frontiers in Education

SYSTEMATIC REVIEW
published: 14 August 2019
doi: 10.3389/feduc.2019.00080

Head-Mounted Display Virtual Reality in Post-secondary Education and Skill Training

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Background: This review focused on how immersive head-mounted display virtual reality (VR) was used in post-secondary level education and skill training, with the aim to better understand its state of the art as found from the literature. While numerous studies describe the use of immersive VR within a specific educational setting, they are often standalone events not fully detailed regarding their curricular integration. This review aims to analyse these events, with a focus on immersive VR's incorporation into post-secondary education.

Objectives: (O1) Review the existing literature on the use of immersive VR in post-secondary settings, determining where and how it has been used within each educational discipline. This criterion focused on literature featuring the use of immersive VR, due to its influence on a user's perceived levels of presence and imagination. (O2) Identify favorable outcomes from the use of immersive VR when it is compared to other learning methods. (O3) Determine the conceptual rationale (purpose) for each implementation of immersive VR as found throughout the literature. (O4) Identify learning theories and recommendations for the utilization of immersive VR in post-secondary education.

Methods: A literature review was undertaken with searches of Education Research Complete, ERIC, MEDLINE, EMBASE, IEEE Xplore, Scopus, and Web of Science: Core Collection to locate reports on the use of immersive VR in post-secondary curricula.

Results: One hundred and nineteen articles were identified, featuring disciplines across Arts and Humanities, Health Sciences, Military and Aerospace, Science and Technology. Thirty five out of 38 experiments reported to have found a positive outcome for immersive VR, after being compared with a non-immersive platform. Each simulation's purpose included one or more of the following designations: skill training, convenience, engagement, safety, highlighting, interactivity, team building, and suggestion. Recommendations for immersive VR in post-secondary education emphasize experiential learning and social constructivist approaches, including student-created virtual environments that are mainly led by the students themselves under team collaboration.

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Digital Education, a section of the journal Frontiers in Education

***Received:** 02 March 2019*
***Accepted:** 19 July 2019*
***Published:** 14 August 2019*

Citation:
Concannon BJ, Esmail S and Roduta Roberts M (2019) Head-Mounted Display Virtual Reality in Post-secondary Education and Skill Training. Front. Educ. 4:80. doi: 10.3389/feduc.2019.00080

Conclusion: Immersive VR brings convenient, engaging, and interactive alternatives to traditional classroom settings as well as offers additional capability over traditional methods. There is a diverse assortment of educational disciplines that have each attempted to harness the power of this technological medium.

Keywords: virtual reality (VR), head-mounted display (HMD), immersive technology, educational technology, education, training, simulation

INTRODUCTION

In the year 2012, Palmer Luckey initiated a Kickstarter campaign to fund the Oculus Rift: an affordable head-mounted display (HMD) virtual reality (VR) system that would allow tech-savvy enthusiasts to begin building and experiencing their own virtual environments. Prior to this time, HMD VR technology had often contained head-tracking issues, resulting in inaccurate and poor representations within the virtual world (Robinett and Rolland, 1992). Despite using the most sophisticated HMD graphics processors that were available in the early and late 1990s, realistic image processing of virtual environments would often overburden the system's computation ability, causing the user to experience tracking and latency issues. In other words, the actions of the user from the real world would often fail to translate accurately into the virtual world. Latency issues were brought to acceptable standards in the early 2010s when computer engineers were able to identify and correct the delays associated between a user's actions and the hardware's capability. Since the mid-2010s, an "unprecedented" uptake of HMD VR has been seen in both academic and industry contexts (Elbamby et al., 2018). VR has steadily been adopted into post-secondary educational systems with relative success, because of its ability to retain student learning and interest while saving resources and improving experimental efficiency (Liang and Xiaoming, 2013).

This review focused on immersive VR in post-secondary level education and skill training to gain a better understanding of its potential ability to train users under higher-order thinking conditions, which typically requires advanced judgment skills such as critical thinking and problem solving. Immersive VR is also capable of training users for advanced conditions that simulate hazardous environments or undesirable social situations that may be less appropriate for users below post-secondary educational levels. Although the literature regarding the use of immersive VR within post-secondary educational settings is quite diverse, these events are often standalone and seldom provide details on how immersive VR is adopted into associated curriculums. This review aims to analyse these events, focusing on how immersive VR can be incorporated into post-secondary education.

Rationale

The International Data Corporation (IDC) expects compound annual growth rates of VR to increase by 78.3% for the next 5 years, rising from $16.8 billion in 2019 to $160 billion by 2023 (Nagel, 2019). The fields for this growth are expected to include the education sector, with VR for lab and field work in higher education settings having a 5-year compound annual growth rate of 183.4% (Nagel, 2019). With the increased availability of consumer-level HMD VR hardware on the market, such as the Oculus Rift, HTC Vive, Playstation VR, and mobile phone technology, this newfound accessibility has led to an upshift in immersive VR adoption into academic settings. There has also been an increase in available software that runs on HMD VR, yet research on what is utilized in academic settings is ever changing and upgrading. An update to understand the "how and for what" aspects of virtual technology, affecting performance in academia, has been recommended (Jensen and Konradsen, 2018). This state-of-the-art review observes the disciplines, methods and theories in post-secondary practice that features the use of immersive VR.

Virtual Reality (VR)—Definition and Features

VR is broadly defined as an environment where users can accept and respond to artificial stimuli in a natural way (Zhang, 2014). Other definitions of VR include the human-machine interface that allows users to "project" themselves into a computer generated world, where specific objectives can be achieved (Zhang, 2014). VR is sometimes known as "Ling-jing" technology (Hui-Zhen and Zong-Fa, 2013; Hu and Wang, 2015). Depending on the setup of the human-machine interface, the components of the hardware and the amount of real-world images that are placed into the virtual world; a user's experience will vary between the differing types of mixed reality including augmented reality (AR), augmented virtuality (AV), mirror reality (MR), and virtual reality (VR) (Cochrane, 2016; Tacgin and Arslan, 2017). See **Table 1** for a glossary of terms. Note that the proper usage of these terms has not caught up with the rate in which virtual reality concepts have grown (Cochrane, 2016; Tacgin and Arslan, 2017). There are often misconceptions between VR concepts and types. For example, some scientific literature will refer to AR applications as VR and vice versa (Tacgin and Arslan, 2017).

Immersion

One feature of VR is its physical level of immersion, defined by the degree a user associates being within a virtual environment (Rebelo et al., 2012; Parsons, 2015). Immersion is reduced when a user is able to perceive aspects of the real world while experiencing the virtual world. For example, users who can perceive the frame of a projection screen, depicting a virtual environment that simulates being in outer space, may compromise the users' level of immersion. When classifying the level of immersion, based on the human-machine interface, there

TABLE 1 | Glossary of common terms describing Virtual Reality.

Term	Definition	Examples
Immersive VR	The user is entirely surrounded by the virtual environment, encompassing optimal field-of-view (Rebelo et al., 2012).	HMD VR. CAVE.
Non-immersive VR	The user is not entirely surrounded by the virtual environment, allowing images of the virtual world and real world to both be seen simultaneously (Rebelo et al., 2012).	AR. AV. Desktop computer experience.
Augmented Reality (AR)	Also known as stacked VR, computer images are superimposed onto a glass or lens display, simultaneously showing both real world and computer generated images. The view is mainly the real world, supplemented with computer generated graphics.	A marker overlay is projected onto a pair of glasses (Smart Glasses) so the user can see both the real world and virtual overlay at the same time.
Augmented Virtuality (AV)	A real-world image is projected into a virtual world, allowing the integrated real-world image to interact with the virtual world in real-time. A view that is mainly the virtual world, supplemented with captured real-world images.	A camera places a real-world image of the user into a computer generated soccer field, allowing the user to see him or herself move and kick a virtual ball. (Immersive Rehabilitation Exercise (IREX) systems).
Avatar	Derived from the Sanskrit word that refers to the God Vishnu's manifestation on earth (Milgram et al., 1995; Trepte et al., 2010), this is a projected image and representation of a user or artificially intelligent character within a virtual world.	User acts as a firefighter in a fire-safety virtual environment. World of Warcraft character.
Cave Automatic Virtual Environment (CAVE)	Images are projected onto the walls, ceilings and floors of a room-sized cube, which change based on a user's actions while he or she is inside the room. The movements of the user are often detected by tracking technology.	A user sits in a fixed wheelchair, placed in the middle of a room. The projected images on the floors, ceilings, and walls create the effect that the user is moving along a path, within a garden, as the chair's wheels are spun.
Distributed Reality	A web-based virtual environment, where multiple users control their avatars to interact with each other in the virtual world, despite the users being physically located in different geographical locations.	Second life. World of Warcraft.
Engine	A framework of coding used to script and animate computer programs such that they become virtual worlds.	Unity. Unreal Engine 4.
Latency	The delay between a user's action (head rotation) and corresponding change in the virtual environment to represent the user's new field of view.	Lag. Sensor sampling delay. Image Processing delay. Network delay.
Mirror Reality	A virtual environment that aims to recreate a copy of the real world.	The digital viewfinder of a camera shows a pixel image of the real world.
Mixed Reality	Also known as hybrid reality, real-world images are combined with a virtual world. The amount of real-world images that are used in the virtual world determines the mixed reality's abilities as defined by the reality-virtuality continuum (Milgram et al., 1995).	AR. AV.
Smart Glasses	Mobile computers that combine HMD with sensors to display computer graphics in the real world.	Google Glass. Microsoft HoloLens.
Stereoscopy	Also known as stereoscopics or stereo imaging. The perception of three-dimensional (3D) images that are often created by presenting two offset images, separately shown to the left and right eye.	Anaglyph 3D films, viewed with red and blue filter glasses. Most modern HMD units feature stereoscopic 3D.
Tracking Technology	Sensors that detect movement, position, and angle of an object or user while in a virtual space. The sensors relay numeric coordinates to the computer or base station for processing.	A user's hands are represented in the virtual space with the use of controllers. Infrared sensors or gyroscopes on the controllers provide positional data to a base station for processing.
Virtual Reality (VR)	A computer system that creates an artificial environment where users can project themselves and respond to artificial stimuli in a natural way or complete specific objectives (Zhang, 2014).	A user enters a virtual world, seeing and interacting with the virtual environment, with the use of a HMD and gloves, respectively.

are three types: full immersion is achievable when the user utilizes a HMD (goggles, VR helmet or headset); semi-immersion is achievable when the user utilizes large projection or liquid crystal display (LCD) screens; and non-immersion is achievable when utilizing typical desktop computer setups with keyboards and mice (Gutiérrez Alonso et al., 2008; Rebelo et al., 2012; Parsons, 2015). Note that the main difference between these levels of immersion is due to the user's field of vision (FOV), where an optimal FOV of 180 degrees horizontal and 60 or more degrees vertical is achievable with the HMD hardware (Rebelo et al., 2012). Reduced perception (seeing, hearing, touching) of the real world tends to result in greater levels of VR immersion (Gutiérrez Alonso et al., 2008; Rebelo et al., 2012).

