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# The role of virtual environment and virtual reality for knowledge transfer

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### Abstract

Virtual Reality (VR) is a technology tool for workplace training that can lessen the total training time needed to learn complex cognitive tasks and aids a learner in converting abstract ideas into practical understanding. This review explores the use of VR training and its role in assisting a learner with knowledge transfer. A comprehensive literature search was conducted of peer-reviewed journal articles published between 2003-2018 and then 44 sources were selected for analysis. The reviewed research studies indicated that immersive VR training can provide a learner with a highly engaging virtual learning environment VE and stimulating experience that accommodates self-paced and self-directed learning. Trainers would benefit from potential immersive VR training outcomes such as bridging the gaps in understanding and promoting knowledge transfer and skill acquisition in a faster and more permanent manner when compared to traditional classroom training. It is recommended that future research should be conducted on the effects of VR cognitive load as it pertains to knowledge transfer.

# The Role of Virtual Environment and Virtual Reality for Knowledge Transfer

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## Abstract

Virtual Reality (VR) is a technology tool for workplace training that can lessen the total training time needed to learn complex cognitive tasks and aids a learner in converting abstract ideas into practical understanding. This review explores the use of VR training and its role in assisting a learner with knowledge transfer. A comprehensive literature search was conducted of peer-reviewed journal articles published between 2003-2018 and then 44 sources were selected for analysis. The reviewed research studies indicated that immersive VR training can provide a learner with a highly engaging virtual learning environment VE and stimulating experience that accommodates self-paced and self-directed learning. Trainers would benefit from potential immersive VR training outcomes such as bridging the gaps in understanding and promoting knowledge transfer and skill acquisition in a faster and more permanent manner when compared to traditional classroom training. It is recommended that future research should be conducted on the effects of VR cognitive load as it pertains to knowledge transfer.

The Role of the Virtual Environment and Virtual Reality for Knowledge Transfer

## Introduction

Frequently people encounter workplace situations where they must adapt and act upon continuous changes that can be life-threatening (van Meeuwen, Brand-Gruel, Kirschner, de Bock, & van Merriënboer, 2018). One such situation is described by Fink (2017),

> By the time I spotted the shotgun, it was too late. I feel a sting in my thigh. I've been hit. I was distracted by the hysterical wife, while my partner was dealing with a nosy neighbor. We get off thirteen shots, all high, merely grazing the assailant. (p.1).

Fink is describing his immersive virtual reality (VR) training experience with the L.A. County Sheriff's Department. The rookies in this department had the advantage to learn from their mistakes in a virtual environment (VE) versus while on active duty, where the chances for personal harm would have been greater.

Law enforcement training is one of many industries breaking the mold of the classroom and moving forward with technology as its partner. Deloitte Work-Trends 2030 report forecasts the future workplace as a compilation of collaboration, communication, innovation and diversity (Deloitte Touche Tohmatsu, 2016). Working successfully on a team requires personal aptitude for the technical aspects as well as the Knowledge, Skills and Abilities (KSAs) associated with being an effective team member (Cannon-Bowers, & Salas, 1998). However, team training is just one aspect that the trainer will need to accommodate in order to build an effective workforce for the future (Deloitte Touche Tohmatsu, 2016). According to the Association for Talent Development (ATD), much of occupational training is focused on improving job specific KSAs while capturing changes in digital, mobile, and social technology; demographic shifts; globalization; and economic forces (ATD, 2014). Di Bello and Missildine (2011) argue that the issue for many instructional design strategies is that it has become outpaced by global knowledge and the rapid growth of technology implementation.

VR training assists a learner with knowledge transfer because it can place the learner in asemblance of the actual situation and find the best approach to solve a problem or acquire a new skill (Berg & Vance, 2017; Langley, Lawson, Hermawati, D′Cruz, Apold, Arlt & Mura, 2016; Sacks, Perlman & Barak, 2013). Training that supports building KSAs in the workplace is a precursor to an adaptable workforce (Cannon-Bowers, & Salas, 1998; Pulakos, Arad, Donovan & Plamondon, 2000). Wilkins (2011) suggests that the role of a trainer requires that information be disseminated and that the material be tailored to suit the requirements of each learner. Successful organizations are now required to accelerate the speed of innovation and gain a competitive advantage by shifting strategies to meet evolving demands (Di Bello & Missildine, 2011). One solution for accommodating diversity and perceived occupational challenges may be immersive VR training programs. Through applicability (cognitive fit) and a self-directed learning (constructivism-based learning), immersive VR training is a medium that can provide a VE that can meet the instructional strategies needed to build an adaptable workforce (Aik & Tway, 2006; Chen & Teh, 2013; Huang, Rauch, & Liaw, 2010; Wilkins, 2011).

Immersive VR training and the VE can provide many benefits such as reduced exposure to risks (Lucas, Thaber, & Worlikar, 2008; Park, Jang, & Chai, 2006), reduced training time and expenses (Lucas et al., 2008; Ramírez, Rico, Riofrío-Luzcando, Berrocal-Lobo, & de Antonio, 2018; Rienties & Townsend, 2012), increased team collaboration for decision making and problem solving (Berg & Vance, 2017), elimination of labor-related material costs (White, Prachyabrued, Chambers, Borst, & Reiners, 2011), decreased error rates (Langley et al., 2016), and decreased periods of off-tasking or disengagement (Sacks et al., 2013).

This literature review draws on and contributes to the field of occupational training. Immersive VR training is a versatile technology tool that supports many goal-driven outcomes. The guiding question raised in this review is: How does the VE and immersive VR training affect the process of knowledge transfer? To further refine the purpose, this study uses the following research questions as the framework of analysis:

RQ1: How can the VE affect knowledge transfer?

RQ2: How does self-directed learning inherent to VR training affect knowledge transfer?

RQ3: How does VE feedback design affect knowledge transfer in VR training?

Because instructional designers and trainers often collaborate to select the right technology, then having a basis of understanding about knowledge transfer as presented in this review could be further applied to the construct of a VE and VR training programs by instructional designers and trainers [Canadian Association of Instructional Designers (CAID), 2017; Huang et al., 2010]. Additionally, VR training programs can be a significant budgetary investment therefore this analysis would be advantageous to stakeholders involved in the decision process to purchase the VE technology for their workplace VR training program because it serves as a primer in which to assess a new methodology that promotes learning effectiveness and trainee engagement (Berg & Vance, 2017; Huang et al., 2010).

**Key Terms:**

Virtual Environment (VE) is the learning environment created by computer software that presents alternative perceptual stimuli allowing a learner to perceive three dimensional data and allows immersion with objects which achieves a degree of presence while engaging in activities outside the normal real-world (Dalgarno & Lee, 2010; Fernandes, Raja, & Eyre, 2003; Huang et al., 2010; Park et al., 2006).

Immersive Virtual Reality (VR) training systems allows the trainer to deliver large amounts of complex information in a visually attractive way within a VE that can make it easier for a learner to comprehend and retain complex procedural knowledge and abstract ideas (Langley et al., 2016).

As a refresher, the International Organization for Standardization (ISO) is responsible for creating specifications and guidelines to ensure consistency in products, processes and services for member subscribed organizations (ISO, 2018). The ISO defines technology-based training efficiency as the ability of the system to provide effective training in minimum time as based on the ISO standard reference #9241-210 (Langley et al., 2016).

Traditional training is described as classroom-based lectures, paper, video, demonstrations and on-the-job training (Langley et al., 2016).

## Methodology

A comprehensive literature search was conducted in order to build a complete picture on how the process of knowledge transfer relates to the VE and VR training. The selection of 53 sources used in this review were located using a multitude of steps. The first step was to use Google Scholar to narrow the search. Investigating the titles of articles in this step was key to building a search term list that could be used as keywords in a database search. The second step was to find suitable databases. The databases utilized were ERIC, Business Source Elite, Cambridge Core, Corporate ResourceNet, and Education Full Text because of the rich depth and access of materials. In order to maintain quality and integrity of information, searches had the added parameters of peer-reviewed journal articles and a time frame ranging from 2003 to 2018. The descriptors used in the searches were Immersive Learning, VR Training, Virtual Environments, Virtual Teams, Knowledge Transfer, Performance, Simulations and Training, Virtual Safety Training, Team Performance, and Group Decision Making. These methods produced thousands of results. Results were narrowed to occupational training with emphasis on learning process. The third step was to add articles into a software program called Mendeley. The presence of specific articles in the My Library section of the program gives the software a basis in which to offer additional suggestions similar to those already accumulated through a feature called suggest tool. This helped expand the number of resources and provided a source for current publications.

