Universities and their Engagements with Augmented Reality (AR) and Virtual Reality (VR) Initiatives: An Environmental Scan

Manasvini Narayana, eConcordia/KnowledgeOne Inc., Canada
Wynnpaul Varela, eConcordia/KnowledgeOne Inc., Canada
Jihan Rabah, eConcordia/KnowledgeOne Inc., Canada

The IAFOR Conference for Higher Education Research- Hong Kong 2019
Official Conference Proceedings

Abstract
The ongoing rise of digitally immersive technologies is hard to ignore. According to a recent study by the Global Virtual Reality Association, by 2020 the augmented and virtual reality (AR-VR) sector will create an estimated 225,000 to 480,000 jobs in Europe alone. Come 2025, the global economic impact of immersive technologies is expected to reach USD 80 billion. And in the probable race for dominance, AR's fusion of virtual reality and real life is likely to triumph over VR's alternate digital reality model, with the former on track to generate revenues of 90 billion USD by 2022, in contrast to VR's projected 15 billion. Unsurprisingly, the rapid evolution of AR-VR in higher education raises important questions about how best to establish intelligent AR, VR, and simulations programs that truly enhance learning outcomes. To better understand the current adoption of immersive technologies, this environmental scan provides an overview of how institutions of higher education are presently engaging with digitally immersive technologies—both academically and administratively. This scan also emphasizes industry and university collaborations where they occur. For the purposes of this report, however, the environmental scan takes the primary perspective of the universities and does not include a scan of industry players or their perspective of AR-VR in higher education.

Keywords: University, Augmented Reality, Virtual Reality, Immersive Technologies

iafor
The International Academic Forum
www.iafor.org

Introduction

Online students can now experience, practice, and learn by being immersed in virtual reality (VR) and augmented reality (AR) as well as other immersive, high-fidelity simulation technologies. The continuum of AR-VR hardware and software is also sometimes referred to as Extended Reality (XR), a flexible superset that accommodates all of (or combinations of) these terms.

A variety of collaborative and experiential learning options are made possible by recent advances in these technologies. Immersive XR experiences can help students visualize difficult concepts by offering a multi-dimensional perspective. They could also help learners explore physical environments that are difficult to access (such as the inside of an engine) or dangerous to manipulate (such as a nuclear reactor), thus enhancing a student's ability to practice skills or learn about such environments. The potential combination of XR with artificial intelligence (AI), machine learning, and big data could also allow for more powerful or feature-rich XR learning environments. While these developments in immersive technologies have garnered tremendous interest in the entertainment industry, they are attracting attention within universities as well, for a variety of reasons. This paper is an overview of the ways in which institutions of higher education are engaging with XR—both academically and administratively. It takes the primary perspective of the universities. It does not, therefore, include a scan of industry players in XR nor their perspective of XR in higher education.

Method

This study is an environmental scan. By definition, an environmental scan observes broad stroke patterns, prioritizing breadth over depth of information. In order to conduct such a scan, an iterative approach was adopted. First, an open search on Google was undertaken using keywords such as virtual reality, augmented reality and mixed reality in conjunction with the term higher education. This established the most popular and visible projects, news and happenings at the intersection of XR and higher education. Then, the study focused on identifying how top ranked universities were engaging with XR. Using the Times Higher Education Ranking, a list of the top 10 universities for 2018 was drawn up for North America, Europe, Asia and Australia. Given the concentration of top-ranking universities in some countries such as the UK and China, a further categorization was made among the continents: China and 'Rest of Asia' as well as UK and 'Rest of Europe'. Next, a detailed search was conducted for the top 3 universities in each list. The researchers faced a roadblock with Chinese universities since information was only available in Mandarin, and the websites themselves did not seem to structure information in the way that universities in other parts of the world typically do. Consequently, it was decided to exclude China from this study, with the intention of reviewing it separately at a future time. The search was based on publicly available information on university and other websites. Maximum efforts were made to triangulate information from multiple sources to ensure a degree of validity. The review of projects also focused on ways in which Universities were engaging with XR, in terms of how they used and worked with XR. The researchers also tabulated XR related research projects that were described in university websites. However, a search through academic databases to assess the nature and quantum of published XR research in each university was not undertaken

at this time. Once the XR projects from the selected universities were identified, they were analyzed. Seven themes in XR use emerged.