Interactivity

The second feature of VR is its level of interactivity, defined as the degree of accuracy and responsiveness a user's actions represent when using the input hardware (Rebelo et al., 2012; Parsons, 2015). For example, with the use of physical hardware such as motion-sensing gloves, VR systems will allow users to interact with objects that are located within the virtual environment. Using input hardware to interact with a virtual environment is analogous to using a mouse and keyboard to give commands to a desktop computer. Common VR input devices include motion-sensing gloves, remotes, controllers, Lycra suits, Leap Motion (for barehanded gestures) or photo sensors to transfer the user's real-world actions into the virtual world. The position and motion of the user's hands can be updated in real-time with the use of sensors that allow for up to six degrees of freedom. Some input devices are equipped with features to provide kinaesthetic communication to the user, such as force or haptic feedback response. An example of this force feedback occurs in skill training when an operator's surgical tools become resistant to movement, after colliding with visceral tissues in a virtual patient, during simulated laparoscopic surgery.

Imagination

The third feature of VR is grounded with the user's imagination, defined as the extent of belief a user feels is within a virtual environment, despite knowing he or she is physically situated in another environment (Burdea and Coiffet, 2003; Rebelo et al., 2012). Note that interactivity and immersion have a direct effect on a user's level of imagination, which is dependent on the VR's input devices, graphics, and objectives (Rebelo et al., 2012). These features of immersion, interaction and imagination form the "VR Triangle (Burdea and Coiffet, 2003)." Note that not all VR setups attempt to emphasize all three features (immersion, interaction and imagination) in a virtual environment. For example, a surgical simulator, designed for skill training, requiring force, and haptic feedback controls would place interactivity above immersion and imagination.

Presence is a subjective concept that defines the psychological degree a user understands where it is possible to act within the virtual environment (Rebelo et al., 2012). A user feels present in a virtual environment when he or she feels the experience is derived from the virtual environment, rather than the real world (Rebelo et al., 2012). Deep presence occurs when a user feels both immersion and involvement in the virtual environment (Rebelo et al., 2012). Involvement has been formally defined as the user's attention and effort being placed on a "coherent set of stimuli or meaningful activities and events" (Witmer and Singer, 1994).

The state of presence can be explained with the term fidelity, derived from the Latin word "fidelis," meaning faithfulness or loyalty. A virtual environment is deemed to be of high fidelity when the user's actions, senses and thought-processes closely or exactly resemble those that would be experienced while in the same situation as in the real world. VR experts have classified fidelity into different parts including functional (Swezey and Llaneras, 1997), physical (Champney et al., 2017) and psychological fidelity (Rehmann et al., 1995). An example of a low fidelity virtual environment would be a driving simulator that uses a gamepad instead of a steering wheel, while the driver's FOV is limited to that of an LCD screen. Whereas, an example of a high fidelity virtual environment would be an airplane simulator that has all the relevant controls and visual layout, exactly matching that of a cockpit from a real-world model, allowing pilots to conduct their skill training in the virtual world to prepare for flying in the real world.

Incentives for Adopting Immersive VR Into Post-secondary Education

One principle underlying the development and evaluation of the VR experience is experiential learning, which is aligned with the constructivist theory of learning. Educational simulation is grounded in the pedagogy of mastery learning (Guskey, 2010; Alaker et al., 2016). Users are generally more motivated to participate in a virtual environment, which can be instantly adjusted to differing levels of challenge, accommodating varying amounts of cognitive ability (Shin and Kim, 2015). VR can safely provide answers to inaccessible and intangible concepts that would otherwise be considered too dangerous or unethical to perform in real life (Grenier et al., 2015). It is a safe, ethical and repeatable system that produces objective measures of performance while providing real-time feedback to users (Alaker et al., 2016). Non-immersive VR has already been adopted in desktop and distributed platforms, allowing users to share a common virtual space, despite the users being physically located in geographically different locations (Hu and Wang, 2015). Immersive VR users have shown a piqued curiosity to learn with the HMD hardware, which often results in enhanced learning enjoyment (Moro et al., 2017).

Immersive VR users commonly feel that they have been projected into a different location (place illusion), while experiencing events that are perceived to be real (plausibility illusion; Sanchez-Vives and Slater, 2005). Sometimes, users will feel their own body is different when represented as an avatar with varying characteristics (embodiment illusion; Spanlang et al., 2014). Whenever a student is listening to an instructor or reading literature in order to better understand a concept, the student is mainly acting as an observer. The student may perhaps have the ability to interact with the learning experience by asking the occasional question or by completing exercises that are printed in the textbook, yet with immersive VR the student acts as both an observer and "the center of the system" (Gonzalez-Franco and Lanier, 2017). Place, plausibility and embodiment illusions are created by computer generated stimuli that may persuade a user's brain to respond as though the illusions were real. When multiple senses are incorporated into the user-to-object interaction within the virtual world such as vision, audition, and tactile/proprioception, a coordination of brain mechanisms are required to process this afferent sensory input and interpret the data coherently (Kilteni et al., 2015). In other words, immersive VR allows a user to learn how they would feel and respond (physiologically, tactfully, and procedurally) when interacting with virtual situations that the brain treats as real.

Obstacles Inhibiting the Adoption of Immersive VR Into Post-secondary Education

One obstacle inhibiting the adoption of immersive VR may involve the ability of educators to schedule immersive VR into their traditional methods of teaching, potentially being unaware about VR technology and how it could be integrated into the curriculum (Cochrane, 2016). It is possible that some universities have concluded that the amount of knowledge or skill gained from using immersive VR is not worth the financial risk. Another possibility is the specific level of detailed knowledge the HMD VR hardware requires in order to use it properly, posing yet another barrier to entry (Gutierrez-Maldonado et al., 2015). Perhaps VR's biggest obstacle to being accepted into post-secondary education systems is its psychometric validation, where stakeholders must carefully judge the degree to which virtual environments offer training in skills that can be obtained in other less expensive or complex modalities, which are free from simulator sickness (Parsons, 2015). There are two obstacles that inhibit the adoption of immersive VR into post-secondary education: (a) Software—There is a lack of applicable content for each discipline and most of what is available is mainly marketed toward self-learners, (b) Hardware—HMDs default to being entertainment systems that were not originally intended for classroom use (Jensen and Konradsen, 2018).

Criticisms of Immersive VR in Post-secondary Education

Immersive VR offers a modern learning channel that caters to multi-sensory learning styles, which sometimes can be more effective than traditional learning methods (Bell and Fogler, 1995; Gutierrez-Maldonado et al., 2015). However, there is meta-analysis literature stating that there is no adequate evidence supporting the consideration of learning-style assessments into general educational practice (Pashler et al., 2008). Perhaps the most convincing argument for adopting immersive VR into post-secondary education systems would be the already existing disciplines that have integrated such simulations into their curriculums, such as full-room and team simulated robot-assisted (da Vinci Surgery) endovascular procedures in surgical education (Rudarakanchana et al., 2015). Unfortunately, medical treatment injuries from these simulated endovascular procedures, due to faulty simulation trainings, have resulted in hundreds of lawsuits due to individual product liability cases (Moglia et al., 2016). The amount of evidence supporting the transfer of user surgical skill from simulation (da Vinci Surgery) applications to real-world settings has sometimes been found to be insufficient (Moglia et al., 2016). In matters of affordability, the incorporation of immersive VR into post-secondary educational systems was initially limited by the cost of the equipment used, yet commercialization of consumer headsets have brought down costs considerably (Gutierrez-Maldonado et al., 2017). Mobile phone technology has reached a level where immersive VR can be readily adapted into HMD format, simply by using low-cost Google Cardboard or Samsung Gear VR headsets (Hussein and Nätterdal, 2015). Although there is little data supporting the use of mobile phone HMD VR technology in post-secondary education, this accessible option is expected to be a "necessary tool in education in the near future" (Hussein and Nätterdal, 2015). Based on a survey that was presented in 2015 by the Educause Center for Analysis and Research (ECAR), 92% of university students within the United States have mobile phones that are capable of accessing enterprise level systems and VR software applications (Cochrane, 2016).

Aim of This Review

This review aims to uncover how post-secondary programs are incorporating immersive VR into post-secondary educational curricula. Its focus involves an interdisciplinary consideration, due to immersive VR's applicability across a wide variety of disciplines. The core assumption is that students optimize learning and practical skill acquisition through experiential learning and hands-on experience, thus a brief summary of each case when immersive VR's positive outcomes will be noted when applicable. The focus on post-secondary level education and its associated goal, skill training, is to gain further understanding of immersive VR's potential ability to train users under higher-order thinking conditions. Specific audiences for this review include: post-secondary education developers, program administrators, curriculum developers, technology research labs (video performance and enhancement labs on academic campuses), and potential instructors who are considering immersive VR as a technological option for experiential learning.

RESEARCH QUESTIONS

This state-of-the-art review was designed to answer the following research questions:

1. How is immersive virtual reality being used in post-secondary level education and skill training?
2. What conceptual and theoretical perspectives inform the use of immersive VR in post-secondary education and skill training?