Another effort deployed to further expand the topic was the snowball method of selecting cited sources from other journal articles. Articles were scrutinized for their applicability to the topic and their references were scanned to identify which would be useful in further expanding the list of possible sources to investigate.  This fourth step proved to be valuable in building the key focal areas as outlined in the aforementioned research questions.

The articles were evaluated based on the following criteria: type of adult education, type of workplace training and type of research methodology. The articles collected were selected based upon how the researchers demonstrated knowledge transfer in both the individual and team level since so many existing trends in training rely heavily on building a workforce that is skilled and adaptable. There was not a particular industry that dominated the searches, therefore, multiple industries were considered during the selection process. There were a few studies involving higher education that were included because of their practical application to work-related knowledge, tasks and application of strategic thinking. In many cases, the referenced sample size amongst the studies were small; however, this is in synch with the traditional training group size for most organizations.

## Analysis and Discussion

Because occupational training relates to teaching adults, it is helpful to understand the andragogy learning philosophy, as introduced by Knowles (1968 as cited in Wilkins, 2011), which is defined as the art and science of helping adults learn (Wilkins, 2011). Andragogical methods, which are generally learner-focused and emphasize the need for learner support, have demonstrated effectiveness in re-training individuals to adapt to new jobs and support those who have weaker academic aptitudes (Wilkins, 2011). The end goal of andragogy, on a philosophical level, is to provide direction by which adults develop into independent learners who are adaptable and self-sufficient (Forrest & Peterson, 2006). Comprehending the factors specific to a VE enable instructional designers and trainers to make effective decisions that affect learner outcomes in an immersive VR training program.

A challenge for an instructional designer or trainer is to provide information that aligns with a learner's job role within an organization. A key component of andragogy is that adults are self-directed learners and do so from the standpoint of either a problem or performance-centered mindset (Forrest & Peterson, 2006). When facts are learned within a VE, there is often a greater knowledge transfer and correlation with the real-world environment because of the fidelity and presence that leads to a richer experience and influences transfer of learning (Dalgarno & Lee, 2010). Immersive VR training can enhance a learner's motivation to learn new knowledge while also discovering deficiencies in his/her job specific knowledge which promotes both knowledge transfer and self-efficacy (Bandura, 1993; Chen, 2006; Podgórski, 2010).

Because of the complex nature of this technology, it is essential to provide a basis for understanding of the elements of the VE and immersive VR training. Additionally, there are three specific areas that will be reviewed regarding how immersive VR training can promote knowledge transfer. These areas are the VE, self-directed learning, and feedback design. These areas are of interest as they align with the process of knowledge transfer in immersive VR training.

**What is Virtual Reality?**

There are two types of VR systems; immersive and non-immersive (Chen, 2006). Immersive VR training provides learners with the opportunity to experience computer-based artificial virtual environments (VEs) filled with situations that seem real and generate images that respond to a learner's movements and actions and allow a learner to manipulate virtual objects, structures and metaphorical representation of ideas which allows a learner to perform specific tasks in a realistic and safe environment (Dalgarno & Lee, 2010; Fernandes et al., 2003; Huang et al., 2010; Park et al., 2006). The scenario depicted at the beginning of this review is an example of immersive VR training inside a computer-based artificial virtual environment. As the computer algorithms create the VE, the display then renders the information to a learner's senses, this becomes the catalyst that provokes a learner to weave the pieces that are needed to understand the entire experience which then can be applied to situations in a real environment (Berg & Vance, 2017).

Because of diversity in the workplace, learning styles accommodation is essential in building a supportive learning environment (Deloitte Touche Tohmatsu, 2016; Nissim & Weissblueth, 2017). Immersive VR training can provide unilateral access to learning which means, for learners with disabilities, most are able to participate in a way that they would not be able to do otherwise in traditional training (Nissim & Weissblueth, 2017). Mace (1985 a cited in Watanuki, 2010) developed the concept of universal design. Watanuki (2010) expresses the principles of universal design as being equitable use, flexibility in use, simple and intuitive in use, perceptible information, tolerance for error, low physical effort, and size and space. A VE makes allowances for simultaneous observation of visual and kinesthetic information (Wantanuki, 2010). Wantanuki (2010) contends that through parallel data collection [feedback design], application modifications can be administered. This is an especially welcomed advantage for instructional designers because many principles of universal design can readily be built into the VR training program through adaptations of the VE.

Immersive VR training is effective and efficient because it allows a learner to interact with various objects inside the VE in such a way that simulates real-world scenarios and allows for intuitive learning; enabling a learner to experience success or failure and experience near-reality sense of the hazards associated with working in dangerous environments (Langley et al., 2016; Lucas et al., 2008; Park et al., 2006). These design objectives can be difficult to emulate with a traditional training programs (Langley et al., 2016).

Instructional design strategies incorporating immersive VR Training may allow for further customization for each occupation and learning style. Examples in which VE would be advantageous might be an electrical worker learning about doing live-line repairs virtually versus doing so in an on-the-job training situation where it could be treacherous to learn by trial and error. Conversely, it would be safer for a patient if a resident surgeon-in-training practice first in a VE before performing a new medical procedure on the patient.

For most organizations, VR training programs are considered an investment and building the VE necessary to support such a program can be complicated (Berg & Vance, 2017; Huang et al., 2010). It takes upfront planning but can be the conduit in which instructional designers and trainers construct and deliver complex information in a visually attractive package (Nissim & Weissblueth, 2017). A VE can range from simple screens and pre-made software to complex physical spheres with optical and motion trackers with extensive computer processors that record visual, spatial, psychological arousal, error rate and much more (Berg & Vance, 2017; Huang et al., 2010; Watanuki, 2010). In the majority of the studies reviewed, the trainers had to spend a significant portion of their time testing and explaining the process of how to use the VE technology system to the learners before they were comfortable participating in the VR training program.

## A Brief History of Virtual Reality

Sutherland (1965 as cited in Berg and Vance, 2017) is recognized as the founder of VR as he first conceptualized the idea in an article entitled, “The Ultimate Display,” with a discussion about technology that had not yet been invented. The very first company to sell VE devices emerged in the 1980s when VPL Research was formed by Jaron Lanier (Berg & Vance, 2017). Sutherland’s conceptualization of using all the senses began to take shape in the 1990s when companies such as Caterpillar, Chrysler, Boeing, and NASA began their own research and partnered with a number of universities to advance the field (Berg & Vance, 2017). The following decade ushered more advances such as motion capture, haptics, tracking systems, high-resolution displays and the enhanced support of presence (Berg & Vance, 2017). The leader from that point forward was the medical community which saw this technology as an impressive training platform as well as a way to treat patients with physical rehabilitation concerns and mental health disorders (Berg & Vance, 2017). As the price of the VE technology declines, more industries continue to adopt immersive VR training programs including architects and engineers who benefit from VE spatial experiences that can assist a learner in visualizing spaces and flaws before construction commences (Berg & Vance, 2017).

**What is Knowledge Transfer?**

With the immense quantity of allocated resources poured into VEs and VR training, it follows that the transfer of learning would be a needed to measure the outcomes and objectives of the training for the specific job-related skills needed to remain competitive in the workforce. Knowledge transfer success can be described as either positive, negative, or nil (Alexander, Brunyé, Sidman, & Weil, 2005). Positive transfer occurs when the training environment improves the work-situated role (Alexander et al., 2005). Negative transfer happens when training appears to have degraded actual performance and nil is when no change in performance occurs at all (Alexander et al., 2005). The degradation of knowledge transfer is sometimes known as the "expertise reversal effect" and is usually caused by inhibited learning fueled by poor instructional design such as using novice examples for expert learners (Di Bello & Missildine, 2011).