Emerged Themes

Basic Research in XR. We define this theme as "under the hood" research, and it refers to research into fundamental issues, technologies and processes that drive XR. Such fundamental research is essential for the growth of the technology as well as the industry. Our scan revealed that basic research in immersive technologies is being conducted within the fields of engineering, computer science, biomedical, neuroscience, or cognitive science. Some of this basic research is conducted in conjunction with industry or other players, and an example of that would be Caltech-NASA's collaboration with Virtualitics, a platform that combines AI, Big Data, Machine Learning, AR, and VR. Other research is more interdisciplinary: ETH Zurich's Department of Neuroinformatics conducts research on neural correlates of virtual reality interactions. Similarly, The University of British Columbia's Emerging Media lab is also involved in research on pain, brain plasticity and suggestibility using VR in the form of the PainBox[1]. The focal goal of this project is to check if it can be demonstrated that pain can be induced by suggestion, because it might be possible to reverse-engineer this finding so as to help people experiencing chronic pain. Yet other projects look at very specific questions about the working of virtual environments such as in the work of McGill's Shared Reality Lab, which studies how to establish haptic feedback in virtual reality environments.

HCI and visualization in XR. The second emergent theme related to design questions related to human-computer interfaces (HCI) and XR. For example, Stanford's Virtual Human Interaction Lab[2], researches human interaction with technological systems, in this case immersive experiences such as VR simulations. University de Montreal has a dedicated center for excellence for "human interaction in a digital world", which is focused on XR. The cognitive science department of ETH, Zurich explores the use of VR in designing buildings, where researchers experiment with the usability of building features (such as signage) in VR, and the users' responses and feedback. Visualization is the other aspect of this theme where immersive technologies were used to present information and data through visual-spatial means to enhance their usability. Examples of such projects are Caltech's Bruce Murray Lab[3] for Planetary Visualization which provides state of the art image processing, visualization and data integration projects. The Center for Data Driven Discovery[4], also at Caltech, works with "immersive and collaborative scientific data visualization" in collaboration with the Jet Propulsion Lab at Caltech.

XR for medical and rehabilitative purposes. A third category of XR projects in universities revolved around the use of XR for medical or health issues of all kinds: physical, cognitive, neurological, behavioral and psychological. This category of projects seemed prolific, with a wide range of projects in universities across the world.

---

1 http://eml.ubc.ca/pain-box/

2 https://vhil.stanford.edu/mission/

3 http://murray-lab.caltech.edu/

4 http://cd3.caltech.edu/

Stanford's Neurosurgical and Virtual Reality Center[5] offers surgeons patient-specific procedure simulation in VR, ahead of the surgery to help them prepare for the actual surgery. The Stanford Center for Continuing Medical Education also hosted a conference[6] on the use of VR for mental health in 2017. The Faculty of Medicine is piloting the use of VR for patient education[7] to prep them for procedures, making them less stressed in the process. University of Toronto Scarborough is piloting a VR based test[8] of cognitive impairment. The University of British Columbia's Emerging media lab is working on a VR approach to help patients with chronic pain[9] in their own homes, built in collaboration with researchers from Simon Fraser university. McGill University Health Center uses AR technology for surgery assistance[10]. The University de Montreal has research projects in which VR is used for therapies for sexual offenders. The Department of Psychiatry at Oxford uses VR to treat psychiatric issues[11] such as fear of heights, psychosis and social anxiety. The results have been successful enough for the researchers to spin out a commercial company called Oxford VR[12] with the same rehabilitative goals. At The University of Melbourne, the University's Engineering department collaborates with industry player Motek Force Link to combine motion analysis with VR[13] tech to study how physical stimuli affect the body and support rehabilitation. The University of Queensland's Center for Clinical Research, is exploring ways in which VR experiences can combat[14] behavioral and psychological symptoms of dementia and Parkinson's disease. The University of Hong Kong houses a virtual reality lab of urban environments and Human health[15]. This uses virtual reality to explore the relationships between urban built environments, and people's physiological and psychological health. The University of Tokyo's Department of Pain and Palliative medicine has successfully used VR to alleviate phantom limb pain[16]. The medical and child psychology departments in the Seoul National University collaborated with a commercial game developer to create a VR game to help young children prepare for surgical procedures[17], and thereby reduce the stress they undergo.