Objectives

The following objectives were derived from the research questions:

1. Review the existing literature regarding the use of immersive VR in post-secondary settings, determining how it has been used within each educational discipline. This criterion focused on literature featuring the use of fully immersive VR, due to its influence on a user's perceived levels of presence and imagination.
2. Identify favorable outcomes from the use of immersive VR when it is compared to other methods. This was to determine incentive reasoning for immersive VR's adoption into post-secondary education.
3. Determine the conceptual rationale (purpose) for each implementation of immersive VR as found throughout the literature. This was to gain better understanding of immersive VR's role in post-secondary education.
4. Identify learning theories and recommendations for the incorporation of immersive VR into post-secondary education. This may provide perspectives for immersive VR's adoption into post-secondary education.

TABLE 2 | Search criteria and terms.

Inclusion criteria	Exclusion criteria
• Report stated immersive VR usage for post-secondary curricula (graduate, undergraduate or college) or skill training • Mentioned the potential use of immersive VR in the future, despite conducting an intervention with an alternative method. • All methods of immersive VR including qualitative, quantitative, descriptive, and review reports were accepted. • Reports were accepted in all languages in article, conference, book, or magazine format.	• VR platform was not immersive or report does not introduce or discuss possible usage of immersive VR technology. • Participants were not specified as post-secondary students (the exception is the investigators were performing the study as part of post-secondary curricula). • The report stated that "VR was used" but the exact platform, nature of simulation modality, or hardware configuration failed to confirm immersive VR hardware.

Search terms used: "virtual reality" OR "Head-mounted display" OR HMD.
AND undergraduate OR college OR post-secondary OR postgraduate.
AND curricul OR educat* OR teach OR learning OR training.*
These terms were entered into the databases mapped to the following fields: title, abstract, subject heading word, and keyword heading word. Each search was limited to reports published on March of 2013 (emergence of Oculus Rift Developer Kits) to January 2019.

METHODS

Search Strategies

The initial literature search was performed during October 2017 and then updated in January 2019. Acceptable reports were required to have been published since March of 2013 as this was the date that Oculus Rift Developer Kits became first available. This date focused on the "unprecedented" adoption of HMD VR before the mid-2010s as stated by Elbamby and colleagues. After discussing the research question in consultation with a university librarian, the following bibliographic databases were searched (2013 to present): Education Research Complete (EBSCO*host*), ERIC (EBSCO*host*), MEDLINE (Ovid), EMBASE (Ovid), IEEE Xplore (IEEE/IEE), Scopus (Elsevier), Web of Science: Core Collection (Thomson Reuters and Clarivate Analytics). The search strategy included a combination of subject headings and keywords to combine the concepts of HMD Virtual Reality, post-secondary students, education, and training. Refer to **Table 2** for the inclusion and exclusion standards of each report.

Each report's screening process was performed by the lead author. All reports that indicated the use of virtual reality, in their title or abstract, were reserved to complete the first pass. For the second pass, all reserved reports from the first pass had their full texts screened again to confirm the context of immersive VR usage. Methodological quality of each report was not formally assessed beyond the study design used.

Determining the Purpose of Immersive VR

For each report, a designated purpose of immersive VR's implementation was applied to rationalize its function, throughout the literature screening process. Each purpose was based on the screening of keywords found from the literature in order of appearance: report title, keywords (index terms), and abstract. In the absence of an abstract, the main text was screened instead. **Table 3** shows the keywords used to define immersive VR's purpose in post-secondary education.

TABLE 3 | Determining the purpose of immersive Virtual Reality in Post-secondary Education.

Keywords in title, index terms, abstract, or main text	Assigned purpose
Augmented Reality or Guiding	Highlighting
Attitude, Enjoyment, or Interest	Engagement
Education, Training, Teaching, or Learning	Skill Training
Interaction, Response, Real, Gesture, Role Play	Interactivity
Low Cost, Cost or Portability	Convenience
Empathy, Influence or Motivate	Suggestion
Leadership, Team Collaboration, or Virtual Teams	Team Building
Risk-assessment, Accident avoidance Safety	Safety
A report with four or more above qualifying labels	Various

RESULTS

The search resulted in a total 1,495 reports being found. After the first pass, 215 reports remained after titles and abstracts were screened, along with duplicates removed. During the second pass of screening, the full texts of 215 reports were screened to further confirm eligibility (see **Figure 1**). This resulted in a net total of 119 reports being included in this review. It is noteworthy that in the previous search of October 2017, there were 874 reports found with 58 studies deemed eligible after the screening process, resulting in a 105.17% increase in eligible immersive VR literature in post-secondary education in the span of 15-months.

The 119 reports included in this review discussed the use of immersive VR in experimental, proposal, review, or curricular format. Note that some of the reports discussed usage of immersive VR across two or more disciplines, while others may not have included a specific discipline in their description. **Table 4** provides a breakdown of the literature by discipline under each of the following headings: Arts and Humanities, Health Sciences, Military and Aerospace, and Science and Technology.

Where Immersive VR Was Implemented

The majority of immersive VR usage was reported from the field of Science and Technology, specifically in the Education discipline ($n = 17$). Within the same field, the disciplines of Computer Science and Engineering—General constituted second and third-most of immersive VR usage at $n = 6$ and $n = 4$, respectively. The field of Health Sciences' most common disciplines were Psychology and Surgical Education—General at $n = 16$ and $n = 9$, respectively. Within the same field, Anatomy represented the third most common discipline at $n = 4$. The field of Arts and Humanities' most common disciplines to report on immersive VR were Music and Design Thinking at $n = 3$ and $n = 3$, respectively. Military and Aerospace was the field to include the minority of reported instances of immersive VR usage with Aerospace at $n = 1$ and Military at $n = 2$.

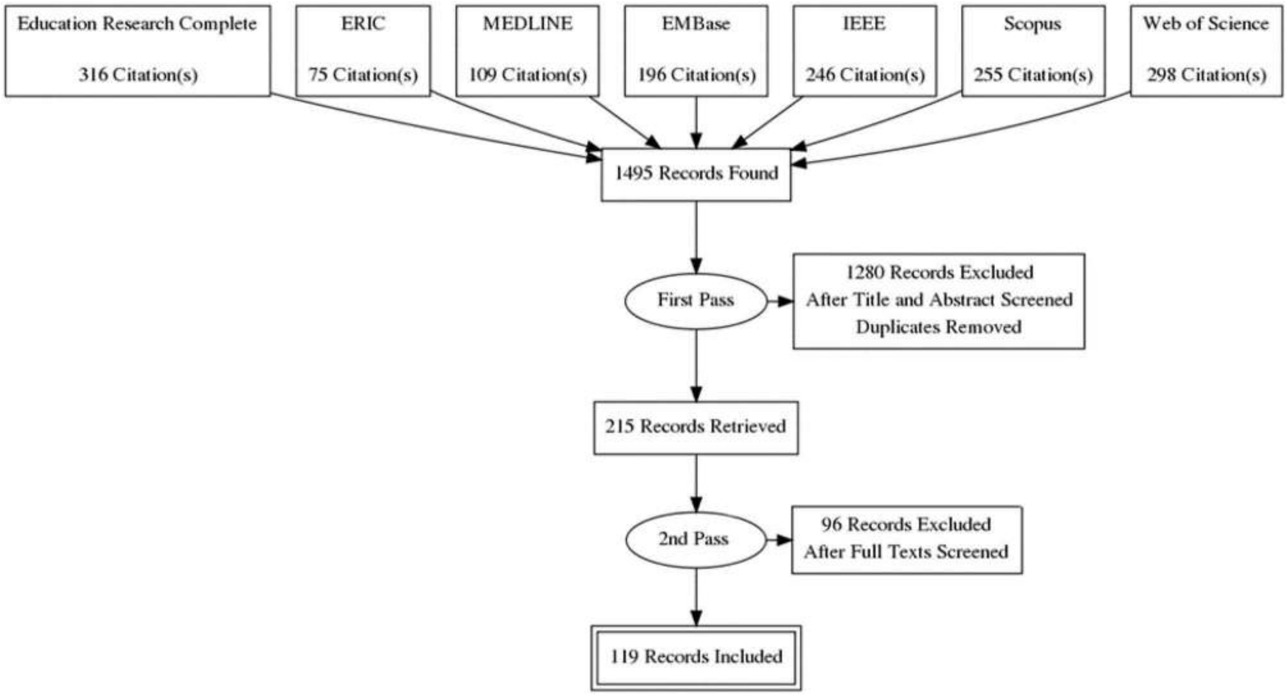

FIGURE 1 | PRISMA flow diagram of search results.

TABLE 4 | Frequency of immersive Virtual Reality literature across educational disciplines.

Heading	Frequency of use in literature	Total
Arts and Humanities	2x Art, 2x Business, 3x Design Thinking, 2x History, 2x Journalism, 3x Music, 1x Political Science, 1x Religious Studies	16
Health Sciences	4x Anatomy, 1x Dentistry, 3x Nursing, 1x Optometry, 3x Paramedicine, 3x Physical Education, 16x Psychology, 2x Public Health, 2x Rehabilitation, 9x Surgical Education—General, 3x Surgical Education—Neurosurgery, 2x Veterinary Education	49
Military and Aerospace	1x Aerospace, 2x Military	3
Science and Tech	3x Architecture, 2x Astronomy, 1x Chemistry, 6x Computer Science, 2x Driving, 17x Education, x3 Engineering—Civil, 2x Engineering—Computer, 1x Engineering—Electrical, 4x Engineering—General, 2x Engineering—Mechanical, 1x Engineering—Numerical Control, 1x Engineering—Pneumatic, 1x Forensics, 1x Geology, 1x Industrial Plant Operation, 1x Information Interfaces, 3x Physics	52
Various	4x Various	4

Objective 1—How Immersive VR Was Used in Post-secondary Education

Descriptions summarizing the use of immersive VR across each discipline are presented in **Table 5**. It was found that the field of Science and Technology had the majority of literature featuring the use of immersive VR, which is congruent with the findings Freina and Ott reported in 2015. The greatest distribution of reports in this review were found in Education disciplines, next to Psychology in the field of Health Sciences, unlike Freina and Ott's report from 2015 which had most of the representative disciplines being Computer Science, Engineering, and Mathematics. While this review focused on the use of immersive VR at the post-secondary education level, Freina and Ott's review in 2015 was inclusive to all levels of education, including middle school. This paper's focus on higher level education could explain why disciplines such as of Education and Psychology had the greatest proliferation of immersive VR usage, possibly due to VR's ability to support environments that allow for more control than what would be available in real life, especially when dealing with intangible concepts. Having access to a platform that can subject users to intangible stimuli such as fear, addiction, and violence was found to be a definite incentive for Psychology to adopt immersive VR.