**How Can the VE Affect Knowledge Transfer?**

There are many elements to a VE and its characteristics that potentially impact a learning experience. From an instructional design standpoint, some of the elemental focus will shift depending upon if it is a single-user or multi-user environment. Educational theories such as the constructivist paradigm are fundamental part of the VE (Huang et al., 2010). Dewey (1916 as cited in Huang et al., 2010) emphasizes constructivism as making affordance for the learner to remain active role in their learning and, furthermore, that learning should be real and applicable to daily life (Huang et al., 2010). These principles are present in VE as a natural extension of self-directed learning which allows the learner to absorb information, to connect it with previous knowledge, and to construct new knowledge (Huang, et al., 2010).

**Elements of the Virtual Environment**

A VE creates the ability to cross time in past, present or future parallels and affords a learner the opportunity to experience cultures that are unlike their own (Nissim & Weissbleuth, 2017). This is a factor that is unique to a VE because both the context and the learning environment can be manipulated at various levels. According to Podgórski (2010), an effective VE can also promote the transfer of tacit knowledge which is difficult to acquire in a classroom. In general, the characteristics of VE are: fidelity, presence, immersion, social presence, authenticity and immediacy of control (Dalgarno & Lee, 2010).

Fidelity in a virtual environment. The underpinning of a VE is fidelity which is often associated with realism (Gilbert, 2016). Fidelity, in general, is defined as the extent to which the VE emulates the real world (Alexander et al., 2005). Representational fidelity is defined as how well the system renders transitional changes in the field of view and the consistency of object behavior during interaction (Dalgarno & Lee, 2010). Depending on context, different types of fidelity may be important such as visual fidelity (does it look realistic?), auditory fidelity (does it sound realistic?) physical fidelity (does it feel realistic?), functional fidelity (does the virtual equipment function realistically?), and psychological fidelity (does it provoke fear, stress, and arousal?) (Alexander, et al., 2005; Gilbert, 2016). The following are some examples of the importance of fidelity in various learning situations: if a learner's task is to understand how to drive a car then visual fidelity may be ranked as most important. If a learner's task is to work with explosives, then auditory fidelity may take precedence. Finally, if a learner's task is to understand a specific type of surgery then physical or tactile fidelity would rank highest. A combination of types of fidelity can be used to create a VE and an immersive VR training experience but certainly some types would be perceived to be more important to the learner depending on the assigned task or tasks.

***Presence and immersion in a virtual environment.***

The effectiveness of the VE has been debated based on its deemed level of presence or immersion (Grabowski & Jankowski, 2015; Skarbez, Brooks, & Whitton, 2017). Presence is the measure of a learner being engaged in non-reality and is context-dependent and related to a learner's psychological response to the VE (Alexander et al., 2005; Dalgarno & Lee, 2010). Huang et al., (2010) argues that a strong sense of presence is what induces motivation on the part of the learner to process the learning in a deeper and more reflective way. Known factors that may affect presence are control factors, sensory factors, distraction factors, and realism factors (Alexander et. al., 2005).

Immersion refers to the VE and the computer-based system and its technical capabilities that generate the context for the activity which allows a learner to feel absorbed in the process (Dalgarno & Lee, 2010; Gilbert, 2016). Huang et al., (2010) suggests mental immersion is when the learner reaches the state of being deeply engaged within a VE. The opportunity to have a robust VE is most certainly tied to hardware and software constraints which tightly aligns with the organization's VE build-out budget (Huang et al., 2010)

***Social Presence in a virtual environment.***

Social Presence involves engaging additional users and often leads to collaborative learning (Huang et al., 2010). These Multi-User Environments (MUEs) are three-dimensional environments that allow multiple users, even those who are geographically distant, to access simultaneously which commonly offer avatar-based interactions which are synchronous: users have the ability to interact with each other while offering cues such as gestures and behaviors that mimic real-life interactions (Papachristos, Vrellis, Natsis, & Mikropoulos, 2014). These interactions can be imperative in team building KSAs (Di Bello & Missildine, 2011; Papachristos et al., 2014; Schouten, Van den Hoof, & Feldberg, 2010). Generally speaking, MUEs provide a realistic collaborative environment that enhances the learning experience (Le, Pedro, Pham, & Park, 2016).

For the instructional designer, a MUE is advantageous because it is cost effective and scalable (Di Bello & Missildine, 2011). A MUE can also help a learner overcome many cultural barriers faced by traditional training as a learner can create his/her own avatar to represent their virtual embodiment; this aligns with social fidelity (Dalgarno & Lee, 2010; Di Bello & Missildine, 2011). MUEs are useful for teaching a team how to work together on tasks such as repair but can also be used to teach soft skills like how to effectively anticipate and interpret complex social interactions (Di Bello & Missildine, 2011). Most MUEs offer some immediate social discourse which allows the group to communicate in a natural manner and is considered to be more effective than text-based interactions (Papachristos et al., 2014). The MUE can also be embedded with real-time feedback to aid the acceleration of knowledge transfer (Di Bello & Missildine, 2011).

***Authenticity in a virtual environment.***

The concept of authenticity in a VE, refers to the perception of a learner and whether the VE provides a learner with the expected experience (Gilbert, 2016). Authenticity can be represented through both expectation and motivation (Gilbert, 2016). Motivation and mental immersion increases as a learner becomes more involved in the VE experience (Huang et al., 2010). A learner's participation is regulated by the ability to take actions, manipulate objects, control views, and navigate the VE (Dalgarno & Lee, 2010). Somewhat akin to this term is a training concept referred to as "buy-in", which generally refers to the degree to which a learner recognizes a training experience to be beneficial (Alexander et al., 2005). Buy-in influences the motivation of a learner to put forth the effort to gain knowledge that will transfer to the real-world (Alexander et al., 2005). Therefore, the authenticity in the construction of the VE is important because the level of immersion and realism felt by a learner can influence both a learner's buy-in, as well as his/her understanding and decision-making process (Alexander et al., 2005; van der Land et al., 2013). A learner's buy-in is a typical obstacle for a trainer when presenting content to multiple groups of employees because applicability of job alignment and flexibility for application is a challenge (Eggleston, 2017). Without relevance, an adult learner typically will disengage from the learning process (Forrest & Peterson, 2006).

There is much debate among researchers on what constitutes an effective VE and how much immersion is needed. However, for the purpose of this literature review, any type of VR will be considered immersive regardless of its immersion ranking or the type of technology used in the VE.

**Implied Constructivist Principles**

According to constructivist theory, learners have control of the learning process which delivers the freedom to actively construct personal meaning and knowledge from individual experiences (Huang et al., 2010). The nature of the VE aligns with the constructivist principle (as attributed to Piaget, 1972) where the learner constructs meaning through an intuitive way and creates personal meaning from interacting with the learning environment which can be applied to different situations which may not be directly related to the same skill in the real world. (Langley et al., 2016). Because Constructivism contends that interactions require an “other” in order to be a relevant learning experience, the VE is a reasonable substitute for real experiences (Huang et al., 2010). Engagement with the training content increases as the learner explores the VE which offer rich perceptual cues and multimodal feedback (e.g. visual, auditory, and haptic) which is applicable to the transfer of VR learning into real-world skills (Alexander et al, 2005; Huang et al., 2010). Asserting the role of constructivist-oriented learning, Fernandes et al. (2003) indicate a learner can freely travel in a VE and engage in objects that are of interest while having autonomy because he/she must interact with the material in order to sustain the learning environment. Interacting with objects that are true to scale can be one of the strongest visual principles associated with a VE as it meets authenticity expectations and is often tied into haptic feedback (Berg & Vance, 2017). Companies such as Boeing, Ford, and John Deere frequently make use of physical props attached to tracking markers to enhance the learning and evaluation of the VR training program (Berg & Vance, 2017).

Huang et al., (2010) describe five instructional design strategies for constructivist approach which are applicable development of a VE. The underlying theme is to emphasize the design of learning environments rather than instructional sequences. Huang et al., (2010) asserts that the learning environment must be crafted in such a way as to provide real-world case-based environments for meaningful and authentic knowledge.