Teaching and learning through and about XR. The fourth category of XR projects in universities is related to the use of XR for teaching and learning purposes in the university. This included learning about XR as well as learning another subject through XR. A sampling of courses about XR are as follows; Stanford's EE267[18], an undergraduate course on creating components of VR, both hardware and software. At

---

5 https://med.stanford.edu/neurosurgery/divisions/vr-lab.html

6 https://med.stanford.edu/cme/courses/2017/psychiatry17.html

7https://www.utoronto.ca/news/not-just-gamers-u-t-anesthesiologists-taking-virtual-reality-patients-facing-surgery

8 https://www.utoronto.ca/news/virtual-reality-test-real-world-impairments

9 http://eml.ubc.ca/projects/vr-in-pain-control/

10 https://muhc.ca/newsroom/news/muhc-takes-augmented-reality-operating-room

11https://www.psych.ox.ac.uk/research/oxford-cognitive-approaches-to-psychosis-o-cap/projects-1/oxford-virtual-reality-vr-for-mental-health

12 http://oxfordvr.org/

13 https://pursuit.unimelb.edu.au/articles/using-virtual-reality-to-treat-real-world-injuries

14 https://shorthand.uq.edu.au/medicine/virtual-reality-frees-the-mind/

15https://www.arch.hku.hk/researchcentre/virtual-reality-lab-of-urban-environments-human-health/

16 https://www.u-tokyo.ac.jp/focus/en/articles/a_00513.html

17 http://en.snu.ac.kr/media-coverage?bm=v&bbsidx=125098

18 https://stanford.edu/class/ee267/

the National University of Singapore, the school of Computer Science offered a course on interaction design[19] for VR and AR in 2018. The University of Hongkong offers a course on the human aspect of virtual worlds[20] in this humanities program. Caltech's Art 88 course in Critical Making[21] explores the nature of many technologies including VR. On the other hand, are a range of projects that use XR for teaching students and communities a particular subject or topic. Examples of this include: Stanford University's science education VR content for the public about ocean acidification[22] and Harvard Graduate School of Education's pilot VR program to help middle schoolers explore ecology related issues[23]. NASA, Brown University and Harvard have collaborated to combine several astronomy and imaging technologies to create a VR experience of walking within stellar debris[24]. The Harvard Law School published a series on legal issues[25] relating to virtual reality in 2017, which we also classified as being related to teaching and learning. At the University of British Columbia, the HoloBrain[26] AR app was created as a teaching tool that could be implemented in neuroanatomy instruction, and to evaluate its effectiveness in the classroom. The University of British Columbia has also developed Physics World[27] to help students visualize physics concepts and. Math World[28] with a similar objective. UBC Faculty of Medicine and Faculty of dentistry collaborate on a VR experience to learn about the structure of the skull in Fossa Finder[29]. Exploration of an ancient city in Cyprus[30], being developed both in AR and VR. Soil TopARgraphy[31] is an AR app that showcases soil orders. Students view the AR terrain in a satellite or height-map view, watch videos, or take quizzes to learn about soils in a visual and interactive approach. Journey with me[32] is an AR journey from Syria to Vancouver while listening to real stories of people who have had to immigrate under difficult circumstances. This project aims to help people understand and empathize with the emotional journeys of refugees. UBC also conducted a summer institute in 2018 called Viewpoints on a New Medium[33], referring to VR. The National University of Singapore Center for Instructional Technology showcases Technology Enabled Learning Initiatives. This demonstrates the ways in which individual professors or departments use AR and VR as part of their instructional practices[34].

