). No consensus: the median and mode responses were less than 3 and less than 50% of the experts scored the element proposed as positive (1 or 2).

3.5. Ethical Considerations

Participation was voluntary and although anonymity was stated by participants, they were given the choice to be acknowledged as a collaborator towards the final outputs with their name and role included in certain documents. All participants provided their information for this purpose of collaboration acknowledgement. The study received approval from the Research and Ethics Board of the School of Health Sciences at The University of Nottingham.

4. Results

The mean years of experience was 12.1 (SD =7.5, mdn=10) for 27 participants in round 3, of which 15 participants had 10 or more years of experience. The results were coded into 4 sections consisting of approximately 10 statements in each section for round 2. The tables below show the mode and mean for each statement and if High, low, or no consensus was met.

Table 1: Weighted Rank score per question showing Mode and Mean to identify non-consensus questions. Weighted scores were required as response frequency differed for some questions.

Rank Score	Question	Mode	Mean	Median	Theory/ Model
59	9	1	2.11	2	Cognitive load theory
60	1	1	2.15	2	Cognitive affective model of immersive learning
68	6	2	2.5	2	Social learning theory
76	2	2	2.7	2	Kolb-Experiential Learning Cycle
77	5	2	2.83	3	Davis- Technology acceptance model
80	3	3	3	3	Schön-Reflective practice
85	4	3	3.05	3	Malone and Lepper-Intrinsic Motivation
86	8	3	3.25	3	Humanism learning theory
87	12	2	2.57	3	Sociocultural learning
92	11	2	2.67	3	Dual-task paradigm
95	10	3	2.75	3	Knowles-Adult Learning andragogy

The theories/models scoring 80 or above were not included in Round 3 due to no positive consensus evidenced by neutral mode, median, and/or mean. Further to Table 1, the thematic analysis of open-ended suggestions supplied each model/theory with limitations not relevant to the study's goals. The second section of round 2 was regarding methods of practice towards immersive reality education in healthcare. The modes for the questions with strongly agree/agree, which meant majority consensus was reached with 8/10 questions. The medians and modes concurred therefore the rank score of 89 or above represented the cut-off criteria. Distance learning and formative- summative assessments were filtered out in round 3.

Table 2: Methods of practice. The methods scoring a mode of 3 or above were not included in Round 3 due to no consensus.

Rank Score	Question	Mode	Mean	Median	Methods
66	1	1	2.2	2	Discovery-Based Learning / Enquiry-Based Learning
70	7	2	2.33	2	procedural step-by-step acquisition
76	9	1	2.53	2.5	1:1 teaching
77	8	2	2.57	2	Instructional design
77	6	1	2.6	2	Co-design/co-creation
78	2	2	2.6	2	Expert-novice learning processes
78	10	2	2.6	2	Online VR courses
86	3	2	2.8	3	Flipped reverse classroom
89	5	3	2.97	3	Distance Learning
94	4	3	3.13	3	Formative- Summative Assessments

The third section of the Round 2 survey was regarding implementation, impact, and evaluation towards immersive reality education in healthcare. The modes for the questions with strongly agree/agree (1 or 2) which meant majority consensus was reached with 3/6 questions.

Table 3: The actions scoring 80 or above were not included in Round 3 due to no consensus.

Rank Score	Question	Mode	Mean	Median	Organisational Actions
67	4	1	2.23	2	Accommodate ease of use and access
67	3	2	2.23	2	Integration to existing systems
71	2	1	2.37	2	Make equipment available 24/7
71	6	3	2.37	2	Implement demonstrations from educators to students
81	1	3	2.7	3	Standardisation of the development process of a VR resource
85	5	3	2.83	3	A certificate course or application of immersive technology in healthcare

The fourth section of the Round 2 survey was regarding strategies that can be used by educators to maximise VR efficacy in training/pedagogy. Analysing the responses from the Likert Scale for this section, the modes for the questions with strongly agree/agree which meant majority consensus was reached with 7/7 questions. No statement was removed as all had positive ratings about the criteria. As strong consensus was reached for these items they were not continued to the next round.