Huang et al. (2010) propose the first instructional design strategy as “situated learning” (p. 3). Dede (2009) expresses situated learning as the building of authentic contexts, activities, and assessments coupled with guidance. Huang et al., (2010) argues that when a learner is immersed in a VE and interacting with objects and events, they do so as if if were the real-world and the knowledge acquisition is transferable to everyday situations. In creating a supportive learning environment for job-specific transfer, Gilbert (2017) similarly presents a conceptual model for VR training that marries learner-centered pedagogy (labeled Critical Pedagogy) with learning and doing (labeled Situated Learning) which produces similarly desired results.

The second instructional design strategy as outlined by Huang et al. (2010) is “role playing” (p. 4). The learners play and engage in multi-player gaming context with the opportunity to role play and complete competitive and interactive tasks (Huang et al., 2010). This is often labeled as “edutainment” and is an appropriate way to motivate learners (Huang et al., 2010).

The third instructional design strategy as indicated by Huang et al. (2010) is “cooperative/collaborative learning” (p. 4). In a group, learners freely exchange ideas, share experiences and obtain knowledge (Huang et al., 2010). The VE can be built to accommodate for multi-participants which promotes the development of social skills and team problem solving (Huang et al., 2010).

The fourth instructional design strategy as promoted by Huang et al. (2010) is “problem-based learning” (p. 4). Within a VE an authentic problem is often presented with smaller, vague associated tasks (Huang, et al., 2010). The advantage of using a VE for problem-based learning is that it can be customized to a level of difficulty suitable for the learner (Huang et al., 2010). Huang et al. (2010) suggests that problem-based learning leads a learner by means of free discovery and engagement to construct their own new knowledge.

The fifth instructional design strategy advocated by Huang et al. (2010) is “creative learning” (p. 4). The VE promotes creative learning by allowing a learning an open-ended problem solving process (Huang et al., 2010). Learners can also use imagination to construct something new within a VE or contribute to the VE building process (Huang et al., 2010).

***Increased engagement for the learners.***

Learners typically feel an overall increase in stamina and endurance while engaged in a VE which helps them maintain longer periods of learning (Nissim & Weissbleuth, 2017). This can be explained by a heightened sense of presence or engagement which often leads to an increase in the learner's time spent working on training tasks (Alexander et al., 2005). Even students who received lessons by lectures while immersed in a VE stayed focused on the lecture longer than with the traditional text-based lecture methods (Le et al., 2016).

Sacks et al. (2013) offer subjective data in their study that supports the plausibility that a learner can maximize the effectiveness of his/her learning in a VE in comparison to the traditional lecture and video presentations. Because a learner is actively engaged, this may lead to more effective information processing which is the strongest predictor of knowledge and skill acquisition (Alexander et al., 2005; van der Land, Schouten, Feldberg, van den Hooff, & Huysman, 2013). In a study by Grabowski and Jankowski (2015), the outcomes of training coal miners in a VE consisted of positive influences on knowledge transfer and self-efficacy, which were attributed to learner engagement.

***Increased perspective for the learners.***

One unique benefit of a VE is that it can rapidly generate multiple views of the same object and events which is completely different from the real-world where a learner is constrained by his/her body which presents only one viewpoint (Lindgren, 2012). Providing a context that separates the learner from his/her fixed viewpoint in accordance to fidelity of the virtual environment and psychological factors is key to shifting perspective, improving performance, enhancing learning, and promoting knowledge transfer (Bertram, Moskaliuk, & Cress, 2015; Lindgren, 2012). This is primarily achieved by leveraging features that meet authenticity expectations while omitting irrelevant information (Gilbert, 2016). Sometimes shifting perspective can mean creating an unexpected VE as was noted in a study by Papachristos et al. (2014), which determined that the VR group that was asked to learn the content in an outdoor VE classroom setting versus a VE rendered as a traditional classroom performed better. VEs can be created and accepted as believable even though they do not yet exist or could never be experienced in the real-world in the same way (Berg & Vance, 2017).

In contrast, Skarbez et al. (2017) argue that there is not a clear definition of what constitutes an effective VE and it still remains an open research problem. For the instructional designer, the effectiveness of a VE may always be an unconstrained computational problem due to differences in perceptions and the means in which to manipulate them (Gilbert, 2016).

***Shared understanding in a multi-user environment.***

Immersive VR training can be an effective method for teams because of the immediacy of feedback and the aspect of social presence. Complicating the essence of knowledge transfer, creating a MUE has the added burden of interweaving between an individual and shared understanding (van der Land et al., 2013) Through multiple means of interpretation, there seems to be a distinct difference between individual understanding and shared understanding (van der Land et al., 2013). According to van der Land et al. (2013), a shared understanding must be negotiated based on mutual meaning of patterns and shared perceived differences. The added variety accommodates different learning styles while building collaborative knowledge (Bertram et al., 2015; Schouten et al., 2010). A MUE in a VR training program is more likely to assist learners in reaching a shared understanding and consensus with immersion in a relevant task and also generates feelings of satisfaction and positive experiences about social presence when compared against traditional training (Papachristos et al., 2014; Schouten et al., 2010). A learner's state of alertness, mood and prior experiences will also affect the perceived level of social presence in a VE (Zhao, 2003).

Capitalizing on shared understanding, immersive VR training for teams can be used to problem solve and accept prospective change. In a study by Berg and Vance, (2017), they noted that engineers received greater buy-in from assembly workers when they asked the operators to experience proposed workstation modifications in the VR lab first and then the engineers incorporated a shared perspective into the upgrades. This allowed the transition from the old work environment to the new environment to run more smoothly while also allowing the operators to train in a new setting before it was implemented (Berg & Vance, 2017).

In respect to design, the construction of the VE for a team would be quite different than that for an individual as multiple points of view must be managed (van der Land et al., 2013). Through an influential VE, a trainer can align a learner's buy-in which is a key factor to the overall effectiveness of the team (Cannon-Bowers & Salas, 1998). Additionally, cognitive load (as explained in the next section), must be considered as it could also distract from the necessary communication process at a group level and slow the rate of information sharing in MUE (van der Land et al., 2013).

**Cognitive Load and the Virtual Environment**

Cognitive load is the concept that a learner's cognitive capacity is overwhelmed based on the richness of the VE (van der Land et al., 2013). Cognitive load is determined by three kinds of processing: extraneous, which refers to the cues that support the tasks; intrinsic, which is the understanding of the tasks, and germane, which is the mentally organizing of the elements with the convergence of prior knowledge (van der Land et al., 2013). Holzinger, Kickermeier-Rust, Wasstertheurer, and Hessinger (2009) suggest there is a cognitive load strain produced by the VE process and requires careful handling by the trainer and a great deal of prior knowledge for a learner. Cognitive load seems like a demonstrated flaw in VR training, however, a plausible explanation of why this occurs lies in the process of working memory. Working memory is when short-term memory is used to process information for immediate perceptual outcomes. (Merriam-Webster Online Dictionary, 2018). When working memory becomes overloaded, the outcomes may be reduced to the point of less effective learning (Chen, 2006). Van Meeuwen et al., (2018) suggest that cognitive load can be aptly adjusted by reducing the number of non-nominal situations (emergencies) and increasing guided support from the trainer with the use of full examples or immediate feedback.

Cognitive load can strain learning and slow the process and its influences have an overall negative effect except in the area of spatial visualization. Spatial visualization is defined as the ability to mentally restructure, retain, recall and configure visual stimulus (Chen, 2006). Lindgren (2012) implies the perceived cognitive load may actually help explain how learners who were immersed in a VE demonstrated a higher understanding of spatial relationships compared to that of a control group when given tasks to draw diagrams to scale after the training had concluded. Development of spatial knowledge can be facilitated by the assignment of learning tasks that allow a learner to freely explore the VE while controlling the view from any position and manipulating objects within his/her field of vision (Dalgarno & Lee, 2010).