Procedural practice through XR. The fifth category of XR projects includes those that use these technologies to learn and practice high risk procedures in the low risk

---

[19]https://ivle.nus.edu.sg/V1/lms/public/view_moduleoutline.aspx?CourseID=06c4d3a7-d2ff-4a67-a7c5-6e9ec32d910b

[20] https://commoncore.hku.hk/cchu9056/

[21] http://www.hss.caltech.edu/courses/undergrad/department/Art/2017-18

[22]https://news.stanford.edu/2016/10/18/virtual-reality-simulation-transports-users-ocean-future/

[23] https://www.gse.harvard.edu/news/uk/14/11/virtual-reality-real-science

[24] http://chandra.harvard.edu/vr/

[25] https://jolt.law.harvard.edu/assets/articlePDFs/v30/30HarvJLTech601.pdf

[26] https://news.ubc.ca/2017/08/28/mixed-reality-gives-neuroanatomy-lessons-a-boost/

[27] http://eml.ubc.ca/projects/physics-world/

[28] http://eml.ubc.ca/math-world/

[29] http://eml.ubc.ca/projects/fossa-finder/

[30] http://eml.ubc.ca/projects/exploration-of-ancient-city/

[31] http://eml.ubc.ca/projects/soil-topargraphy/

[32] http://eml.ubc.ca/journey-with-me/

[33] http://pdce.educ.ubc.ca/virtual-reality/

[34] http://www.cit.nus.edu.sg/tech-day/

environment of VR, such as for surgery. Some of these projects may also be reasonably categorized as medical, but given the variety of procedural practice projects, we decided to create a separate category. For example, at the ETH, Zurich's Department of Computer Science, a project combines virtual reality and AI to create a driving simulator that supports adaptive tutoring for driving[35]. HongKong University Faculty of Engineering has created 'imseCAVE', a high performance, low cost, virtual environment for industrial applications and training[36]. This platform has also been used by the Hong Kong corrective service department[37]. At McGill, the Open Orchestra projects is described as a "flight simulator for orchestra musicians", which allows musicians to practice as if with a live orchestra. At the University of Tokyo an inter-faculty initiative in Information studies is working on the concept of "Augmented Humans[38]", where sensory inputs from robots, drones or other people is accessed by a person. This has implications for sports training, disaster management and the like.

Narratives and experiences in XR. The sixth category of projects that we encountered can best be described as the use of VR to create experiences or to immerse the viewer in a story or narrative. These projects explore environments and the human condition through performance and the arts. For example, Stanford's Communications Department is considering future of journalism with VR[39] and has developed a course related to it. At MIT, the Computer Science and Artificial Intelligence Lab created a VR program to build empathy[40], underlying the importance of being at the intersection of technology and social issues. A related project is the interesting 'Machine to be another'[41] performance. University of British Columbia's Stanley Park VR tour[42], is a geography field trip created using a combination of immersive technologies. The university's Emerging Media Lab has also created a series of 360-degree videos[43] of iconic sites on UBC's campus as well as in Vancouver. This serves as an orientation to new students, apart from being available to the public.

