Organizational Transformation utilizing Learning Science as an instrument via Virtual Reality Instructional Design

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Abstract

This is an action research study on how learning science elements were injected into a digital agency's product development process. The cooperation and collaboration occurred through the interaction and production of a virtual reality case study with projected outcomes for the organization to utilize learning science tools and concepts. Over the course of five and a half months, I interacted with various levels of developers, graphic designers, executive management, and consultants to answer the question of what learning science concepts if applied to an educational virtual reality application would help the firm transform into a learning organization where their products and services would benefit from such a transformation. This cooperative discovery project provided a vehicle that delineated several recommendations adapted from the works in organizational management and instructional design.

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Acknowledgments

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To the professors at Peabody college Vanderbilt, their dedication and commitment to excellence and far-reaching knowledge gave me the ability to tackle the hard work of understanding what I needed to learn about my positionality, the broad realm of learning science knowledge, and the importance of educational communities.

Dedication

I dedicate this research to my partner and spouse, their support and belief in myself and my work has been there to provide a never-ending light at a very long tunnel of enlightenment, humility, and education during a most dark and chaotic global pandemic.

SECTION ONE (Introduction, Significance, Research Question)

Introduction

This is an action-based research study (Adelman, 1993) where I collaborated with a firm to achieve a set of outcomes through cooperative participation. This examination of the organization was conducted with the chief objective of utilizing a shared research vehicle, a case study displaying the firm's virtual reality software and application capabilities. Thus, the firm's initial request was to create a case study displaying their prowess in a technical training and educational virtual reality application. The firm would use the case study either published in an academic journal and/or via various marketing channels to promote their expertise in the virtual reality training and interactive education market space. As time progressed within the development of the case study the goals and objectives broadened to include organizational transformation at the individual, team, and organizational level.

The following paper is an examination of this collaborative action between an immersive experience company and me. The examination will be positioned around the development process of the firm's case study project and expand to include the firm's attempts to transform and achieve its goals of being a leader in the emerging market space of virtual reality technical training and education.

The Firm

The organization of interest is Digital-3D (pseudonym), a VR/AR digital consulting agency. Digital-3D (D3D) was founded over two decades ago, in the Midwest of the United States. D3D is focused on combining visual design, software development, and user experiences utilizing mobile, experiential, virtual, and augmented reality technologies for business customers. They have a small but dedicated team of less than five dozen employees that help deliver immersive and engaging marketing, promotional, technical training, or recruitment applications or experiences from business conferences to mobile applications development. For the majority of their first 20 years of business, their core services were based around developing immersive or interactive conference or exhibit booths for business-to-business tradeshows.

Covid-19 caused challenges with new pillars within their services portfolio. These changes have been in response to COVID-19's effect on their core industry conference business. With fewer in-person trade shows, the organization was forced to pivot and consider other VR opportunities. One attempted direction was 'VR Sales as a Service' or VRSaaS. Due to a soft roll-out, the company recently let go of the new CEO Bob Smith (pseudonym) and VP of Sales Roger Cooper (pseudonym) who were to develop VRSaaS as an essential offering of the consulting firm. During the last several months the VP of Marketing, Sally Remington (pseudonym), has become the new CEO and is leading a new pillar initiative around college recruitment and talent management using the D3D VR core technologies. This new initiative called D3D Network is focused on connecting rural 2-year and 4-year college students with companies eager after the post-pandemic to fill still vacant positions. This virtual reality based 'Day in the Life' application directed at various enterprises is quickly gaining interest from current and prospective clients.

The company has an impressive list of Fortune 500 accounts and major universities. Currently though, VRSaaS and D3D Network are still in continuous development as business services. Core components and deliverables are being defined as they interact with current and potential customers focused on technical training, sales, and recruitment. Though these services are in their infancy, several customers are using the D3D platform as a sales tool and technical training platform. Their current services do not contain what many learning management platforms have (Ellis, 2009; Cavus, 2015): assessment modules, preloaded learning frameworks, SCORM/xAPI compliance, gamification, course management, user management, skill certification, or any facilitator content creation design tools. These challenges lead us to the problem of practice.