**How Does Self-Directed Learning Inherent to VR Affect Knowledge Transfer?**

Because self-directed learning is a motivating factor for most adults, VR training is a technology tool that can help a learner stay engaged in the learning activities (Forrest & Peterson, 2006; Wilkins, 2011). In many learning situations, proceeding with a trial and error process can only safely be achieved through a VE and not through live demonstrations or other alternative methods (Di Bello & Missildine, 2011). VR training can be an effective method for teams because of the immediacy of feedback and the aspect of social presence. Most of the research reviewed indicates learners asked to participate in procedural learning through immersive VR training typically outperform control groups who are selected to participate in traditional training.

**Self-directed Learning and the Process of Trial and Error**

Because self-directed learning forces a learner to infer connections between actions and results, this leads a learner to develop strategies for handling unforeseen events while building self-efficacy (Burke, Sarpy, Smith-Crowe, Chan-Serafin, Salvador, & Islam, 2006). Self-directed learning is identified as a potentially motivating factor amongst adults and is paramount to andragogical methods because if a learner feels his/her experience and expectations are being met than he/she typically performs better and retains the knowledge longer (Wilkins, 2011). Furthermore, the reflective nature of action-focused learning is regarded as the key to knowledge acquisition and transfer of training and integrates with andragogical paradigm (Burke et al., 2006; Forrest & Peterson, 2006).

Immersive VR is a technology tool that meshes with self-directed learning in a way that is comfortable for the learner. The VE lends itself well to the representation of knowledge and the learner's expertise while progressing at the learner's own pace (Lucas et al., 2008). This bodes well for instructional designers who align constructivism with their design strategy (Huang et al., 2010). Adding to that constructivist viewpoint, Sacks et al. (2013) argue that learners using immersive VR training are able to assess the situation, choose a course of action, implement the action and observe the results. This exploratory outcome environment is precisely the strategy to accommodate higher-level decision making skills (Di Bello & Missildine, 2011).

Quite possibly the greatest potential benefit from immersive VR training is the interaction with objects within a VE (Dalgarno & Lee, 2010). Lindgren (2012) argues that effective learning is not always about the information in front of the learner but rather allowing the learner the time to discover alternative perspectives in which information can be considered and then finding optimal approaches to solving problems. For example, in an effort to understand potential stressors for bridge design, a construction engineer may virtually apply specific forces to a bridge and observe the reactions to that application, thus improving conceptual knowledge.

While self-controlled, self-paced learning is identified as a favorable strategy in immersive VR training, von Websky, Raptis, Vitz, Rosenthal, Clavien and Hahnloser (2013) outlined an outcome in their study that indicated giving the learner complete autonomy does not always produce the best results. In fact, their research concluded that the group that had full autonomy performed poorly compared to the group that was provided with a structured experience with goals to achieve before advancing (von Websky et al., 2013). Their findings seem to imply that full autonomy led a learner to feel a false sense of self-efficacy, undermining the process of necessary skill acquisition (von Websky et al., 2013). A study by Lindgren (2012) suggests a tight coupling between action and person-oriented perspective is needed for successful learning outcomes.

***The implications for occupational safety.***

While it is nearly impossible to provide training for all variables that may occur during the workday, the need for solid training for high-risk jobs and complex cognitive tasks is apparent (van Meeuwen et al., 2018; Lucas et al., 2008). An important facet of occupational training is safety for avoidance of public peril and the protection of an employee's health and well-being (White et al., 2011). In 2009, the construction industry was responsible for 19% of deaths occurring in the United States which earmarked a shift to a zero-accidents culture leading to an emphasis on knowledge, implementation, and compliance with safety regulations (Wilkins, 2011). Working conditions and safety hazards in a work environment can be the primary focus for many industries due to state and federal regulations. Insufficient training and poor retention of relevant safety knowledge for live-line electrical workers, those in the mining industry, law enforcement and construction fields have been identified as the key factors to higher rates of injury and the leading cause of accidents, some of which are fatal for the worker (Lucas et al. 2008; Park, et al., 2006; Wilkins, 2011). Burke et al. (2006) concluded through their research that the most engaging methods of safety training are more effective at reducing accidents and avoiding other negative outcomes.

In addition to concern for employee safety, construction mistakes are extremely costly to correct. Construction defects occur due to errors, omissions, and misunderstanding in the work process and represent serious problems (Le et al., 2016). In an effort to proactively prevent potential defects from occurring during the construction process, researchers Le et al. (2016) created a working VE prototype to support learners with virtual activities with the aim to improve defect education while enhancing learners' cognitive and spatial skills. There are many sequential steps involved in recognizing and understanding construction processes which can be difficult to deliver through traditional training (Le et al. 2016). There were 26 participants in the study who were asked to learn by doing (Le et al., 2016). First the instructor would introduce the work procedures, common errors and omissions, and safety guidelines (Le et al. 2016). Next, the students who had adequate knowledge were asked to perform tasks within a VE (Le et al., 2016). The instructor was able to provide feedback within the VE with audio and visual cues (Le et al., 2016). Based on post-evaluation data, the learners were able to improve defect identification and achieve knowledge transfer (Le et al., 2016).

The use of VE has an advantage over settings where training under actual conditions is correlated to the potential risks of life and health and where cooperative efforts of multiple operators is required to complete the process (Grabowski & Jankowski, 2015; Li, Gao, Zhang, & Huang, 2012). Park et al. (2006) concluded that overall training time was reduced, and participants were better able to recognize hazardous objects and situations through repeated VR training sessions.

Ergonomic engineers apply the potential of immersive VR to proactively protect the employee. In a VE, engineers can gain an understanding of how the effects of height, strength, and posturing can be used to create an assembly environment that is safe for the worker (Berg & Vance, 2017). Data collected within a VE specifically about physical force and posturing can be a more effective problem-solving tool for design issues than mere observation (Berg & Vance, 2017). Engineers can collaboratively run multiple scenarios for tooling as a means of assessment to ensure that workers have both an efficient and safe environment in which to work and also a means in which to reduce material cost (Berg & Vance, 2017).

***The implications for teams.***

The 2030 megatrends report predictions show a movement towards a lean, diverse, global, and virtual workforce that has the flexibility to work across boundaries (Deloitte Touche Tohmatsu, 2016). Knowledge will become borderless and have no geographic, economic, or political boundaries (Deloitte Touche Tohmatsu, 2016). No longer is it adequate for organizations to wait for the right scenarios to emerge to help their workforce gain expertise; to remain competitive requires training that is immersive, intensive and repetitive (Di Bello &

Missildine, 2011). Thus, the need for team training is a dominant theme for most organizations. A team is defined as two or more individuals who interact interdependently towards a common goal in which no single member can accomplish the task without the other members (Cannon-Bowers & Salas, 1998). An effective team is able to reorganize themselves, provide objective feedback, and adapt to unpredictable situations (Cannon-Bowers & Salas, 1998).

Because most organizational problems rarely have a single correct solution, immersive VR training is a tool that can help turn theories into practice which can lead to greater understanding. Rienties and Townsend (2012) discovered that existing research on expertise development indicated that many new college graduates had theoretical skills but lacked practical understanding and experience in the workplace. They created an action research study to redesign an existing college course, “Brand Management” at Maastricht University using the application of immersive VR training in a MUE.  This was a viable option because it allowed the participants to practice developing and implementing a new product in a virtual world as a group through trial and error. In this study, they selected 40 participants who were broken into groups of three to five individuals and participated in taking a fictional product to market in a MUE setting.. As an instructional design strategy, participants could see the results of their choices immediately which led to more autonomy and self-efficacy. The exams were replaced with tasks inside the MUE and participants were asked to write self-assessments about the learning process and make a presentation about the reasons for their choices as evidence of knowledge transfer. The vast majority of students felt encouraged by learning from their own choices in the self-directed MUE and the instructor indicated the group was more successful than their predecessors. The drawbacks of this action research study were the small participant sample and its relevance to other cases (Rienties & Townsend, 2012).