XR as a hook. The seventh category of projects in the sample were ones where XR was used in practical ways to engage with students or the larger community. This aim of engagement was to "hook" people in order for them to engage in other, traditional ways with the university. Typically hook projects were used to attract students during recruitment events, or for knowledge mobilization. In an era where national and international student mobility is high, it is often not feasible for potential students to actually visit campuses they are interested in. Universities are therefore experimenting with XR applications to attract potential students, or provide campus tours for those who are unable to physically attend. In 2015, the Savannah College of Art and Design

---

[35]http://www.gtc.inf.ethz.ch/publications/adaptive-tutoring-on-a-virtual-reality-driving-simulator.html

[36] https://www.hku.hk/press/press-releases/detail/12995.html

[37]https://www.imse.hku.hk/events/virtual-reality-scenario-training-applied-in-staff-institute-of-the-correctional-services-department

[38] https://www.u-tokyo.ac.jp/en/whyutokyo/science_16_2.html

[39] https://news.stanford.edu/thedish/2016/08/29/virtual-realitys-future-in-journalism/

[40] http://news.mit.edu/2017/student-profile-danielle-olson-0531

[41]https://docubase.mit.edu/lab/case-studies/the-limits-of-virtual-reality-debugging-the-empathy-machine/

[42] http://eml.ubc.ca/projects/geography-vr/

[43] http://eml.ubc.ca/projects/360-videos/

sent Google Cardboard headsets to 30,000 accepted students to let them visually explore the school's campuses. SCAD featured a 26 percent jump in admissions within 12 months of starting the program[44]. In 2017, SCAD debuted an enhanced version of its course catalog[45], which offered prospective students a detailed view of the school via AR videos of students' creative sessions, games they'd designed and other items[46]. A wide variety of universities use some form of XR for campus tours including University of Miami, Georgia College, Bates College, Florida Polytechnic, University College London, Bloomfield college, University of Shanghai for Science and technology, Trinity University, Hartford University, Regis University, Princeton, Kent State. On a related note, Iowa State University uses VR specifically to attract future athlete students. Attracting sportspersons is a high priority for universities such as Iowa State, but game day visits are complex and expensive to arrange. VR seems to provide some options[47]. Most of these tours are not developed internally by the university but are either outsourced or developed in collaboration with commercial entities such as YouVisit and Lucid VR. Ecity Interactive, one such provider, claims that "Virtual reality tour companies now have more than 1000 colleges and universities on the roster, and these numbers will only grow over time." XR technology is also used in some instances to share the research work being done in the university. Iowa state has used VR in a public outreach program to educate the community on the experience and impact of an upcoming bridge over the Missouri river.

The XR Sandbox. Many universities appear to have a general collection of XR hardware and software, that is available for the university community to experiment with, or just to try out as an experience. Universities typically have extensive XR equipment within specific departments if those departments are already involved in XR projects of some kind, usually in science, engineering, computer science, the arts and media departments. However, the use of this equipment often needs to be multi-disciplinary. On this account, it is often university libraries that make XR equipment available for use just as they would make other library resources available. Typically, libraries and centers for teaching and learning also provide the learning support to help the community actually use the equipment. While a large number of universities reviewed appeared to have some sort of XR Sandbox, some of the bigger sandboxes are to be found at the National University of Singapore, Oxford University, and Caltech. In fact, the Caltech library also houses VR software developed in-house by the Caltech community[48].

Conclusion and Recommendations

AR-VR is currently penetrating the higher education sector. The general themes we characterizes the AR-VR initiatives in higher education are as follows: Basic research, research in HCI and data and information visualization for AR-VR, use of AR-VR in medical and rehabilitation contexts, AR-VR for teaching and learning, VR for

---

[44]https://www.scad.edu/about/news-press-and-recognition/2015-02-23-scad-extends-campus-experience-through-virtual-reality

[45]https://www.prnewswire.com/news-releases/savannah-college-of-art-and-design-introduces-groundbreaking-augmented-reality-college-experience-300418478.html

[46]https://edtechmagazine.com/higher/article/2018/05/4-ways-colleges-are-embracing-virtual-reality

[47] https://www.news.iastate.edu/news/2015/10/16/gameday

[48] https://www.library.caltech.edu/VR

professional practice, VR for narratives and arts-based experiences, VR as a hook, and AR-VR sandbox. Most AR-VR initiatives encountered in the HE sector can further be characterized along two dimensions. The first dimension describes its application in either teaching or research; the second is whether AR-VR is the topic or the medium of the activity. This creates four quadrants of activity: (1) AR-VR as the object of research; (2) AR-VR as the technology through which research & research creation takes place; (3) AR-VR as the subject of study; and (4) AR-VR as a learning technology.