Table 4: Potential recommended strategies used by educators for immersive reality education in healthcare. All had strong consensus determined by the central tendencies. No recommendations were excluded

Rank Score	Question	Mode	Mean	Median	Strategies/actions that can be used by educators
63	4	2	2.1	2	Use for training of cognitive knowledge, and kinaesthetic skills
65	5	1	2.17	2	Training of team cooperative procedures including multi-personnel management of patients
68	6	2	2.27	2	Providing clarity about learning objectives before VR usage
70	7	1	2.33	2	Training of medical procedures for remote learners, joined by a VR group
72	1	1	2.4	2	Encourage reflection of scenarios after usage
73	2	1	2.43	2	Perform pre-briefing and de-briefing of VR scenarios
74	3	2	2.47	2	Establish rule on how to behave in virtual groups

Round 3

After closing the final round, 2 authors reviewed the participants' 'include with modification' suggestions. The changes were either accepted or rejected and moved to the appropriate 'include' or 'do not include' option. For example, a comment was '*The last sentence…needs to be: Feedback is provided throughout and at the end of the experience*.,' and several comments were present for the word 'should' to be replace with a more assertive word. Additionally, to reduce bias named 'bandwagon effect' [20], 3 questions were added in round 3 that were not favoured or had problematic wording. These questions were 2.1, 4.1, and 5.2. For example, 5.2 was "Learners' opinions have priority over the development of the Learning Resource, unless the overall learning goal becomes unachievable."- this is problematic as learner's needs can be priority, but they may not have expertise to decide how best to develop a resource to meet those needs.

Table 5: Final consensus of the main recommendations from round 2, some with expanded recommendations to improve specificity within their concepts.

Recommendation	**Include as a recommendation (%)**	
1	**96**	cognitive load theory
1.1	**93**	
1.2	**93**	
1.3	**80**	
2	67	cognitive affective model of immersive learning
2.1	70	
2.2	**88**	
2.3	**82**	
2.4	**61**	
3	71	social learning in immersive reality
3.1	60	
3.2	74	
4	78	discovery-based learning
4.1	66	
4.2	**89**	
5	**90**	

5.1	**90**	Co-creation of immersive reality resources
5.2	40	
5.3	**88**	
6	70	Real-time feedback
7	**92**	Supporting Challenge and Failure
8	**93**	Expert knowledge
9	72	Decision-making
10	**81**	**Accommodate the ease of use**
11	**80**	**Integrated into existing systems**

Therefore, there were 14 recommendations in round 3. These were added to the consensus items in round 2 to produce 21 bias-controlled expert-based recommendations (See Appendix).

5. Discussion

Healthcare education is constantly challenged by the ever-exploding size of its curriculum. In that context, Technology Enhanced Learning (TEL) has emerged as a necessary approach that can support the ever-growing needs of the healthcare learner [20]. VR resources have a position of privilege as TEL enablers because they have distinct educational advantages for healthcare training [21]– [23]. Development of VR resources involves significant overheads both in terms of time and in terms of financial needs. According to a previous study, it was identified that the cost, for designing and implementing only one, albeit complex, VR training exercises for healthcare professionals in hospitals, reached approximately $106 387.00 [24]. These significant costs can only be reimbursed only through widespread and streamlined re-usability of resources. A significant body of literature describes the generic necessities for re-usability of healthcare education resources, such as the break of knowledge silos, unified standards for transferability and integration of such resources across institutions, amongst other factors [25]. However, before this project, no systematic effort has been put, so far, against the challenge of providing concrete recommendations for the characteristics and the theoretical underpinnings of re-usable VR e-resources. In this project the elicitation of recommendations from experts has been an almost horizontal activity starting at IO1 and finishing at the last topical (i.e., not institutionally horizontal, like project management or dissemination) intellectual output of the project.