Problem of Practice

As previously noted, the pandemic wiped out the central revenue stream of building interactive exhibit booths at D3D. As can be seen in Figure 3, the decrease in exhibition revenue at the beginning of 2020 dropped like a steep cliff reducing growth by nearly a negative 100%. As seen in Figure 3 Insight Partners accounted for a $11.69 billion dollar drop in B2B trade show revenue for the years between 2019 to 2020. Yet, the market for AR/VR is predicted to grow nearly 10X over the course of the next 5-8 years (see Figure 4). While much of this study will be focused on organizational transformation from the injection of learning science for change, the ability of D3D executives to leverage their emergent VR booth skills into sales, recruitment, and technical virtual reality training cannot be understated.

Surprise & Delight vs Train & Assess

If one were to find a thematic umbrella D3D is confronted with, it is being a company whose aim was to surprise and delight at tradeshows and is transitioning to an organization that must attempt to master the skills of virtual reality development, educational design, technical training, recruitment, and assessment. This is a huge pivot not just in terms of market focus and skill sets, but also in overall organizational behavior. And it is important to note that this is being done during a global pandemic. The resources involved in aligning the new trajectory cannot be minimized.

D3D has had great success in developing interactive conference booths, yet this is vastly different than educational VR software. Because of their expert focus on surprise and delight, they have developed a strong set of skills and technical expertise. In particular, they have created mobile applications and floor to ceiling interactive touchscreens. This ability to work across mediums and modalities creates a tension between successful interactivity knowledge and engrained past models of client needs and objectives with that of their new focus around learning and educational design and outcomes.

Research Environment

As noted, the object of the study is the firm Digital-3D or D3D (a pseudonym), a virtual reality educational development agency in transition. The space the firm has been positioning itself is dynamic. Technologies such as AR or augmented reality, the ability to layer in place virtual objects in the real-world using glasses, or VR (virtual reality), with the use of a head mounted screen and the ability to immerse the participant in a completely virtual environment, have many companies today providing commercial tools for both developers and consumers. Facebook's Meta, Microsoft, Lenovo, HTC, Snap Inc. (SnapChat) and Magic Leap all sell commercial virtual or augmented head gear to consumers (See Figure 1).

The market according to IDC analysts for AR/VR market is growing from just over $12.0 billion this year to a projected $72.8 billion in 2024 ("AR & VR Headsets Market Share," 2022), while this includes gaming, this research shows that business commercial development in AR/VR has been calculated at over 90% compound annual growth rate in next five years. Insight Partners predict that by 2028 B2B AR/VR will be a $252 billion market. Yet despite this growth, in a Perkins Coie XR survey, they found that AR/VR industry stakeholders saw the two greatest barriers to mass adoption was user experience and content offerings (Ho et al., 2021). In the same report, 54% of industry stakeholders believe that developers don't understand what makes for compelling content from the consumer standpoint.

This same report found that nearly 60% of respondents said investment in further research is needed to efficiently integrate AR/VR into education (Ho et al., 2021). Therefore, it would be beneficial to investigate how to help an organization transition to a position of increasing learning performance in the instructional design of VR/AR applications. Despite the dynamics of the market, there is a window of opportunity for agile and future focused companies to gain market share in this accelerated market space. Yet many variables remain undefined especially in the VR educational space that may affect D3D.

Education Science Challenge

A recent study found that immersive virtual reality training increased cognitive load and decreased knowledge transfer compared to PC-based training, yet it only did so when inserting text and narration (Makransky et al., 2019). Yet in an early landmark double-blind study, traditionally trained resident surgeons made more than six times as many errors compared to the virtual reality trained group of residents who also completed procedures in a third of the time (Seymour et al., 2002). With conflicting results across many studies on virtual reality or augmented reality training (Radianti et al., 2020; Abich et al., 2021; Howard et al., 2021), it becomes necessary to consider the literature as a whole in order to develop a set of pedagogical insights for D3D to use as they develop a virtual reality learning environment.

As AR/VR training is in its infancy, the frameworks, standards, and guiding principles are embryonic at best (Beetham & Sharpe, 2007, Abidi et al., 2019). There is not yet a clear set of principles from learning science (e.g., Gagne's nine events of instruction or Bloom's revised digital taxonomy) that has been revised to include augmented or virtual simulations. Considering the explosion of augmented, 3D mobile, and virtual technologies to create and scale simulations, the work to aid in filling the gap between immersive virtual learning or serious games (Wouters et al., 2013; Ma et al., 2011; Lamb et al.,2018) with instructional design of AR/VR learning could benefit many in this emerging field.