The incentives for immersive VR being incorporated into post-secondary education and skill training may include one or more of the following: the maintenance of ethical principles, overcoming problems concerning time and space, increasing the physical accessibility of environments that are not normally accessible and/or overcoming what would normally be a dangerous situation (Freina and Ott, 2015). Surgical Education's demand for immersive VR can be explained by ethical principles, which allows users to train technical skills without subjecting patients or the users themselves to the possibility of harm (Ziv

TABLE 5 | Literature summary of immersive VR usage across educational disciplines.

Heading	Discipline	References	Purpose	Description
Arts and Humanities	Art	Kuhn et al., 2015; Leue et al., 2015	Skill Training/Highlighting	Google Glass implemented in art galleries.
Arts and Humanities	Business	Lee et al., 2017	Engagement	Experiment: Compared Google Cardboard HMD units to non-immersive VR. Google Cardboard users reported greater levels of enjoyment and interest than the non-immersive users
Arts and Humanities	Business	Schott and Marshall, 2018	Convenience/Interactivity	A virtual environment of a Pacific Island allowed users to find avatars of community members and government officials, who explained how the island's relationship with tourism acted as the main source of income. The project was based on a "situated experiential education environment."
Arts and Humanities	Design Thinking	Cochrane, 2016	Interactivity	Proposal: A curriculum for the field of new media production and design, where artwork and graphical design showpieces can be displayed in virtual showrooms and allow user interactivity.
Arts and Humanities	Design Thinking	Cochrane et al., 2017	Team Building	Proposal: A curriculum for the field of visual design, where students can collaboratively share their artwork through Google Maps, providing 360-panoramic views of their project ideas.
Arts and Humanities	Design Thinking	Rive and Karmokar, 2016	Team Building	Proposal: VR design communities to team-collaborate online.
Arts and Humanities	History	Checa et al., 2016	Skill Training/Engagement	Experiment: Compared HMD VR to regular video for historical virtual environments tour. Students' overall satisfaction was found to be rated higher for the immersive VR method.
Arts and Humanities	History	Yildirim et al., 2018	Skill Training/Interactivity/ Engagement	VR glass experience featured historical 360-degree views of Kaaba to learn about Islamic History. Users could interact with learning points to receive audio information. Users stated during interviews that VR in history course activities would be beneficial.
Arts and Humanities	Journalism	Cochrane, 2016	Engagement	Panoramic VR video to enhance readers' experience.
Arts and Humanities	Journalism	Markowitz et al., 2018	Engagement/Skill Training/Suggestion	HMD VR (Oculus) users experience climate change (ocean acidification) from the perspective of either a human scuba diver or piece of coral reef. Users reported positive knowledge gained and improved interest about climate change.
Arts and Humanities	Music	Orman et al., 2017	Highlighting/Skill Training	Experiment: Compared HMD VR to no VR to enhance a user's wind band conducting ability. HMD VR learning environment demonstrated greater conducting ability than those not using VR
Arts and Humanities	Music	Hong-xuan, 2016	Skill Training/Engagement	VR musical teaching system was found to enhance student enthusiasm and learning.
Arts and Humanities	Music	Kilteni et al., 2013	Engagement	Experiment: Behavioral changes in a user's hand drumming ability, while performing as an appropriately perceived avatar while using HMD VR.
Arts and Humanities	Political Sciences	Hui-Zhen and Zong-Fa, 2013	Skill Training/Suggestion/Team Building	Proposal: HMD VR classrooms to encourage communication between students and teachers.
Arts and Humanities	Religious Studies	Johnson, 2018	Convenience/Skill Training	360-videos of each religion were shown with HMD VR, requiring users to identify each based on narrative and environmental cues. Students learned empathetic understanding, ritual and behavior involving religious theory.
Health Sciences	Anatomy	Moro et al., 2017	Highlighting/Skill Training/Engagement	Experiment: Immersive VR compared with non-immersive for cranial anatomy learning. No differences found between immersive and non-immersive VR, AR or tablet devices on student learning, except immersive VR promoted user immersion and engagement and promise to enhance student learning in anatomical education.
Health Sciences	Anatomy	Maresky et al., 2018	Skill Training/Interactivity	Experiment: Immersive VR compared with independent study for cardiac anatomy learning (Sharecare VR). VR condition demonstrated enhanced learning performance and student engagement.
Health Sciences	Anatomy	Albabish and Jadeski, 2018	Skill Training	Proof of concept: Dissection-based human anatomy course (for thorax and abdominal regions) both for on-site and distance learning.
Health Sciences	Anatomy	Stepan et al., 2017	Skill Training/Engagement	Experiment: Randomized controlled study compared online textbooks with VR HMD (Oculus) to enhance student neuroanatomical knowledge (ventricular and cerebral). HMD VR was shown to be more engaging and similar to online for knowledge acquisition.

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TABLE 5 | Continued

Heading	Discipline	References	Purpose	Description
Health Sciences	Dentistry	Hoffman et al., 2001; Sabalic and Schoener, 2017	Engagement/Convenience	3D goggles to patients, depicting relaxing virtual environments, in an effort to reduce anxiety during dental procedures.
Health Sciences	Nursing	Kleven et al., 2014	Various	Proof of concept: Both medical and non-medical users learn applicable material in a Virtual University Hospital.
Health Sciences	Nursing	Smith et al., 2018	Skill Training/Interactivity	Experiment: Immersive VR compared with desktop to enhance student learning on decontamination skills. No significant difference found between groups, but immersive VR system showed greater interactivity capability.
Health Sciences	Nursing	Aebersold, 2018	Skill Training/	Report summarizes VR concepts in nursing, providing simulation design ideas that are supported by theoretical concepts.
Health Sciences	Optometry	Leitritz et al., 2014	Highlighting/Skill Training	Experiment: Measured user's ability to draw an optic disc, comparing conventional binocular indirect ophthalmoscopy vs HMD AR ophthalmoscopy (ARO). ARO found to allow for learning various retinal diseases.
Health Sciences	Paramed.	Cochrane, 2016; Cochrane et al., 2017	Safety	Proposal: A curriculum for students to use VR (Google Cardboard) to analyze potential safety risks, prior to entering paramedical situations.
Health Sciences	Paramed.	Ferrandini Price et al., 2018	Skill Training	Experiment: HMD VR (Samsung Gear) compared with clinical simulation (live actors) to enhance student rapid treatment ability in Mass Causality Incidents. HMD VR found to be as efficient as clinical simulation. HMD VR users showed lesser stress levels than clinical simulation.
Health Sciences	Physical Education	Li, 2014	Skill Training/Highlighting	HMD VR used for sports training and telemetry data.
Health Sciences	Physical Education	Pan, 2015; Choiri et al., 2017	Skill Training/Interactivity/Safety	HMD VR to imitate real training situations and compensate for lack of equipment. Enhance an athlete's mental concentration.
Health Sciences	Psychology	Gutierrez-Maldonado et al., 2015	Skill Training	Experiment: HMD VR compared to non-immersive stereoscopic computer while performing a virtual interview on a virtual client who was diagnosed with an eating disorder. No difference found.
Health Sciences	Psychology	Gutierrez-Maldonado et al., 2017	Skill Training/Engagement	Experiment: Follow-up. HMD VR compared to non-immersive stereoscopic computer while performing a virtual interview on a virtual client who was diagnosed with an eating disorder. No difference found. No difference in learning. HMD VR more engaging.
Health Sciences	Psychology	Lin, 2017	Interactivity	VR goggles for users in a survival horror game to analyze fear coping strategies.
Health Sciences	Psychology	Gupta and Chadha, 2015	Skill Training/Suggestion	HMD VR to overcoming physical withdrawal symptoms from cigarette and drug addictions.
Health Sciences	Psychology	Parsons and Courtney, 2014	Interactivity	Experiment: Compared HMD VR version of the Paced Auditory Serial Addition Test (PASAT) with paper-and-pencil version. HMD VR has extra capability over paper-and-pencil. VR-PASAT unanimously preferred.
Health Sciences	Psychology	Kalyvioti and Mikropoulos, 2013	Skill Training	HMD VR for testing/training short-term memory of dyslexic users featuring environments with household objects, geometric shapes and virtual art galleries.
Health Sciences	Psychology	Kniffin et al., 2014	Safety/Skill Training	Experiment: Used HMD VR to compare diaphragmatic breathing to attention control training for the enhancement of self-regulatory skills in female students exposed to virtual aggressive males. Concluded that HMD VR effective for training self-regulatory skills.
Health Sciences	Psychology	Jouriles et al., 2016	Interactivity/Safety	Experiment: VR (goggles) Measure bystander behavior in response to sexual violence. Concluded that immersive VR allows researchers to determine behavioral effectiveness.
Health Sciences	Psychology	Lamb et al., 2018	Interactivity	Experiment: VR goggles were compared with desktop educational games, video recorded lecture and hands-on paper cut-outs to determine user blood-brain hemodynamic responses while interacting/learning about DNA structures. Hemodynamic responses were analyzed with functional near-infrared spectroscopy. Results suggested that greater cognitive processing, attention and engagement occurred in VR goggle and desktop education game conditions.
Health Sciences	Psychology	Parong and Mayer, 2018	Skill Training	Experiment: Immersive VR (The Body VR) compared with desktop slideshow to determine student cellular biology learning ability and