From the Delphi study that was presented, a consensus of several recommendations has been identified. The practical recommendations themselves are not an impressive new set of knowledge, for those who have been entangled in the endeavour of reusable XR resource development. However, the experts' consensus provides affirmation that these actions have been, and can be, successful therefore the study should be of significant interest to the reader because it provides two further extremely important results. First, it is one of the few studies, which provide evidence of best practice recommendations for the use of VR e-resources not from the literature, but from the very leaders of healthcare education communities of practice. Thus far, such recommendations were either treated as practical truisms, or they were extracted from single silo studies (i.e., one institution evaluations). This work offers the consensus of several diverse healthcare educators providing an unprecedented weight of evidence to these recommendations.

Secondly, the recommendations about the theoretical underpinnings for the use of re-usable VR resources (cf. appendix items Recommendation 1 – Recommendation 2.3), through a consensus of communities of practice leaders in healthcare education have rarely been encountered. Identifying the consensus of the expert practitioners, regarding theoretical underpinnings for the impact and the ways to use VR e-resources is an important result on its own.

Specifically, Cognitive Load Theory [26]– [29] is a prominent theory of pedagogy and provides a theoretical framework of cognitive architecture. The main premise is that working memory and information processing is limited. Learning and skills acquisition can be hindered if a user's total cognitive load is not enough for the demands of the learning system. The limits in working memory and processing of information are exceeded when the learner fails to integrate multiple complex sources of information [30]. For users to gain positive experience and increase likelihood of practice success, users' cognitive load needed consideration in the learning environment.

On the other hand, the Cognitive Affective Model of Immersive Learning (CAMIL) posits around immersive virtual reality usage in learning- instructional method is the point of focus of efficacy when facilitated by the virtual relative medium. The groundwork to the model's development was from previous affective and cognitive research along with support for a previously developed [31]. The CAMIL was advanced from growing evidence of systematic differences between IVR and other forms of media for educational delivery [32]– [34]. This evidence surrounds interaction effects between media and method of delivery improved knowledge transfer, retention, and self-efficacy. The model has predictive power for how the relationships between six key affective and cognitive factors can influence and relate to different learning outcomes. The six factors are formed from Presence and agency and are named intrinsic motivation, self-efficacy, embodiment, cognitive load, and self-regulation. These form the desired types of knowledge necessary for skill progression.

Immersive resources that can be repurposed have emerged and proliferated for more than a decade now. With the subsequent proliferation of VR, specifically, and the advent of participatory design methods emerges a trend towards democratization of digital resources and the creation of an ever-increasing crowdsourced resource pool. In that landscape of multiple emerging VR resource instantiations pools, there is a need for a theoretical base to support their pedagogical value. The present work not only presents the theoretical base that must drive the use of such resources, but also founds this and practical insights on the expert feedback of multiple communities of practice. As such, it can support the streamlining of VR resource transferability across curricula and their subsequent integration in the mainstream of healthcare education.

6. References

[1] "Programmes – e-learning for healthcare." https://www.e-lfh.org.uk/programmes/ (accessed Jan. 12, 2022).

[2] "Augmented and virtual reality in learning and teaching | Jisc." https://www.jisc.ac.uk/reports/augmented-and-virtual-reality-in-learning-and-teaching-2019 (accessed Jan. 12, 2022).

[3] "Oxford Medical Simulation - Virtual Reality Healthcare Training." https://oxfordmedicalsimulation.com/ (accessed Jan. 12, 2022).

[4] J. Raffort, C. Adam, M. Carrier, and F. Lareyre, "Fundamentals in Artificial Intelligence for Vascular Surgeons," *ANNALS OF VASCULAR SURGERY*, vol. 65, pp. 254–260, May 2020, doi: 10.1016/j.avsg.2019.11.037.

[5] "Scientific Advisory Board - Osso VR." https://ossovr.com/advisory-board/ (accessed Apr. 20, 2021).

[6] R. K. Mathew and F. Mushtaq, "Three principles for the progress of immersive technologies in healthcare training and education," *BMJ Simulation and Technology Enhanced Learning*, vol. 7, no. 5, pp. 459–460, Jul. 6375, doi: 10.1136/BMJSTEL-2021-000881.