In another study of turning abstract ideas into practical understanding and experience in the workplace, Gilbert (2017) conducted a quasi-experimental research study consisting of a group of 43 school principals with the goal to increase legal literacy through immersive VR training using role-play scenarios with avatars. Through the process of trial and error, the VR role-play scenarios supported the knowledge transfer of theory into practice in a risk-free VE while improving skills (Gilbert, 2017). Research outcomes by Gilbert (2017), revealed that with a VE, participants were able to learn a lot in a short amount of time. The qualitative analysis of participants' perceptions, in the study revealed that they viewed the experience as an effective means to improve their skills and understanding (Gilbert, 2017). Limitations of this study are the low sample size and the fact that the research was conducted in only one state of the U.S. (Gilbert 2017).

In a qualitative study by Nissim and Weissbleuth (2017), there was a group of 176 students studying to be K-12 teachers selected to participate as a group tasked with constructing a 3-D object in a MUE. The researchers noted that the MUE acted as an emotional amplifier for emotions such as happiness, sadness, awe, curiosity, pride and attachment (Nissim and Weissbleuth, 2017). The aim of the study was to introduce emotional intelligence, awareness and to promote self-efficacy (Nissim and Weissbleuth, 2017). Qualitative analysis of participants' reflections were grouped into themes (Nissim and Weissbleuth, 2017). The researchers noted the success in fulfilling the task at hand was tied to the social presence felt in the MUE (Nissim and Weissbleuth, 2017). One participant had this to say, " I think about the process I went through in the course, both personally and socially. What set me is the working in groups, an experience I had not done before." (Nissim & Weissbleuth, 2017, p. 56). Nissim and Weissblueth concluded that the immersive VR team training process can change perceptions, and make meaningful learning experiences by increasing what is learned virtually which then, in turn, promotes knowledge transfer to real-life.

The unique contribution of each team member brings about skills, observations, and ideas that will only be effective if his/her voice is being heard (Bowers et al., 2012). Selecting the correct team members to tackle specific projects is a delicate balancing act (Croft, 2015). Team training to build positive-based assertiveness can lead to an increase in the willingness to voice concerns and avert potential tragedies (Bowers et al., 2012). This is especially true in healthcare, where questioning a course of action could potentially save a life (Bowers et al., 2012). Lecture-based assertiveness training can influence attitudes but does not enhance performance whereas the unique experience of an immersive VR training program can allow for the practice of the behaviors needed to be effective (Bowers, et al. 2012).

In a study by Di Bello and Missildine (2011), a group of project managers (PMs) were selected to participate in a VR training program using immersive MUE that replicated client engagement with repetitive iterations of IT implementation. The objective was to allow the PMs to break from the traditional view as defining success as being on time and within budget and instead focus on using strategic thinking to incorporate short-term and long-term project performance ideology (Di Bello & Missildine, 2011). There were 25 participants who worked as teams with the end goal of achieving better results for a fictitious client (Di Bello & Missildine, 2011). The training consisted of 2 hours segments of training for eight days which would have been the real-life equivalent of 16 months (Di Bello & Missildine, 2011). The groups were required to run through two iterations (Di Bello & Missildine, 2011). During the first iteration, the learners used trial and error with detailed feedback before selecting a solution (Di Bello & Missildine, 2011). During the second iteration, the learners were given graphical data that displayed their performance against an ideal (Di Bello & Missildine, 2011). They then were required to answer: 1) what went wrong; 2) what would they do differently; and 3) how will they know it is working? (Di Bello & Missildine, 2011). These answers were needed prior to the group proceeding through the exercise again (Di Bello & Missildine, 2011). Through quantitative and qualitative data collection, the researchers concluded that facing collective failure motivated teams to devise plans to rework, redirect and revise adaptive strategies that were ultimately successful on the second iteration (Di Bello & Missildine, 2011). The VR training process provided the experience of consequences of acting on inadequate strategies while working as a team on a complex challenge (Di Bello & Missildine, 2011).

As previously mentioned, situated learning is very powerful instructional design strategy for creating a VE but it is very rarely used in a classroom setting because of the difficulty of arranging complementary, tacit, unstructured but yet real-world setting experiences (Dede, 2009; Huang et al., 2010). Gilbert (2017) argues an instructional strategy that supports this model is individualized coaching that provides scaffolding to support a learner's progress, and meaning making opportunities with a nod towards communities of practice. It is fair to say that immersive VR training has the potential to be the champion of situated learning which can enable the learner to interact with others with similar skills and interests and to work together as problem solving communities (Dede, 2009).

**Virtual Reality for Self-Regulation and Task Mastery**

Much of occupational training is procedural learning which is associated with the skills needed to perform the technical aspects of a job and makes an employee competent (Bowers et al., 2012). While there are different methods to teach procedural learning, a common workplace method is on-the-job-training which is a practical way to give a learner hands-on experience

(Reddy, 2018). Drawbacks to on-the-job-training include loss of work productivity, extended training times and increased work-related accidents (Reddy, 2018). For complex cognitive tasks, the underlying job performance safety concern can be that an employee must act on continuous changes and an omission of task is considered an error with potentially fatal or substantial consequences (van Meeuwen et al., 2018). For occupational training, error rate is generally considered the best way to measure task mastery (Gallagher, Lederman, McGlade, Satava, & Smith, 2004; Langley et al., 2016).

Unlike cognitive load which relies on the individual's cognitive processes, cognitive fit is the way information is presented and how that matches with the tasks to enhance performance (van der Land et al., 2013). Cognitive fit is linked to motivational outcomes where a learner accepts the training and perceives it as being relevant to his/her daily work (Bertam et al., 2015).

One of the best features of immersive VR training is that through structuring of the VE with certain images, viewpoints, and tasks, a learner is forced to identify critical aspects that may have not otherwise been considered which then allows a learner the potential to construct a more complete, resilient and empathic understanding of domain knowledge (Lindgren, 2012). The best instructional strategies for building expertise requires immersion, dynamic-feedback, and actions and consequences (Di Bello & Missildine, 2011). Under these circumstances, learning is transferable to the real-world (Di Bello & Missildine, 2011). Additionally, a learner must be able to unlearn misconceptions and must be able to practice in a trial and error method. (Di Bello & Missildine, 2011).

In a study by Grabowski and Jankowski (2015), the researchers were able to delineate a connection between VR training and long-term effects of knowledge transfer and retention in a follow-up study that concluded three months after the original VR training. Greater recall of events by participants in VR training was also noted in a study by Lindgren (2012); additionally, self-efficacy was also noted as higher for the VR group as well as less hesitation and less asking for help to complete the assigned tasks when compared to the group that was trained with a video from a third-person perspective.

In a study conducted by Ramirez et al. (2018), the control group received conventional lecture-based training and the experimental group received immersive VR training. While both groups performed equally as well on the pretest, the experimental group achieved posttest grades that were 22% higher than that of the control group (Ramirez et al., 2018). The two groups were also asked to perform the set of procedural tasks and the participants in the experimental group were able to outperform the control group when asked to complete the practice (Ramirez et al. 2018).

In the automotive industry, assembly workers are required to assemble multiple models of vehicles which requires memorization of a large number of parts and variations (Langley et al., 2016). When a worker spends time consulting a manual or asking a supervisor, it reduces the efficiency of plant operations (Langley et al., 2016). In a study by Langley et al. (2016), they selected 60 participants to be included in two separate studies; one objective and subjective. The first study selected 30 participants to complete 3 real-world tasks which compared VR training to traditional training (Langley et al., 2016). The performance evaluation was measured with overall errors, trainer-corrected errors, self-corrected errors, and total task completion time (Langley et al., 2016). The outcome of the first study saw no discernable difference between the two groups in task completion time (Langley et al., 2016). However, the VR training group had an error rate that was 50% lower than that of the control group (Langley et al., 2016). The second study was subjective with 30 participants and included a questionnaire for evaluation

(Langley et al., 2013). Trended themes were that the VR group found the training to be enjoyable versus the control group, text feedback during the session was valuable, and the pre-instruction for the use of the VE equipment was inadequate (Langley et al., 2016). The researchers concluded VR training has the ability to provide training with greater retention rates of procedural knowledge and the ability to support domain knowledge in complex competencies (Langley et al., 2016).