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TABLE 5 | Continued

Heading	Discipline	References	Purpose	Description
				interest. Segmented VR learning was compared to continuous VR learning. Desktop slideshow showed greater learning ability, yet lower interest level. Segmented VR showed greater learning ability than continuous.
Health Sciences	Psychology	Fominykh et al., 2018	Convenience	This paper presents a detailed conceptual framework for therapeutic practice with VR. A virtual environment of a beach scene relaxation scenario will change from calm to stormy, depending on the user's heart rate. Results showed the system may be useful for implementation of therapeutic training with biofeedback.
Health Sciences	Psychology	Wiederhold et al., 2018	Convenience	Mentions immersive VR use to supplement treatments for low-back pain, anxiety, PTSD, stroke, post-surgery palliation, etc.
Health Sciences	Psychology	Leader, 2018	Interactivity/Highlighting	Immersive VR and AR for psychotherapy, featuring adjustable clinic designs to optimize therapy for clients.
Health Sciences	Psychology	Singh et al., 2018	Engagement/Interactivity	Electroencephalogram measures of cognitive processes were recorded as a user's avatar hands were switched between varying levels of realism. The realistic virtual hands led to users noticing more tracking inaccuracies.
Health Sciences	Psychology	Formosa et al., 2018	Skill Training/Engagement	HMD VR (Oculus) allowed users to enter a lounge room to experience positive symptoms associated with schizophrenic spectrum, complete with auditory and visual hallucination. Results showed an increase in user knowledge and empathetic understanding).
Health Sciences	Public Health	Real et al., 2017a	Skill Training/Suggestion	Experiment: Compare HMD VR with control group for training best-practice communication skills in pediatricians, working with clients who refused vaccinations. HMD VR found valid for training communication skills and reducing vaccine refusal.
Health Sciences	Public Health	Real et al., 2017b	Skill Training/Suggestion	A curriculum featuring immersive VR to address influenza vaccine hesitancy was developed. User's verbally spoke with vaccine-hesitant caregiver avatars (controlled by another user) with open-ended questioning, empathy and education without medical jargon. VR showed promising results.
Health Sciences	Rehab.	Wen et al., 2014	Interactivity/Convenience	VR to monitor stroke patients (motion capture) during exercise while under the guidance of a therapist (HMD VR) who may provide electrical stimulation, despite being in a different location than patient.
Health Sciences	Rehab.	Chen et al., 2018	Skill Training/Engagement	Patients used HMD VR (HTC Vive) to perform upper body tasks for rehabilitation. Virtual environment allowed users to move objects in four different arm positions, which could detect up to 5-degrees of freedom.
Health Sciences	Surgical Education—General	Oyasiji et al., 2014	Highlighting	Google Glass to guide surgeons by providing AR images of portal and hepatic vessels in patients' surgical sites.
Health Sciences	Surgical Education—General	Mathur, 2015	Convenience/Skill Training	HMD VR low-cost surgery-based training for engineering education to enhance student learning.
Health Sciences	Surgical Education—General	Nakayama et al., 2016	Interactivity/Skill Training/Suggestion	Motivate student attitude toward surgical education in urology.
Health Sciences	Surgical Education—General	Huang et al., 2015	Skill Training/Interactivity	VR to simulate myringotomy procedures.
Health Sciences	Surgical Education—General	Olasky et al., 2015	Skill Training	Practice surgical peg-transfer tasks while in an adjustable environment.
Health Sciences	Surgical Education—General	Harrington et al., 2018	Engagement/Skill Training	Experiment: Single-blinded randomized cross-over study compared 360-video HMD VR (Samsung Gear) with two-dimensional video, depicting laparoscopy procedures, to determine attention, information retention and appraisal. HMD VR condition showed greater user engagement and attention with no difference in retention.
Health Sciences	Surgical Education—General	Yoganathan et al., 2018	Skill Training	Experiment: Prospective randomized controlled study compared 360-video HMD VR with two-dimensional video, depicting a surgical reef knot, to enhance surgical student knot tying skill. VR condition showed greater knot tying success rates.
Health Sciences	Surgical Education—General	Andersen et al., 2018	Skill Training	Experiment: An educational interventional cohort study offered additional immersive VR training over the control group, during mastoidectomy dissection training. Results showed that skills acquired in VR further increased student performance.

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Heading	Discipline	References	Purpose	Description
Health Sciences	Surgical Education—General	Benabou et al., 2018	Skill Training	Experiment: Prospective randomized controlled trial compared HMD VR (Sony Playstation 4 VR) with controls to determine surgical (laparoscopic) two-handed efficiency. VR group showed greater dominant and non-dominant hand speed while also increasing user perceived task performance.
Health Sciences	Surgical Education—Neuro	Gallagher and Cates, 2004; Schirmer et al., 2013b	Skill Training	Review: VR applications in neuroscience were found to be focused on skill acquisition, technical task-based applications and team/collaboration.
Health Sciences	Surgical Education—Neuro	Shakur et al., 2015	Skill Training/Highlighting	Users performed neurosurgical tasks such as ventriculostomy; bone drilling, pedicle screw placement, vertebroplasty and lumbar puncture on virtual patients.
Health Sciences	Surgical Education—Neuro	Schirmer et al., 2013a	Skill Training	Experiment: Repeated measures assessing the knowledge of neurosurgery trainees both before and after experiencing a stereoscopic ventriculostomy simulator. VR shown to increase knowledge across all simulation tasks.
Health Sciences	Veterinary Education	Seo et al., 2017, 2018	Skill Training/Engagement	Experiment: HMD VR compared to traditional box method for users to create and manipulate canine skeletons. HMD VR shown to increase user interest.
Military and Aerospace	Aerospace	Bucceroni et al., 2016	Safety/Skill Training	Users pilot a virtual unmanned aerial system (UAS) within a simulated environment that resembles a real-world location.
Military and Aerospace	Military	Champney et al., 2017	Skill Training	Experiment: Room-clearing task training conditions, ranging from high fidelity HMD VR to training video only, showed HMD VR may have faster skill acquisition.
Military and Aerospace	Military	Greunke and Sadagic, 2016	Skill Training/ Convenience/Interactivity	HMD VR systems were used to train Landing Signal Officers (LSOs), outside of formal training facilities (2H111), the skills necessary to help pilots land their aircraft safely.
Science and Tech	Agriculture	Thompson et al., 2018	Skill Training/Safety	360-degree video recordings from high-clearance applicator cabs during nitrogen fertilizer management were shown to users with HMD. Details for optimal recording of 360-degree video were mentioned.
Science and Tech	Architecture	Newton and Lowe, 2015	Skill Training	Used open-sourced software (Simulation Engine) to allow students perform various building construction tasks.
Science and Tech	Architecture	Sun et al., 2017	Skill Training	Proposal: "Bounded Adoption" strategy for HMD VR to learn skills such as component recognition, construction phases and adjusting traffic parameters.
Science and Tech	Astronomy	Tajiri and Setozaki, 2016	Interactivity/Skill Training	Experiment: Compared HMD VR to desktop computers for enhancing college students' understanding of position and direction of celestial bodies. HMD VR claimed to have extra capability.
Science and Tech	Astronomy	Rosenfield et al., 2018	Interactivity	A report on The America Astronomical Society's WorldWide Telescope (WWT) project, allowing astronomical images to be projected into planetariums and HMD VR.
Science and Tech	Chemistry	Lau et al., 2017	Skill Training/ Convenience/Safety	3D VR glasses were implemented to enhance students' abilities in a textile chemical coloring virtual environment.
Science and Tech	Computer Science	Liang et al., 2017	Interactivity	Experiment: Compared user's personal experience level between HMDs and monoscopic desktop-display-screens for VR puppet story; child-operated with hand-gesture controls. HMDs outperformed the monoscopic displays.
Science and Tech	Computer Science	Liarokapis et al., 2002; Stigall and Sharma, 2017; Wang, 2017	Skill Training/Highlighting	HMD AR was used to create training markers and provide" gamification strategies" in software development.
Science and Tech	Computer Science	Timcenko et al., 2017	Team Building	Experiment: Mediaology students used HMD VR to promote team collaboration in game design. When compared to no VR, no difference found in team building ability between users.
Science and Tech	Computer Science	Teranishi and Yamagishi, 2018	Interactivity/Skill Training	VR learning application that allows users to assemble personal computer hardware, with Leap Motion and HMD, with improved visual systems that reduced user eye fatigue.
Science and Tech	Computer Science	Hahn, 2018	Team Building	HMD VR (HTC Vive) was used for text browsing in a digital library, where both librarian and students users worked together.