[7] R. Dubrowski, M. Barwick, and A. Dubrowski, "'I Wish I Knew This Before…': An Implementation Science Primer and Model to Guide Implementation of Simulation Programs in Medical Education," *Boot Camp Approach to Surgical Training*, pp. 103–121, 2018, doi: 10.1007/978-3-319-90518-1_10.

[8] I. R. Diamond *et al.*, "Defining consensus: a systematic review recommends methodologic criteria for reporting of Delphi studies," *Journal of clinical epidemiology*, vol. 67, no. 4, pp. 401–409, Apr. 2014, doi: 10.1016/J.JCLINEPI.2013.12.002.

[9] R. Boulkedid, H. Abdoul, M. Loustau, O. Sibony, and C. Alberti, "Using and Reporting the Delphi Method for Selecting Healthcare Quality Indicators: A Systematic Review," *PLOS ONE*, vol. 6, no. 6, p. e20476, 2011, doi: 10.1371/JOURNAL.PONE.0020476.

[10] J. Suss and P. Ward, "Revealing perceptual–cognitive expertise in law enforcement: an iterative approach using verbal-report, temporal-occlusion, and option-generation methods," *Cognition, Technology and Work*, vol. 20, no. 4, pp. 585–596, Nov. 2018, doi: 10.1007/S10111-018-0493-Z.

[11] K. E.- Interpreting and undefined 2000, "Expertise in interpreting: An expert-performance perspective," *jbe-platform.com*, Accessed: Nov. 18, 2021. [Online]. Available: https://www.jbe-platform.com/content/journals/10.1075/intp.5.2.08eri

[12] K. Ericsson, P. W.-C. D. in Psychological, and undefined 2007, "Capturing the naturally occurring superior performance of experts in the laboratory: Toward a science of expert and exceptional performance," *journals.sagepub.com*, Accessed: Nov. 18, 2021. [Online]. Available: https://journals.sagepub.com/doi/abs/10.1111/j.1467-8721.2007.00533.x?casa_token=yL8_n_teHM4AAAAA:vnc_6toW2WVbq6sMpBEz-ub-9_k1X3LL-z8U9YeuDTwJg8mUfUl18znCUkpdVkr5oS833HIMvHA7Kw

[13] K. E. of expertise and expert performance and undefined 2006, "The influence of experience and deliberate practice on the development of superior expert performance," *clinica.ispa.pt*,

2184, Accessed: Nov. 18, 2021. [Online]. Available: https://clinica.ispa.pt/ficheiros/areas_utilizador/user11/4_-_the_influence_of_experience_and_deliberate_practice_on_the_development_of_superior_expert_performance.pdf

[14] K. Ericsson, J. W. IV, P. W.-A. in N. Science, and undefined 2007, "Expert performance in nursing: Reviewing research on expertise in nursing within the framework of the expert-performance approach," *journals.lww.com*, 2007, Accessed: Nov. 18, 2021. [Online]. Available: https://journals.lww.com/advancesinnursingscience/Fulltext/2007/01000/Expert_Performance_in_Nursing__Reviewing_Research.14.aspx

[15] K. A. Ericsson and A. C. Lehmann, "Expert and Exceptional Performance: Evidence of Maximal Adaptation to Task Constraints," *Annual Review of Psychology*, vol. 47, pp. 273–305, 1996, doi: 10.1146/ANNUREV.PSYCH.47.1.273.

[16] A. M. Mosadeghrad, "Verification of a quality management theory: using a delphi study," *International journal of health policy and management*, vol. 1, no. 4, pp. 261–271, 2013, doi: 10.15171/IJHPM.2013.55.

[17] "Jisc." https://www.jisc.ac.uk/ (accessed Jan. 05, 2022).

[18] C.-C. Hsu and B. A. Sandford, "The Delphi Technique: Making Sense of Consensus," *Practical Assessment, Research, and Evaluation*, vol. 12, no. 1, p. 10, Nov. 2019, doi: https://doi.org/10.7275/pdz9-th90.