In a study by van Meeuwen et al. (2018), an immersive VR training program was developed for 29 air traffic controllers that combined both complex cognitive tasks and procedural learning for a combined total of 50 simulated tasks. What van Meeuwen et al. (2018) were able to determine was that students in an immersive VR training program showed increased self-efficacy when compared to those who were trained traditionally. Furthermore, those students in the immersive VR training program also improved overall performance in domain specific competencies.

In a similar earlier study by Bertam et al. (2015), 23 police officers were divided into three groups, in which one group performed random tasks (control group), another group trained in real-time, and the third group trained in a VE. The immersive VR training group's overall performance in completing the set of complex cognitive tasks was far greater than that of the two other groups (Betram et al., 2015). The situation was repeated three weeks later and the knowledge retention in the immersive VR training group was also higher as well (Betram et al., 2015).

In a study by Abdi, Burdet, Bouri, and Bleuler (2015), 13 participants were selected to learn the concept of controlling a third robotic surgical hand with their foot through immersive VR training. Incrementally difficult tasks were assigned to the group and assessments were based on performance measured by time and efficiency (Abdi et al., 2015). The results of the study found that the participants were able to progress naturally with speed and improved coordination, suggesting knowledge transfer had occurred (Abdi et al., 2015).

In a study conducted by Ramírez et al. (2018), a VE was created to simulate a biotechnology lab for university students. In this study, a total of 66 participants were divided equally between the experimental group and the control group (Ramírez et al., 2018). Altogether, there were 120 separate procedural tasks that the participants were asked to learn and perform (Ramírez et al. 2018). The whole process, if completed as on-the-job-training would typically take two years for a person to learn, but, with the application of immersive VR training, the time frame was condensed to just a few weeks (Ramírez et al., 2018). Quantitative analysis determined the VR training group was able to outperform the control group as determined by error rate (Ramírez et al., 2018). Qualitative analysis of participants' comments found that the experimental group had a positive outlook towards their training experience, while conversely the control group had more negative opinions (Ramírez et al., 2018).

Holzinger et al. (2009) promote the idea that a combination of static instructional material, dynamic simulation, along with the appropriate guidance and feedback prove to outperform an immersive VR training group undertaking a simulation task alone.

Lucas et al. (2008) propose a limitation to immersive VR training is that it should be a supplement to on-the-job training and is not considered a replacement to other types of training. Another consideration presented by Gallagher et al. (2004) is that time to complete a task in and of itself is not an adequate measure of performance.

## How Does VE Feedback Design Affect Knowledge Transfer in VR Training?

In general, feedback is the advice, praise and evaluation that a learner receives. Feedback in a VE can be provided to a learner in multiple formats. There are automated tutors that present the tasks and provide the feedback via text while the task is in progress or has concluded (Ramírez et al., 2018; Westerfield, Mitrovic, & Billinghurst, 2011). There are also trainers who view a learner's experience from a separate room on a monitor and provide either text or verbal feedback throughout the experience as a means of correction, so a learner can know the moment that he/she has ventured down the wrong path. (Meeuwen et al, 2018; Park, et al., 2006).

### Automated Tutor for Feedback

In a study by Ramírez et al., (2018), the experimental group used a VE equipped with an automatic tutor that validated the participant's actions and provided indications of the next step. In alignment with this instructional strategy to provide coaching throughout the process, van Meeuwen et. al (2018) also suggest a key feature to fostering self-efficacy and improving performance and knowledge lies in the ability to provide immediate feedback as a means to give learners more confidence throughout the training process. In a study by Westerfield et al. (2011), the automated intelligent tutor built into the system boosted the post test scores by 25% and task performance by 30% as compared to the control group utilizing the same training without the automated intelligent tutor feature.

### Data Driven Results for Feedback

Depending on the sophistication of the VE, the capturing of psychomotor components can also be used to support tacit knowledge (Wei, Shou, & Nahavandi, 2018). This is especially valuable to both the practicing and the surgeon-in-training who face an ever-changing demand for new skills while being confined by regulations, economic factors, and increased patient throughput (Gallagher et al., 2004). The ability to assess technical performance can be obtained through a VE data driven platform which is a critical aspect of assessing technical performance, most notably of which is instrument manipulation. Gallagher et al. (2004) collected data that revealed the resident surgeons-in-training in the study by were able to meet their goals although the number of attempts in the training sessions varied greatly by participant. Through computer differential analysis of the statistics it was clear which group was the resident surgeons and which was the experienced surgeons who performed the same tasks. The resident surgeons could not outperform the experienced surgeons which suggests the development of an expert perspective may require a long-term curriculum that involves the coupling of activities within a VE as well as traditional approaches and experiences (Gallagher et al., 2004; Lindgren, 2012).

In delving into distinction between novice learners and expert learners, Di Bello and Missildine (2011), indicate the instructional design strategies differ greatly. A novice learner needs scaffold learning with examples and preconceived outcomes and steps with fixed solutions. An expert learner needs complex collaborative opportunities with the potential to explore higher level thinking and goals. To develop expertise requires repeated challenging events, active problem solving and immediate feedback (Di Bello & Missildine, 2011).

In an effort to enhance the interactions within a VE, haptic devices can be installed which can be used to provide force feedback and this often leads to a greater understanding of the relationship between how objects in a VE physically interact (Berg & Vance, 2017). Wei et al. (2018) provide a an example of this in their study that features a firearm shooting training platform combining visual and tactile fidelity with haptic devices. The system used in the study incorporated physical effects of the weapon such as recoil and trigger pull weight which heightens the force felt by a learner and assists with muscle memory training as well as immersion (Wei et al., 2018). The physical force felt is referred to as haptic feedback which generally brings about an increase in the speed and accuracy needed to master skills in procedural learning (Wei et al., 2018).

**Trainer/Collective Feedback**

According to Park et al. (2006) and Lucas, et al. (2008), the acquisition of safety knowledge is crucial to the success and well-being of the workers in high-risk occupations. In their action research study, an immersive VR training program was developed for repetitious training of 24 workers (Park et al., 2006). In this study, the trainer had a monitor that displayed in real-time what the trainee could see in the VE. This allowed the trainer to correct mistakes as they happened and provided ample feedback to redirect the efforts of the participants (Park et al., 2006). The trainer monitored process is also a recurrent theme in the study discussed earlier by van Meeuwen et al. (2018). In Park's and his colleagues' study, they promoted a feedback process as a means to impact cognitive and affective processes because the participants learned tasks and procedures while being influenced by real-time feedback from the trainer. This method eventually led the trainees to acquire "field adaptability" (p. 287) which arguably could not have occurred without the adaptation of self-efficacy and knowledge transfer for task and performance (Park, et al., 2006).

In an example of collective feedback, Berg & Vance (2017) outline how a lead designer immersed in VE can problem solve with his/her team as they look at the experience from another monitor placed in another room but with the ability to provide audio feedback to a learner. The focus of the task in this example is product improvement (Berg & Vance, 2017). This scenario typically used by the automotive industry where one engineer virtually experiences sitting in a prototype of a car and can look under the seat or open the glove box, while the other engineers can observe and provide feedback on how to improve value and aesthetics as the designer progresses through the experience (Berg & Vance, 2017). Among the articles examined in this review, the type and amount of guidance was an active discussion point among most researchers.

**Results of No Feedback**

In a study by von Websky et al. (2013), the researchers compared a group using immersive VR self-controlled training (SC) with a group that was using immersive VR peer-group derived benchmark (PGD) training. The immersive VR program trained 66 participants in laparoscopic cholecystectomy surgery (von Websky, et al., 2013). The focus shifted from task-based repetitions to proficiency-based training and the study found the group using immersive VR self-controlled training (SC) (with self-assessment) on a VE simulator was not as efficient as the group using immersive VR peer-group derived benchmark (PGD) training with external formative assessment (von Websky, et al., 2013). Von Websky and his colleagues argued that the group using immersive VR self-controlled training (SC) proceeded with a false self-efficacy that led to the individuals in this group to move more quickly to carry out procedures that they were ill-prepared for; the data also indicated they were slower and had more errors than the group using immersive VR peer-group derived benchmark (PGD) training.