It is an exciting time to fundamentally rethink, reconceptualize the affordances of the technologies, how they may be relevant to research and teaching activities along with the rethinking of the technologies themselves. Finally, our scan was entirely based on publicly available data. As such, we did not contact people and speak to them directly to validate these findings and analyses. Direct communication with universities and their industry partners would potentially grant us access to richer data, which would in turn permit yet deeper levels of analysis.

Resources

"Pain Box." *Pain Box | Emerging Media Lab*, eml.ubc.ca/pain-box/.

"The Murray Lab." *Caltech*, murray-lab.caltech.edu/.

"Virtual Human Interaction Lab, Stanford University." *VHIL*, vhil.stanford.edu/.

"Dollhouse V." *Dollhouse VR*, www-ui.is.s.u-tokyo.ac.jp/projects/dollhousevr/.

Neurosurgery. "Virtual Reality Lab." *Neurosurgery*, med.stanford.edu/neurosurgery/divisions/vr-lab.html.

Stanford Center for Continuing Medical Education. "3rd Annual Innovations in Psychiatry and Behavioral Health: Virtual Reality and Behavior Change." *Stanford Center for Continuing Medical Education*, med.stanford.edu/cme/courses/2017/psychiatry17.html.

"Not Just for Gamers: U of T Anesthesiologists Taking Virtual Reality to Patients Facing Surgery." *University of Toronto News*, www.utoronto.ca/news/not-just-gamers-u-t-anesthesiologists-taking-virtual-reality-patients-facing-surgery.

"Virtual Reality Test for Real-World Impairments." *University of Toronto News*, www.utoronto.ca/news/virtual-reality-test-real-world-impairments.

"VR in Pain Control." *Immersive Multimedia as an Adjunctive Measure for Pain Control in Cancer Patients*, eml.ubc.ca/projects/vr-in-pain-control/.

"MUHC Takes Augmented Reality into the Operating Room." *McGill University Health Centre*, muhc.ca/newsroom/news/muhc-takes-augmented-reality-operating-room.

"Oxford Virtual Reality (VR) for Mental Health." *Department of Psychiatry*, www.psych.ox.ac.uk/research/oxford-cognitive-approaches-to-psychosis-o-cap/projects-1/oxford-virtual-reality-vr-for-mental-health.

"Oxford VR." *Oxford VR*, oxfordvr.org/.

"Music Therapy in Virtual Environments." *Networked Society Institute*, networkedsociety.unimelb.edu.au/research/projects/2016/virtual-reality-in-health/music-therapy-in-virtual-environments.

Stanton, Kate, and University of Melbourne. "Using Virtual Reality to Treat Real-World Injuries." *Pursuit*, The University of Melbourne, 9 Oct. 2019, pursuit.unimelb.edu.au/articles/using-virtual-reality-to-treat-real-world-injuries.

Virtual-Reality-Frees-the-Mind, shorthand.uq.edu.au/medicine/virtual-reality-frees-the-mind/.

"Virtual Reality Lab of Urban Environments & Human Health: HKU Faculty of Architecture." *Virtual Reality Lab of Urban Environments & Human Health | HKU Faculty of Architecture*, www.arch.hku.hk/researchcentre/virtual-reality-lab-of-urban-environments-human-health/.

"Effective Rehabilitation of Phantom Limb Pain with Virtual Reality." *The University of Tokyo*, www.u-tokyo.ac.jp/focus/en/articles/a_00513.html.

Seoul National University. "Medical Marvels: This Virtual Reality Game Is Helping Young Patients Having Surgery." *SEOUL NATIONAL UNIVERSITY*, en.snu.ac.kr/media-coverage?bm=v&bbsidx=125098.