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Heading	Discipline	References	Purpose	Description
Science and Tech	Education	Potkonjak et al., 2016; Akçayir and Akçayir, 2017	Various	Review: AR usage found to have increased in educational curricula and promotes enhanced learning achievement. VR of laboratories was noted to have increased capability and safety outside of real world.
Science and Tech	Education	Jensen and Konradsen, 2018	Various	Review: Performed a quality assessment and analysis on 21 experimental studies, featuring the use of immersive VR in education and training.
Science and Tech	Education	Yang et al., 2018	Skill Training	Experiment: HMD VR compared with paper-and-pencil condition to determine effect on student creativity, flow, attention and stress. VR condition showed greater quality, creativity, attention. VR environment allowed for 3D drawing and painting on a human model to create gear.
Science and Tech	Education	Dolgunsöz et al., 2018	Skill Training/Engagement	Experiment: VR Goggles were compared with two-dimensional video (about Chernobyl or Bear Habitat) to enhance EFL writing performance. VR was shown to possibly improve writing performance in the long term (1-month later) and be more engaging.
Science and Tech	Education	Tepe et al., 2018	Safety	VR Goggles, depicting a warehouse environment, allowed users to perform tasks in response to a fire.
Science and Tech	Education	Alfalah, 2018	Various	A report detailing institutional supports, motivations for adoption and teaching staff perceptions for the incorporation of VR into education curricula.
Science and Tech	Education	Makransky and Lilleholt, 2018	Engagement	Experiment: Crossover repeated-measures compared HMD VR (Samsung Gear) with desktop, depicting a laboratory simulation, to determine several factors, including user enjoyment and perceived learning. VR was found to be preferred over desktop for various reasons as detailed in report.
Science and Tech	Education	Murcia-Lopez and Steed, 2018	Interactivity	Experiment: Efficiency of bimanual 3D block puzzles was measured between HMD VR (Oculus) and physical assembly exercises. VR users showed results that were similar to physical assembly. VR performance was promising.
Science and Tech	Education	Al-Azawi and Shakkah, 2018	Suggestion	Report summarizes VR concepts in education, with the goal to motivate instructors to adopt its use in their teaching methods.
Science and Tech	Education	See et al., 2018	Convenience/Highlighting	Report summarizes VR concepts in massive open online course education, detailing potential obstacles, issues with adoption, practices and requirements.
Science and Tech	Education	Bryan et al., 2018	Engagement/Highlighting/ Skill Training	Report details gamification strategies with Google Maps. The objective is for users to find a country flag by answering questions about each location they encounter.
Science and Tech	Education	Misbhauddin, 2018	Engagement/Interactivity	Proposal: A VR framework to enhance learning experiences in classroom settings. Framework includes recording of lecture, visualization of instructor communication, user input for verbal note-taking.
Science and Tech	Education	Hickman and Akdere, 2017	Skill Training/Engagement/ Team Building	Proposal: Compare 360-video recorded images with computer generated avatars in HMD VR, desktop with HMD VR, high-cost and low-cost hardware, to determine student engagement and learning outcomes. Modules includes intercultural business exchanges, where user contributions affect project success.
Science and Tech	Education	Chin et al., 2017	Engagement	HMD VR (Google Cardboard) for education is briefly described and exemplified with SplashSim- users experience stages of the water cycle from the perspective of a water droplet.
Science and Tech	Education	Zaphiris and Ioannou, 2017	Skill Training	Book: Conference presentations of immersive VR systems for training in teacher education (bullying prevention).
Science and Tech	Education/Psychology	Hashimura et al., 2018	Interactivity	Experiment: Used HMD VR (Oculus) and motion controls to determine attention capacity (head, eye and hand movement) while under cognitive load (sort English words in VR space). VR showed possible ability to measure a user's cognitive load.
Science and Tech	Engineering—Civil	Wang et al., 2018	Skill Training	The construction of 3D building information models for quantity surveying practice in immersive VR were detailed in this report.
Science and Tech	Engineering—Civil/Driving	Veronez et al., 2018	Convenience/Safety/Skill Training	Driving setup (Oculus HMD and Logitech G27 Racing Wheel system) to enhance learning for road design. Users can test-drive their roads during development.

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Heading	Discipline	References	Purpose	Description
Science and Tech	Engineering—Civil/Driving	Likitweerawong and Palee, 2018	Safety/Skill Training	Immersive VR driving setup (Oculus) to provide users with basic driving lessons and rules before actual road-tests. User skill evaluated by completion of checkpoints on a virtual driving course including parking, speed and cornering.
Science and Tech	Engineering—Computer	Alhalabi, 2016	Skill Training	Experiment: Effectiveness of four different VR setups analyzed to determine student performance on engineering tests. All forms of VR found to improve performance. HMD VR with tracking shown to excel over CAVE, no-tracking HMD VR and no VR.
Science and Tech	Engineering—Computer	Akbulut et al., 2018	Skill Training	Experiment: MultiPeer Immersive VR compared with traditional teaching material to determine student performance on sorting algorithms.VR system showed an improvement on student test results over traditional methods.
Science and Tech	Engineering—Electrical	Liang and Xiaoming, 2013	Skill Training/Convenience	Students used VR workbench software to design analog and digital circuits, encouraging autonomous exploration.
Science and Tech	Engineering—General	Haefner et al., 2013	Various	Curricula: Recommendations on how to implement practical VR coursework in engineering education by encompassing skill development, interdisciplinary teamwork and time management training.
Science and Tech	Engineering—General	Ndez-Ferreira et al., 2017	Team Building/Suggestion	Virtual Mobility: The UbiCamp Experience is a 3D immersive virtual environment that allows groups of users to visit iconic buildings, monuments and universities, promoting cultural and language learning.
Science and Tech	Engineering—General	Lemley et al., 2018	Highlighting	Deep learning achieved by eye-tracking was tested by comparing a standard eye tracker with AR/VR eye-tracking datasets across high-res HMD VR and low-res smart devices.
Science and Tech	Engineering—General	Starkey et al., 2017	Skill Training	Experiment: Systematic disassembly of a product was performed across three interfaces (computer desktop, iPad, immersive VR). Student learning was found to be the same for each condition, yet immersive VR showed greater student satisfaction and perceived learning.
Science and Tech	Engineering—Mech	Muller et al., 2017	Skill Training/Interactivity	Immersive VR workshops were reported to allow mechanical engineering students to expedite the learning process by interacting with virtual workbenches.
Science and Tech	Engineering—Mech	Im et al., 2017	Skill Training/Engagement	Proposal: HMD VR (Oculus) and Leap Motion allowed users to disassemble and reassemble engines. Results showed high user interest, immersion, satisfaction, perceived learning and effectiveness.
Science and Tech	Engineering—Numerical Control	Hu and Wang, 2015	Skill Training	Proposal: Incorporating VR technology courses for environment shape design, animation, interactive functions and internet related content.
Science and Tech	Engineering—Pneumatic	dela Cruz and Mendoza, 2018	Convenience/Skill Training	HMD VR, depicting a lab environment, allowed users to operate pneumatic components.
Science and Tech	Forensics	Liu et al., 2017a	Skill Training	Proof of Concept: Details on the development of a crime scene simulation were provided, complete with virtual suspects who would run away if the user failed to maintain line of sight. The project aims to teach users how to prevent damaging crime scene evidence.
Science and Tech	Geology	Ables, 2017	Skill Training/Interactivity	Dynamic topographic data was digitally rendered onto a virtual 'sandbox,' showing different types of terrain within the virtual environment. Users were able to interact with the terrain.
Science and Tech	Industrial Plant Operation	Nazir et al., 2015	Skill Training/Safety	Experiment: Power Point was compared to immersive VR (stereoscopic glasses) for Distributed Situation Awareness (DSA) skill training for industrial plant operators. Immersive VR showed enhanced dynamic security assessment ability in students over PowerPoint method.
Science and Tech	Information Interfaces	Khuong et al., 2014	Highlighting	HMD VR assisted in constructing a block structure with one of two different highlighting guidance information systems: overlay and adjacent.
Science and Tech	Physics	Kozhevnikov et al., 2013	Skill Training	Experiment: HMD VR compared with non-immersive VR to determine which would enhance students' ability to solve two-dimensional relative motion problems. HMD VR performed better than non-immersive VR on solving 2D relative motion problems.

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Heading	Discipline	References	Purpose	Description
Science and Tech	Physics	Matsutomo et al., 2017	Highlighting	VR was used to show real-time graphics of magnetic fields between objects.
Science and Tech	Physics	Kuhn et al., 2015	Highlighting	Immersive VR (Google Glass) was used to determine water-level in a glass to achieve specific tones in physics (acoustics) education.
Various	Various	Dunbar et al., 2017	Highlighting/Safety	Visionless Interfacing Exploration Wearable (VIEW) substitutes the vision sense with wearable haptic feedback, assisting individuals with recognizing obstacles and avoiding walls when navigating a space.
Various	Various	Suh and Prophet, 2018	Various	Review: Determined the trends, theoretical foundations and research methods of immersive VR studies.
Various	Various	Zikky et al., 2018	Various	Report briefly mentions immersive VR programs for distance learning including social media, military skydiving, university campus, lab safety, chemistry and solar systems.
Various	Various	De Paolis et al., 2017	Various	Book: Conference presentations of immersive VR systems for training in industrial processes, tannery processes, motor fine skills rehabilitation, industrial heritage, collaboration, safety training, automotive mechanics and journalism.

et al., 2003; Freina and Ott, 2015). This same ethical principle may also explain the demand of immersive VR in other disciplines such as Dentistry, Nursing, Optometry, Paramedicine, Public Health, Rehabilitation, and Veterinary Education. The field of Health Science's main incentive to incorporate immersive VR is assumed to involve concepts of experiential learning, which allows users to learn by interacting with various environments affiliated with their disciplines. Experiential learning principles may explain the demand of immersive VR for the majority of disciplines in Science and Technology as well as Arts and Humanities. The increase of physical accessibility to environments that are not normally accessible would apply toward disciplines such as Astronomy, while VR's ability to overcome dangerous situations would apply to fields such as Military and Aerospace. Some universities (Maryland University College) are acting to ensure they remain on the technological "cutting edge," allowing students to learn by creating content (Becker et al., 2017).

Objective 2—Favorable Outcomes From the use of Immersive VR

Thirty eight experiments were found in the 119 reports, mostly comparing immersive VR (HMD) with one of the following non-immersive platforms: desktop display screen, 2D video, mobile phone, digital tablet or stereoscopic desktop display screen. Non-VR comparators included live actors, real-world analogs, "traditional methods," pencil-and-paper or nothing as a control. Of these 38 experiments, 35 reported to have found a positive outcome favoring the use of immersive VR with: 13 showing an increase in user skill or knowledge, 10 showing an increase in user engagement or enjoyment, 8 stating immersive VR had some form of extra capability over traditional methods, and 4 stating both an increase in user skill and engagement.

When favorable outcomes were noted from the reports, only experimental processes were considered, since the absence of a comparator, be that either some form of established non-immersive VR or traditional method, may weaken quality inferences to be made. This review reported only the outcomes from reports that had such comparators in their study design and found that 35 out of the 38 experimental outcomes were positive, showing mainly an increase in user skill, knowledge, engagement, and enjoyment. Some reports found immersive VR to have additional capability over those of traditional methods, such as the ability for users to train on an avatar that was diagnosed with a rare disease, which could not be replicated on a traditional model. Immersive VR should not render traditional methods obsolete, such as pencil-and-paper tests, since those methods are already well-established and free from potential simulator sickness.

This review did not assess the quality of each study's experimental design as found throughout the literature, however a review conducted by Jensen and Konradsen (2018) reported the quality assessment of 21 HMD VR experiments, showing a "below average quality" as outlined by the *Medical Education Research Study Quality Instrument*. Jensen and Konradsen identified in 2018 a number of setups where HMD VR is useful for skill training including the training of cognitive skills related to spatial and visual knowledge, psychomotor skills related to head-movement, visual scanning, observational skills, and affective control of emotional response to stressful or difficult situations. Future quality assessments of HMD VR experimentation are warranted as optimal setups in learning and skill training contexts are found, along with continuous improvements to VR hardware and software.