[19] D. Jiménez-Rodríguez, D. Ruiz-Salvador, M. D. M. R. Salvador, M. Pérez-Heredia, F. J. M. Ronda, and O. Arrogante, "Consensus on Criteria for Good Practices in Video Consultation: A Delphi Study," *International Journal of Environmental Research and Public Health*, vol. 17, no. 15, pp. 1–16, Aug. 2020, doi: 10.3390/IJERPH17155396.

[20] P. E. Antoniou, C. A. Athanasopoulou, E. Dafli, and P. D. Bamidis, "Exploring Design Requirements for Repurposing Dental Virtual Patients From the Web to Second Life: A Focus Group Study," *J Med Internet Res 2014;16(6):e151 https://www.jmir.org/2014/6/e151*, vol. 16, no. 6, p. e3343, Jun. 2014, doi: 10.2196/JMIR.3343.

[21] P. E. Antoniou *et al.*, "Biosensor Real-Time Affective Analytics in Virtual and Mixed Reality Medical Education Serious Games: Cohort Study," *JMIR Serious Games 2020;8(3):e17823 https://games.jmir.org/2020/3/e17823*, vol. 8, no. 3, p. e17823, Sep. 2020, doi: 10.2196/17823.

[22] P. Antoniou, G. Arfaras, N. Pandria, G. Ntakakis, E. Bambatsikos, and A. Athanasiou, "Real-Time Affective Measurements in Medical Education, Using Virtual and Mixed Reality," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 12462 LNAI, pp. 87–95, Oct. 2020, doi: 10.1007/978-3-030-60735-7_9.

[23] F. Dolianiti, I. Tsoupouroglou, P. Antoniou, S. Konstantinidis, S. Anastasiades, and P. Bamidis, "Chatbots in Healthcare Curricula: The Case of a Conversational Virtual Patient," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 12462 LNAI, pp. 137–147, Oct. 2020, doi: 10.1007/978-3-030-60735-7_15.

[24] S. L. Farra *et al.*, "Comparative Cost of Virtual Reality Training and Live Exercises for Training Hospital Workers for Evacuation," *Computers, informatics, nursing : CIN*, vol. 37, no. 9, p. 446, Sep. 2019, doi: 10.1097/CIN.0000000000000540.

[25] E. Dafli, P. Antoniou, L. Ioannidis, N. Dombros, D. Topps, and P. D. Bamidis, "Virtual patients on the semantic Web: a proof-of-application study," *Journal of medical Internet research*, vol. 17, no. 1, p. e16, Jan. 2015, doi: 10.2196/JMIR.3933.

[26] J. Sweller, "Cognitive Load During Problem Solving: Effects on Learning," *Cognitive Science*, vol. 12, no. 2, pp. 257–285, 1988, doi: 10.1207/s15516709cog1202_4.

[27] S. A. W. Andersen, P. T. Mikkelsen, L. Konge, P. Cayé-Thomasen, and M. S. Sørensen, "Cognitive load in distributed and massed practice in virtual reality mastoidectomy simulation," *The Laryngoscope*, vol. 126, no. 2, pp. E74–E79, 2016, doi: 10.1002/lary.25449.

[28] J. G. Frederiksen *et al.*, "Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial," *Surgical Endoscopy*, vol. 34, no. 3, pp. 1244–1252, 2020.

[29] J. G. Frederiksen *et al.*, "Cognitive load and performance in immersive virtual reality versus conventional virtual reality simulation training of laparoscopic surgery: a randomized trial," *Surgical Endoscopy*, vol. 34, no. 3, pp. 1244–1252, Mar. 2020, doi: 10.1007/s00464-019-06887-8.

[30] P. A. Kirschner, J. Sweller, F. Kirschner, and J. R. Zambrano, "From Cognitive Load Theory to Collaborative Cognitive Load Theory," *International journal of computer-supported collaborative learning*, vol. 13, no. 2, pp. 213–233, Jun. 2018, doi: 10.1007/S11412-018-9277-Y.

[31] E. Ai-Lim Lee, K. W. Wong, and C. C. Fung, "How does desktop virtual reality enhance learning outcomes? A structural equation modeling approach," *Computers & Education*, vol. 55, no. 4, pp. 1424–1442, Dec. 2010, doi: 10.1016/J.COMPEDU.2010.06.006.