"Art History (Art) Undergraduate Courses (2017-18)." *Art History (Art) Undergraduate Courses | Division of the Humanities and Social Sciences*, www.hss.caltech.edu/courses/undergrad/department/Art/2017-18.

EE267: Virtual Reality, stanford.edu/class/ee267/.

Stanford University. "Stanford Researchers Release Virtual Reality Simulation That Transports Users to Ocean of the Future." *Stanford News*, 17 Oct. 2016, news.stanford.edu/2016/10/18/virtual-reality-simulation-transports-users-ocean-future/.

Machado, David Vazquez. "Kinesthetic Language Learning in Virtual Reality." *MIT Media Lab*, www.media.mit.edu/posts/kinesthetic-language-learning-in-virtual-reality/.

"Virtual Reality, Real Science." *Harvard Graduate School of Education*, www.gse.harvard.edu/news/uk/14/11/virtual-reality-real-science.

"RESOURCES." *Chandra*, chandra.harvard.edu/vr/.

HarvJLTech601, jolt.law.harvard.edu/assets/articlePDFs/v30/30HarvJLTech601.pdf.

"CS50 Moves Away from Traditional Lectures, Toward Virtual Reality: News: The Harvard Crimson." *CS50 Moves Away from Traditional Lectures, Toward Virtual Reality | News*, www.thecrimson.com/article/2016/8/31/CS50-moves-from-lectures/.

Amos, Heather. "Mixed Reality Gives Neuroanatomy Lessons a Boost." *UBC News*, 14 Sept. 2017, news.ubc.ca/2017/08/28/mixed-reality-gives-neuroanatomy-lessons-a-boost/.

"HoloBrain." *HoloBrain | Emerging Media Lab*, eml.ubc.ca/projects/holobrain/.

"Physics World." *Physics World | Emerging Media Lab*, eml.ubc.ca/projects/physics-world/.

"Growing Games from the Ground Up." *AGDA*, amsgda.com/.

"Math World." *Math World | Emerging Media Lab*, eml.ubc.ca/math-world/.

"Fossa Finder." *Fossa Finder | Emerging Media Lab*, eml.ubc.ca/projects/fossa-finder/.

"Exploring an Ancient City." *Exploring an Ancient City | Emerging Media Lab*, eml.ubc.ca/projects/exploration-of-ancient-city/.

"Soil TopARgraphy." *Soil TopARgraphy | Emerging Media Lab*, eml.ubc.ca/projects/soil-topargraphy/.

"Journey With Me." *Journey With Me | Emerging Media Lab*, eml.ubc.ca/journey-with-me/.

"Virtual Reality: Viewpoints on a New Medium." *Virtual Reality: Viewpoints on a New Medium | Professional Development & Community Engagement*, pdce.educ.ubc.ca/virtual-reality/.

"Advanced Research Computing (ARC)." *Arc.ubc.ca*, arc.ubc.ca/.

Partner Organizations, arc.ubc.ca/about-arc/partner-organizations.

"XR:MTL – A New Innovation Factory on Virtual, Augmented and Mixed Reality Technologies in Montreal." *GlobeNewswire News Room*, "GlobeNewswire", 11 July 2018, www.globenewswire.com/news-release/2018/07/11/1535806/0/en/XR-MTL-A-new-Innovation-Factory-on-Virtual-Augmented-and-Mixed-Reality-technologies-in-Montreal.html.

"Module Overview." *Search Modules > CS4240 > Module Overview*, ivle.nus.edu.sg/V1/lms/public/view_moduleoutline.aspx?CourseID=06c4d3a7-d2ff-4a67-a7c5-6e9ec32d910b.

NUS Tech Experience Day, www.cit.nus.edu.sg/tech-day/.

"CCHU9056 – Virtual Worlds, Real Bodies." *HKU Common Core Curriculum*, commoncore.hku.hk/cchu9056/.

"Adaptive Tutoring on a Virtual Reality Driving Simulator." *Adaptive Tutoring on a Virtual Reality Driving Simulator – Game Technology Center | ETH Zurich*, www.gtc.inf.ethz.ch/publications/adaptive-tutoring-on-a-virtual-reality-driving-simulator.html.