Objective 3—Conceptual Rationale of Immersive VR in Post-secondary Education

This review aimed to understand the literature's reasoning for implementing immersive VR, with the use of a conceptual method to determine each system's rationale. This method, based on keywords found in each report's title, index terms, and abstract, allowed for identification of immersive VR's purpose to further understand its role in each context. The majority of reports had the intention of using immersive VR for the purpose of skill training, followed by the optimization of interactivity between users and objects within the virtual world. Highlighting of objects in both the virtual or real world were other reasons for the implementation of immersive VR, especially when visual markers were provided to users in the form of AR. The use of immersive VR for the purposes of engagement, safety, convenience, team building, and suggestion were also found. These purposes might be able to justify the reasoning of immersive VR in higher education, despite the literature rarely showing pedagogical rationales for its use (Savin-Baden et al., 2010).

Regardless of the sophistication of a virtual system's hardware, the rationale of each report affected how a virtual environment was designed, implemented, and presented in the literature. A conceptual pattern of rationale was found, detailing the purpose of each instance of immersive VR's implementation. Each simulation's goal included one or more of the following purposes: skill training, convenience, engagement, safety, highlighting, interactivity, team building, and suggestion.

Skill Training

This purpose resulted in a virtual environment that focused on the development of knowledge and enhancement of a user's competency in a specific task. An example of this purpose includes the military training room-clearing tasks as reported by Champney et al. (2017). Note that it is possible for the skill training to involve teacher-to-student interaction, such as the virtual environment as outlined in the gesture-operated astronomical virtual space as reported by Tajiri and Setozaki (2016).

Convenience

These virtual environments focused on reducing the difficulties and/or resources required to train the same task in the real world. This purpose included factors such as time, location, and cost. An example of immersive VR being used, with a purpose focused on cost convenience, would be the low cost surgical training system a reported by Mathur (2015). For location convenience, this would feature a VR system designed to either allow multiple users to interact with one another, despite being in different geographic locations, or provide a portable system that allows training for a user at any convenient location. An example of immersive VR being used with a location convenience purpose would be the therapist-to-patient training VR system as reported by Wen et al. (2014). Liang and Xiaoming's report in 2013 discussed the concept of a "self-simulation laboratory," used to reduce workspace requirements- a concept that expands on location convenience by featuring a multitude of different electronic engineering equipment that can be experienced within a single space. An immersive VR system that focused on time convenience would expand the windows of opportunities available to beyond what a user is normally allowed. Real-world time constraints that restricted a student's hours of lab availability, plus the preparation and clean-up time required, could be circumvented with VR simulation (Lau et al., 2017).

Engagement

This purpose focused on the implementation of virtual environments that encouraged a user's desire to learn the presented material found in the simulation. This purpose included the use of virtual environments that gained a user's interest, yet expanded further by including VR features such as interaction, immersion, and imagination. Purposes of engagement allowed a user to feel involved in the learning process, usually by being offered challenges or interactive elements within the educational virtual environment. An example of immersive VR being designed with a purpose focused on engagement would be the Jaunt VR video program study, which featured scenic views of Nepal, as reported by Lee et al. (2017).

Safety

A virtual environment that focused on safety may have included some or all of the following: (a) The practice of awareness skills necessary to reduce the probability of accidents occurring, (b) The practice of technical or non-technical skills necessary to handle an abnormal operating condition, (c) The ability to interact with virtual objects that would be deemed too dangerous in the real world. Some virtual environments were mentioned to have been programmed to allow for damage to occur within the virtual world, allowing users to safely learn from mistakes that would normally cause real-world machinery to collapse or cause personal injury (Potkonjak et al., 2016). Dangerous motors and gearboxes in mechanical devices were reported to be exposed in the virtual world, allowing users to see working parts in action (Potkonjak et al., 2016). Taljaard stated in 2016 that virtual field trips allow users to visit simulated places, which could be inaccessible or dangerous. For example, geologists could experience a VR field trip that takes place on the top of a volcano (Taljaard, 2016). An example of immersive VR being implemented with a purpose focused on safety would be the Distributed Situation Awareness study, featuring safety awareness training in industrial plant operators, reported by Nazir et al. (2015). Another example would be the virtual environment Jouriles and colleagues presented in 2016, which was used to measure bystander behavior in response to sexual violence.

Highlighting

This purpose focused on virtual environments that emphasized key elements and variables of objects, supplementing users with additional information. Highlighting was inclusive but not limited to AR. It was also capable of providing quantitative feedback to users, based on their performance on specific tasks within the virtual world. An example of immersive VR being implemented, with a purpose focused on highlighting, would be the software editing training markers as reported by Stigall and Sharma (2017). Another example of highlighting, featuring the use of AR, would be the use of Google Glass in art galleries to provide the user with supplementary information, reported by Leue et al. (2015).

Interactivity

Although interaction is the core emphasis for many immersive VR systems, a simulation with interactivity as the main purpose would attempt to make the virtual environment feel as natural as possible. Interactivity also focused on optimizing the user control, arranging the system to respond to user input information both quickly and accurately, granting users a sense of real human-computer interaction (Liang and Xiaoming, 2013). When computer engineers reported an attempt to optimize user control by reducing latency, increasing computer processing speed or improving motion tracking; the main purpose focused on interactivity from a hardware perspective. An increase in interactivity from a software perspective would be accomplished by programming the virtual object to respond appropriately to multiple forms of user input or by increasing user-friendliness. Purposes of interactivity may have included virtual environments that were designed to feature optimal accessibility, such as the virtual multiplayer child-operated puppet story as presented by Liang et al. (2017).

Team Building

A virtual environment that focused on team building may have included some or all of the following: (a) The practice of technical and/or non-technical skills in groups of trainees so that they achieve proficiency in a skill before the real procedure is performed (Rudarakanchana et al., 2015), (b) The promotion of team collaboration during production and planning. An example of immersive VR being implemented with purpose focused on team building would be the team collaboration in game design curriculum as reported by Timcenko et al. (2017).

Suggestion

This purpose was focused on the use of immersive VR to improve a user's attitude toward a community, cultural movement or service. Immersive VR was reported to be capable of stimulating enthusiasm within the learning of students, changing the way they think about certain perspectives (Hui-Zhen and Zong-Fa, 2013). An example of immersive VR being implemented, with a purpose focused on suggestion, would be Real et al. (2017a) study on best-practice communication skills, encouraging patients to receive vaccinations. Another example featuring the use of immersive VR to discourage specific behavior, would be the cue reactivity study as reported by Gupta and Chadha (2015), aimed at discouraging cigarette smoking for users with an addiction problem.

Suh and Prophet (2018) reported a classification of research themes and contexts for immersive VR by using the stimulus-organism-response (S-O-R) framework, where the variables of their found 54 studies were classified to determine relationships. Several factors were found to be related between immersive VR's system features and sensory, perceptual and content stimuli (Suh and Prophet, 2018). Content stimuli included immersive VR topics such as learning and training, psycho- and physiotherapy, virtual tours, interactive simulation, and gaming stimuli (Suh and Prophet, 2018). The 119 reports as identified from the literature in this review is relatable to Suh and Prophet's (2018) reported classification system, especially for the topics identified as content stimuli.

Objective 4—Theories and Recommendations for Incorporating Immersive VR Into Post-secondary Education

This review found two papers recommending a social constructivist approach for how immersive VR could be incorporated into post-secondary education curricula (Haefner et al., 2013; Cochrane, 2016). Social constructivist approaches include proposals on how student-created virtual environments are mainly led by the students themselves, using a team collaborative style. Experiential learning allows the students to use their newly created virtual environments to role-play their actions in simulated scenarios, aiming to achieve mastery over their discipline. This is reminiscent of Gonzalez-Franco and Lanier's (2017) idea on the student acting as "the center of the system," providing the computer-generated virtual environment triggers the user's learning response as though the virtual stimuli matches that of the real world. The training of student awareness for paramedic clinical practice by using VR 360-degree interactive images, projected by HMD (smartphone), allows for the facilitation of student-created content in authentic simulation (Cochrane et al., 2017). Although Cochrane's recommendations were exemplified in design thinking, journalism, and paramedicine; the method's potential transferability seemed convincingly capable of being used in other disciplines within the fields of Arts and Humanities or Health Sciences. The theory of implementing a virtual event that makes the user feel central to the environment, resulting in an authentic illusion, is a key feature that must be retained when adapting VR learning frameworks from one discipline to another. Haefner and colleagues' recommendations (2013), which mentioned interdisciplinary teamwork, also possessed convincing transferability beyond just the discipline of Engineering. A future study that focuses on a curriculum that is feasible and vastly adaptable to most disciplines would be a definite recommendation for future research. **Table 6** summarizes the educational theories associated with the use of immersive VR.

DISCUSSION

This review focused on how immersive VR was used in post-secondary level education and skill training, determining if any new educational perspectives have emerged, with the goal of obtaining an improved understanding of the state of the art as found from the literature. The most important considerations when conducting this method of literature search included: (a) attaining an unbiased selection of papers for review, (b) accepting only the literature that stated the use of fully immersive VR (HMD hardware or similar), (c) limiting the literature by date of publication to no earlier than March of 2013.

TABLE 6 | Summary of educational theories associated with immersive Virtual Reality.