[32] S. Klingenberg, M. L. M. Jørgensen, G. Dandanell, K. Skriver, A. Mottelson, and G. Makransky, "Investigating the effect of teaching as a generative learning strategy when learning through desktop and immersive VR: A media and methods experiment," *British Journal of Educational Technology*, vol. 51, no. 6, pp. 2115–2138, Nov. 2020, doi: 10.1111/BJET.13029.

[33] R. E. Mayer, "The Cambridge Handbook of Multimedia Learning," *The Cambridge Handbook of Multimedia Learning, Second Edition*, pp. 1–930, Jan. 2014, doi: 10.1017/CBO9781139547369.

[34] O. A. Meyer, M. K. Omdahl, and G. Makransky, "Investigating the effect of pre-training when learning through immersive virtual reality and video: A media and methods experiment," *Computers & Education*, vol. 140, p. 103603, Oct. 2019, doi: 10.1016/J.COMPEDU.2019.103603

7. Appendix:

Final set of Recommendations produced from expert Delphi study for VR resource development and pedagogy:

Recommendation 1 (96): Cognitive Load Theory should be used as one primary theory within the final set of recommendation guidelines for use of virtual reality (VR) reusable e-resources in healthcare curricula, in terms of pedagogical aspects.
Recommendation 1.1 (93): The volume of information experienced by Learners should be measured, during design of a Learning Resource. The weight and impact of each element should be considered for the intrinsic and extrinsic load of the Learners.
Recommendation 1.2 (93): Recognised measures of Cognitive Load should be used during testing with samples of Learners, to identify areas of cognitive overload and/or inefficient data presentation.
Recommendation 1.3 (80): Negative effects from high cognitive demand on Learners' understandings of information, or their learning experience, should be rectified before continuation.

Recommendation 2.2 (88): Self-embodiment by a first-person perspective in Immersive Virtual Reality should be the primary/default perspective for Learners.
Recommendation 2.3 (82): Self-regulation should be encouraged through natural reflective opportunities in an immersive environment. It should aim to scaffold a learner's ability to receive positive feedback, attempt continuation of tasks, and regulate feeling

Recommendation 4.2 (89): Learners should be allowed to draw their own conclusion of meaningful connections in information presented. Feedback is strictly provided only after this occurrence.

Recommendation 5 (80): Co-creation of Immersive Reality resources should be used as one primary method within the final set of recommendation guidelines for use of virtual reality (VR) reusable e-resources in healthcare curricula, in terms of pedagogical aspects.
Recommendation 5.1 (85): Co-creation of Learning Resources should be the primary method of design and development- as guided by a proven conceptual framework.
Recommendation 5.3 (88): A design structure is important for an efficacious outcome- such as Analysis, Design, Development, Implementation, and Evaluation (ADDIE). This can guide and optimize co-creation of Learning Resources.

Recommendation 7 (92): A learning resource should allow Learners to challenge their comprehension of the system, and support failure.
Recommendation 8 (93): Expert knowledge should be included as feedback. When expert knowledge is provided to a Learner, this provides effective scaffolding of the learner's cognitive schema towards more complex comprehension of the system.
Recommendation 10 (81): Assert how the organisation can accommodate the ease of use and access for learners.
Recommendation 11 (80): Newly created learning resources should be integrated into existing systems where possible, to ease the transition to novel resources for the learners.

Strategies/Actions that are recommended to be used by Educators

Recommendation A: Encourage reflection of scenarios after usage.

Recommendation B: Perform pre-briefing and de-briefing of VR scenarios.

Recommendation C: Providing clarity about learning objectives before VR usage.

Recommendation D: Establish rule on how to behave in virtual groups.
Recommendation E: Training of team cooperative procedures including multi-personnel management of patients.
Recommendation F: Use for training of cognitive knowledge, and kinaesthetic skills.
Recommendation G: Training of medical procedures for remote learners, joined by a VR group.