"Augmented Reality Laboratory, National University of Singapore." *Augmented Reality Laboratory National University of Singapore*, blog.nus.edu.sg/nusarlab/.

"Augmented Reality Laboratory, National University of Singapore." *Augmented Reality Laboratory National University of Singapore*, blog.nus.edu.sg/nusarlab/current-research-activities/.

"HKU Faculty of Engineering Creates Innovative 'ImseCAVE' - a High Performance, Low Cost, Virtual Environment for Industrial Applications and Training - Press

Releases - Media - HKU." *The University of Hong Kong*, www.hku.hk/press/press-releases/detail/12995.html.

"Newsletter." *HKU Department of Industrial and Manufacturing Systems Engineering*, www.imse.hku.hk/events/virtual-reality-scenario-training-applied-in-staff-institute-of-the-correctional-services-department.

"Creating a World Where Man and Machine Are One." *The University of Tokyo*, www.u-tokyo.ac.jp/en/whyutokyo/science_16_2.html.

Stanford News. "Virtual Reality's Future in Journalism." *The Dish*, news.stanford.edu/thedish/2016/08/29/virtual-realitys-future-in-journalism/.

CSAIL, Rachel Gordon |. "Danielle Olson: Building Empathy through Computer Science and Art." *MIT News*, 30 May 2017, news.mit.edu/2017/student-profile-danielle-olson-0531.

Ribordy, Antoine. "The Limits of Virtual Reality: Debugging the Empathy Machine." *MIT*, docubase.mit.edu/lab/case-studies/the-limits-of-virtual-reality-debugging-the-empathy-machine/.

"Building Digital Humans: Would-Be U of T Entrepreneurs to Put a Non-'Creepy' Human Face on Digital Assistants." *University of Toronto News*, www.utoronto.ca/news/building-digital-humans-would-be-u-t-entrepreneurs-put-non-creepy-human-face-digital-assistants.

"Quantum Capture." *Quantum Capture*, www.quantumcapture.com/.
"Stanley Park Geography VR Field Trip." *Stanley Park Geography VR Field Trip | Emerging Media Lab*, eml.ubc.ca/projects/geography-vr/.

"Explore the Metaverse - A Virtual Reality Studio." *Metanaut*, 1 Oct. 2019, metanautvr.com/.

"360 Videos." *360 Videos | Emerging Media Lab*, eml.ubc.ca/projects/360-videos/.

"SCAD Extends the Campus Experience through Virtual Reality." *SCAD.edu*, www.scad.edu/about/news-press-and-recognition/2015-02-23-scad-extends-campus-experience-through-virtual-reality.

Savannah College. "Savannah College of Art and Design Introduces Groundbreaking Augmented Reality College Experience." *PR Newswire: Press Release Distribution, Targeting, Monitoring and Marketing*, 26 June 2018, www.prnewswire.com/news-releases/savannah-college-of-art-and-design-introduces-groundbreaking-augmented-reality-college-experience-300418478.html.

Brereton, Erin. "4 Ways Colleges Are Embracing Virtual Reality." *Technology Solutions That Drive Education*, 1 May 2019, edtechmagazine.com/higher/article/2018/05/4-ways-colleges-are-embracing-virtual-reality.

"Visit Iconic Campus Landmarks On Texas A&M's New Virtual Reality Tour." *Texas A&M Today*, 4 Jan. 2019, today.tamu.edu/2017/04/12/visit-iconic-campus-landmarks-on-texas-ams-new-virtual-reality-tour/.

"Virtual Reality Puts Football Recruits in the Middle of Game Day at Jack Trice Stadium." *RSS*, www.news.iastate.edu/news/2015/10/16/gameday.

"Virtual Reality Workstation." *Caltech Library*, www.library.caltech.edu/VR.

Contact email: jihan.rabah@knowledgeone.ca