Theory	Description	References
Cognitive Load Theory	Learning and instruction that optimizes the amount of cognitive load a user experiences within the capacity of working memory. Immersive VR features multiple modes of information that is simultaneously processed by multiple sensory modalities including sounds, images, texts, tactile cues.	Paas et al., 2016; Liu et al., 2017b
Conceptual Blending Theory	Recommends AR users to move "fluidly" between the physical and virtual world. This creates a conceptual blend as users layer multiple, distinct "conceptual spaces," or different "source domains," which enhances learning.	Enyedy et al., 2015
Constructivist Learning Theory	Assumes that knowledge development occurs best through the building of "artifacts" (physical or digital), which can be experienced and shared. Constructivist strategies in VR are effective, because they empower learners to author their own scenarios in which they have an emotional investment.	Papert and Harel, 1991; Liu et al., 2017b
Flow Theory	A positive experience associated with immersive VR leads to optimal learning states induced by intrinsic motivation, well-defined goals, appropriate levels of challenge and feedback.	Csikszentmihalyi, 1990; Liu et al., 2017b
Generative Learning Theory	Practice of learning information by transforming it into usable form by selecting (spending attention on relevant information), organizing (arranging information into coherent structure), and integrating (connecting verbal/image representations with each other and with prior knowledge from long-term memory).	Parong and Mayer, 2018
Interest Theory	Users learn better when they perceive value in the learning material, either intrinsically (individual interest) or as elicited by the situation (situational interest).	Wigfield et al., 2016; Parong and Mayer, 2018
Jefferies Simulation Theory	The development process of simulations includes context, background and design characteristics, resulting in dynamic interactions between the facilitator and learner through the use of appropriate educational strategies.	Jeffries and Jeffries, 2012; Aebersold, 2018
Kolb's Experiential Learning Theory	A four step theory (concrete experience, reflective observation, abstract conceptualization and active experimentation) that form a continuous cycle- reminiscent as users experience immersive VR.	Kolb, 1984; Aebersold, 2018
Motivation Theory	VR learning may enhance user focus, due to an increase in engagement, resulting in further investment of energy to allocate cognitive resources during difficult parts of the lesson.	Parong and Mayer, 2018
Presence Theory	Based on the following immersions: *Actional*—VR empowers users to experience new capabilities as actions are performed with novel/intriguing consequences, *Symbolic/Narrative*—Users learn semantic associations from content of experience, *Sensory*—Immersive VR's ability to encourage a user to imagine being in a different actual location, *Social*—Interactions among other users (or perhaps artificially intelligent avatars) deepens sense of being part of the setting.	Dede, 2009; Liu et al., 2017b
Situated Learning	Virtual environments allow users to interact with objects and apply them within the setting itself, fostering tacit skills through experience and modeling.	Liu et al., 2017b
Stimuli—Organism—Response	The stimuli found in virtual environments affect both a user's cognitive and affective states, which in turn leads to behavioral changes (technology adoption behavior).	Mehrabian and Russell, 1974; Suh and Prophet, 2018
Control Value Theory of Achievement Emotions (CVTAE)	Learning can be facilitated through positive achievement emotions, such as enjoyment, especially when instructional design elicits and promotes appraisal of student autonomy and intrinsic value.	Pekrun, 2016; Makransky and Lilleholt, 2018

Curricular Recommendations

Immersive VR programs could be incorporated into an academic curriculum as either a full-course program or as supplementary material to an already-existing course. Immersive VR for supplementing a large classroom size would possibly be best performed by finding relevant software, in the form of 360-panormic images or videos for mobile phones, depicting environments that resemble lecture materials for users to experience. For example, students of surgical or nursing education could experience 360-operative video, similar to the one used in Harrington and colleagues' surgical study in 2018. Supplementing a small classroom size would possibly allow for relevant software to be experienced on an immersive HMD VR consumer model, similar to the cardiac anatomy setup (Sharecare VR) in Maresky and colleagues study in 2018.

For full-course programs that may attempt to integrate immersive VR, Alfalah (2018) reported the following:

- Faculty members should be prepared to allocate time for training in the development of software and utilization of immersive VR hardware.
- Detail a realistic and practical plan for the transformation or creation of the course.
- Increase the awareness to faculty members about the technology integration via staff emails, learning management systems, seminars, and posters.
- Consider administrative support to reduce faculty member load.
- Enable collaboration between faculty members to share ideas for enhancing the system.

Full-course programs that prefer to feature student-developed immersive VR programs could either be: *Simple*—Videos adapted into 360-degree format for mobile phone VR by using GoPro cameras with their videos merged into a single equirectangular video by Kolor Video Pro and Giga software (Harrington et al., 2018), or *Advanced*—Software creation as an immersive VR program for consumer based HMDs, developed by a graphics rendering engine (Timcenko et al., 2017). It is possible for an immersive VR program to be programmed so that it can switch between HMD VR and desktop PC controls, which would allow for users who are sensitive to simulator sickness to have access to a non-immersive alternative. The option to add platform crossover versatility to software would be expected to require more development time.

Cochrane in 2016 summarized a post-secondary educational framework that allowed students to devise and submit their own VR content in order to learn and classify AR projects, featuring disciplines including journalism, paramedicine, and graphic design. For example, paramedicine would feature students using immersive VR (mobile) to conduct pre-practice of a critical care scenario before they entered a simulation room where they performed resuscitation procedures (Cochrane, 2016). Cochrane in 2016 and 2017 summarized six informing pedagogies and their definitions for the application of mobile VR in education: Rhizomatic Learning—"Negotiated ecology of resources," Social Constructivism—"Collaboration tools for project planning (e.g., Google Docs)," Heutagogy—"Student-generated content: 360 degree camera rig and stitching software," Authentic learning: situated content—"Shared 360 video (e.g., YouTube 360 via HMD and Google Cardboard), Authentic learning: situated context—"360 degree immersive environment simulation," Connectivism—"Community Hub (e.g., Google Plus, Facebook, and Twitter)."

The key requirements of a successful practical VR course in interdisciplinary engineering education were found to be as follows: (a) primary emphasis on VR task design while maintaining student creative freedom, (b) clearly defined tasks for each individual group member's role, (c) the use of software platforms that were open source with strong community followings (Haefner et al., 2013). Based on the student group configuration and information from instructor-to-student collaboration, the students were recommended to define each individual group member's role in accordance to their knowledge and interests. In smaller groups, status meetings of the project's development were expected to be easier to organize and yield qualitative, well-structured project results (Haefner et al., 2013). Larger groups that consisted of more than 10 students would require a project manager (student designated) who is proficient in handling conflict management, with less emphasis on sub-task support (Haefner et al., 2013). It was important for the students to provide continuous progress updates, within the status meetings, so that any issues regarding design of the VR project are detected early (Haefner et al., 2013).

Considerations of Virtual System Design

The purpose of a virtual environment will determine how it is designed and implemented. A post-secondary educational virtual environment can be divided into two types: an environment that represents the real world (e.g., historical location) and/or a computer generated 3D object (e.g., interactive control panel; Lee and Wong, 2008). Depending on whether or not the system is designed to be portable and the amount of interaction a user needs to have with the virtual environment will determine its varying HMD hardware and input devices. If the user is expected to interact with the virtual environment and perform actions that are meant to accurately represent those that would be performed in real life; the input hardware is expected to maximize fidelity (e.g., a haptic arm that provides force feedback during surgical simulation). Likewise, if the user is not expected to interact with the virtual environment or the user's actions do not have to accurately represent those that would be performed in real life; the input hardware can be of low fidelity (e.g., using a gamepad to move within the virtual environment instead of walking).

Although low fidelity simulation may initially seem less useful than high fidelity, low fidelity virtual environments are associated with lower hardware costs and allow for acquiring "procedural knowledge" at the expense of "higher-order skills and strategic knowledge (Champney et al., 2017)." It is important to note that high fidelity virtual environments are associated with greater hardware costs and may "overwhelm and distract early procedural learning" (Champney et al., 2017). An example of public-speaking skill development, featuring low amounts of user interaction, would be a virtual environment depicting a large crowd, where the user is tasked with standing on stage to be exposed to this social anxiety stimulus. The use of exposure therapy in VR simulation in this manner would be designed to habituate a user's fear thought-process into a more adapted one, removing the pathological kind that distorts reality and increases escapist tendencies (Bissonnette et al., 2016).

It should be noted that a user's level of technical proficiency should be factored into how virtual objects are intended to be interacted with. A user with a university background in mechanical engineering would most likely have no trouble utilizing complex button-operated input controllers to interact with a virtual object (e.g., Virtual Workshop as reported by Muller et al. (2017). Likewise, a user who is inexperienced with technical hardware would likely benefit with a simpler input device to interact with virtual objects [e.g., Liang et al. (2017) child-operated virtual puppet story with gesture control, detected by Leap Motion].

Limitations of This Review

Limiting the literature search to March of 2013 and onward allowed this review to focus on a specific point when educational perspectives were formed at a time when immersive VR's rate of availability was greater than before. This date limit, however, may have come at a cost as some papers not included may have discussed educational perspectives, formed prior to this date, which may still be in use. By accepting only the literature featuring the use of immersive VR, this review was able to determine educational perspectives that were potentially and optimally invoked by concepts such as experiential learning, immersion, interactivity, and imagination. This consideration also allowed this review to find positive outcomes determined by the literature when immersive VR was compared with non-immersive VR. This review focused on immersive VR's performance in post-secondary educational settings, containing interpretations that may not be adequate for less advanced levels of education. Further defined subtypes of post-secondary education terms, such as Masters or Bachelor, were not used in this review's search method, which may have impacted the ability to find all applicable literature.

Conclusion

This review on the use of immersive VR in post-secondary education and skill training has revealed recommendations and purposes for how it could be implemented into curricula. Common positive outcomes, featuring the use of immersive VR, have shown to promote student engagement and skill acquisition.

Immersive VR brings convenient, engaging and interactive alternatives to traditional classroom settings as well as offers additional capability over traditional methods. This review has highlighted detailed reports that have successfully implemented immersive VR into their curricula. There is a diverse assortment of educational disciplines that have each attempted to harness the power of this technological medium. It is expected for immersive VR to become further adopted into academic settings in the future. Will your facility be the next to implement immersive VR?

AUTHOR CONTRIBUTIONS

BC, SE, and MR co-conceptualized the review study. BC completed the literature search and analysis in consultation with and guidance from MR. BC led the manuscript writing process. SE and MR contributed to the writing process and revisions. All authors approved the final version.

FUNDING

The study was supported by the Teaching and Learning Enhancement Fund (TLEF), University of Alberta. The content is solely the responsibility of the authors and does not necessarily represent the views of the TLEF, University of Alberta.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of the Rehabilitation Research Centre at the Faculty of Rehabilitation Medicine, University of Alberta.

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Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.