Conversely, a study by Lindgren (2012) where 48 participants were asked to complete 23 separate tasks, found that seeking help within a VE did not lead to greater understanding of the tasks and the relationships. Instead, transfer of learning did not occur during feedback but rather through a carefully constructed selective perspective process presented through construct of the VE (Lindgren, 2012).

# Conclusions and Recommendations

In closing, an exploration of adopting, promoting, and maintaining an immersive VR training program for instructional designers and trainers is provided. The proposed research questions indicated in the introduction are reviewed and conclusions are drawn based on analysis of the reviewed literature. Although I am not a researcher, I have provided a limited number of recommendations based on perceived gaps in research. I also leave behind some parting thoughts that may be useful and interesting.

## Additional Considerations for Instructional Designers and Trainers

This study demonstrates how understanding knowledge transfer could be further applied to the construct of a VE and a VR training program by instructional designers and trainers. VE technology for workplace training programs can be a substantial investment and stakeholders should be well informed when making a commitment to the procurement process (Huang et al., 2010).

The first challenge is raising the capital needed to secure the equipment necessary to create an effective VE and build the VR training program. Even though the initial price tag attached to establishing a VE is significant, the price of the technology continues to decline as time progresses (Berg & Vance, 2017). After initial setup, there is still additional capital that is needed to operate and maintain such a system (Berg & Vance, 2017). The second challenge is to get the organization to adopt the technology concurrently and at the same pace across all departments. The burden lies in communicating the value of immersive VR training program as it is complex in nature and difficult to comprehend without first-hand experiencing (Berg & Vance, 2017). This can be achieved by nominating an internal champion who will advocate for the value of an immersive VR training program with live demonstrations and presentation of assessments (Berg & Vance, 2017).

Often times, organizations will require trainers to demonstrate a return on investment. One achievable method is to keep a log of VE facility usage (Berg & Vance, 2017). An alternative method is to calculate cost avoidance through documentation that the organization has saved either time or money (Berg & Vance, 2017).

## Conclusions

The VE is not a learning method but rather a technology tool that can be used strategically as part of a training program (Wilkins, 2011; Forrest & Peterson, 2006). The purpose of this study was to determine the role that the VE and the immersive VR training program with knowledge transfer. To further refine the process, I proposed using research questions as the framework for the analysis. The essential questions are summarized below.

*RQ1: How does the VE affect knowledge transfer?*

A VE is a computerized rendered presentation of a world with capabilities to cross the parallels of time, cultures, and spatial constructs which may be either familiar or foreign to a learner (Berg & Vance, 2017; Lindgren, 2012; Nissim & Weissbleuth, 2017). The unique features of a VE include fidelity, presence, immersion, social presence, authenticity and immediacy of control (Dalgarno & Lee, 2010). Fidelity is the extent in which the VE emulates the real world and behavior of the objects for a learner's interaction (Alexander et al., 2005). Presence is the concept of a learner being engaged elsewhere (non-reality) and is interdependent with sensory, distractions, and realism factors (Alexander et al., 2005; Delgarno & Lee, 2010).

Lastly, there is the concept of authenticity which aligns with a learner's expectations and cognitive fit (Bertam et al., 2015; Gilbert, 2016).

The acquisition of knowledge and skills is promoted within a VE because a learner is actively engaging with the information (Alexander et al., 2005; van der Land, 2013). Self-directed learning is also a key trait of a VE which is a potentially motivating factor for adults and is also known for promoting knowledge transfer (Wilkins, 2011; Forrest & Peterson, 2006). A VE can be influential in separating a learner from his/her fixed viewpoints in accordance to fidelity which is key to shifting perspective, improving performance, enhancing learning, and promoting knowledge transfer (Bertram et al., 2015; Lindgren, 2012). Additionally, the VE is attributed to boosting increased spatial knowledge transfer and also decreasing learner fatigue which can lead to extended training periods (Dalgarmo & Lee, 2010).

*RQ2: How does self-directed learning process inherent to VR affect knowledge transfer?*

Immersive VR training programs may successfully produce knowledge transfer and retention by allowing a learner the time to cycle through trial and error so as to arrive at a better understanding of the concepts and to find optimal approaches to solving problems (Lindgren, 2012). A VE is engaging experience and allows a learner to participate in real-world concepts and procedures through interactions that would otherwise be too expensive, too dangerous, or otherwise beyond the reach of the trainee group (Burke et al., 2006). Additionally, many industries offer immersive VR training programs to allow the employees to explore a VE so that they may become more cognizant of safety-related hazards in their work environment as a preemptive measure to reduce accidents (Grabowski & Jankowski, 2015).

Immersive VR training is often used for procedural learning especially when it involves a lot of sequential steps for a learner to recognize and understand and tends to prove problematic to learn through text-based lectures (Ramírez et al., 2018). Immersive VR training has also shown through empirical research, referenced within this study, to reduce the total time needed to learn complex cognitive tasks versus traditional training methods (Ramírez et al., 2018). Immersive VR training is ideal for helping a learner turn abstract ideas into practical understanding (Gilbert, 2017; Rienties & Townsend, 2012). Furthermore, the reflective nature of action-focused learning is regarded as the key to knowledge transfer of training (Forrest & Peterson, 2006; Burke et al., 2006). Some researchers have suggested that immersive VR training is not a stand-alone training method but rather a supplemental tool to be utilized alongside other types of training (Lucas et al., 2008).

*RQ3: How does VE feedback design affect knowledge transfer in VR training?*

Feedback within immersive VR training program can be offered in multiple formats built into a VE. There are automated tutors that present the tasks and provide the feedback via text while the task is in progress or upon conclusion of the training (Ramírez et al., 2018). There are also trainers who can view a learner's experience from a separate room on a monitor and provide either text or verbal feedback throughout the experience as a means of correction, so a learner can know the moment that he/she has ventured down the wrong path (van Meeuwen et al., 2018). There is also the idea of allowing a learner complete autonomy and not to provide feedback during training but rather offer it when the training has ended from system collected data that is organized in report form or playback form (von Websky et al., 2013).

When the affective process of immediate feedback is introduced, a learner is readily able to perform the task faster and more proficiently (van Meeuwen et al., 2018). Immersive VR training can be an effective method for teams because of the immediacy of feedback and the aspect of social presence within a VE (Papachristos et al., 2014; Schouten et al., 2010).

Feedback gained through the immersive VR training program can also aid in producing a workforce that is resilient in the field and more confident in their abilities (Chen, 2006; Podgórski, 2010).

**Recommendations**

There are some fundamental challenges in VR training program research. An inherent challenge is the lack of sharing among organizations because results are often considered proprietary information (Di Bello & Missildine, 2011). Another challenge is there is lack of agreement of the proper metrics to be used for research (Di Bello & Missildine, 2011). Lastly, qualitative studies with specific tasks often do not translate well from one industry to the next (Di Bello & Missildine, 2011).

This review raises a couple of other interesting issues that could be applied to future research. First, in an effort to refine and develop instructional design framework, more research is needed on VE's effect on cognitive load to further deliberate on how this phenomenon potentially degrades learning and knowledge transfer; especially in MUEs.

Second, the interaction effects of VR training could extend to include diverse workforce differences. Some examples might include types of personalities, disabilities, gender, age, computer literacy, and field dependency. This would further explore how the features of a VE either aid or inhibit learning and knowledge transfer.

Third, more research is needed to establish industry guidelines on how the effectiveness of VR training is to be measured. Specifically, what multiple measures should be used? Why should they be used? Currently, there is not an agreed upon system which promotes lack of confidence amongst organizations to fully invest in VR training programs (Langley et al., 2016).

**Final Thoughts**

While the future workforce is expected to remain diverse, it is possible that the challenge to get the organization to adopt the technology may start to lessen. As younger employees exposed to VR gaming continue to enter the workforce, a shift in perspective may occur as it could seem like a natural fit for them to use a familiar technology in their work environment for training and team collaboration. It also seems logical that there may be further job expansion in this field to create and maintain these systems, to collect and analyze data, and to develop more complex VR systems as technology continues to evolve.

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