To compound this existing gap in the literature, there is little research connecting AR/VR software development with organizational transformation. While there is ample work around organizational change (Argote & Miron-Spektor, 2011; Holman et al.; 2007 Cyert et al., 1959) via cooperative inquires (Bradbury & Reason, 2008; Bergold & Thomas 2012; Chevalier & Buckles, 2019) and collaboration in action research (Ospina et al., 2008, Heron & Reason, 1997; McTaggart, 1994), there is no framework for instructional design in virtual world development with participatory research emerging from this field. This leads us to focus on specific questions with the firm Digital-3D.

Research Question & Rationale

In this transition from surprise and delight to educate and assess, a set of questions arose. In this examination, I investigated the firm's VR development process of building and delivering a virtual reality application for technical training and job enablement practices. This process or shift presented a friction that was at the core of this action research project. The key research question therefore was *Can learning science be applied to transform an organization via its core products and or services* (VR training applications)?

To support that key question, I examined the science of learning and organizational transformation literature and consequently developed three supporting research questions. First, *What are the learning science elements involved in such a transformation*? Second, *What dynamics in the process would facilitate the continuous change or improvement*? And finally, *What evidence would exist to support that the transformation has occurred*? As these are a broad set of questions, there needs to be some specificity applied.

First, what are the learning science elements involved in an educational VR application that in turn might affect the organization that builds them? There are many learning science concepts that could be applicable to VR technology. These include theories on seductive design (Lehman et al., 2007; Rey, 2012; Mayer et al., 2008), desirable difficulties (Bjork & Bjork, 2020; Rovers et al., 2018), survival processing advantages (Nairne et al., 2012; Hou & Liu, 2019; Leding, 2018), and disfluency (Pieger et al., 2016; Rohrer et al., 2014; Taylor et al., 2020), among others. When looking at virtual reality these elements must be translated into a 3D temporal space with a clarity that untrained software developers not familiar in learning science can comprehend these elements. Even with a few selected learning science elements, the questions of how these theories will be applied is where the second question leads us to.

Secondly, what dynamics in the process of using learning science would facilitate the continuous change or improvement of the organization or their products? Here the researcher must cross over into a participatory role to collaborate and cooperate with the organization. The organization is one that is without learning science expertise and yet is developing educational virtual reality applications. Therefore, this question required that I get involved as deeply as possible to see the evaluation of learning science concepts in the development of their core products and services.

And finally, what evidence would exist to support the product and organizational transformation by the injection of learning science? With in-depth participation and interaction, some modicum of objectivity must produce evidence that supports the research question and remains impartial with an eye on my positionality (Bhattacharya, 2017). Using various action research methods, including PDSA cycles (Lewis, 2015; Speroff & Connor, 2004) and cooperative inquiry (Heron & Reason, 1997; Bilgin, 2009,) while triangulating (McKenney & Reeves, 2012 Ravitch & Carl, 2021,) and perspective taking (Booth et al., 2016) required extensive research and care.

It is my hope that the learnings from this study's contextual problems and research questions may inform immersive instructional designers and stakeholders of the D3D firm with a set of pedagogical and organizational best practices in the delivery models of immersive AR/VR learning. If the forecasts of AR/VR technology are accurate, then developing an understanding of how learning science affects the organization that creates training software could be of use as D3D attempts to define the market.

Positionality

I have been careful to not allow my positionality (Ravitch & Carl, 2020; Paris & Winn 2014) as consultant, software developer, and corporate trainer to filter the experiences of the AR/VR developers and stakeholders who have been interviewed. Because of a varied skill set, in education, software consulting, and business development, an attempt to understand the needs of each group has been made. Thus, the research gathered is from multiple perspectives across education, VR training, and VR development to best provide clarity, integrity, and validity to any discussions captured and analyzed.

AR/VR development of adult learning programs is a very new field. I have been careful to best apply existing standard procedures in how to increase acquisition, retention, retrieval, and transfer when using augmented or virtual reality learning environments through a systematic instructional design process. Regarding the AR/VR learning applications being designed as a kind of educational training, the position of both researcher and educational collaborator was balanced with a triangulation of broad action research paradigms with cooperative input to collect the authentic voices of the instructional designers and the other stakeholders of the organization.

SECTION TWO Literature Review & Frameworks

Introduction

The challenges in doing this kind of participatory research came from the various knowledge gaps that existed. While there was a plethora of academic researchers working with VR simulations, there were three gaps that I confronted in real-world VR training. First, in the emerging field of virtual reality educational applications, there were few connections between actual learning design theories and their application to virtual reality training experiences. To compound the expanse between learning design science and virtual reality training, the organization's understanding of any learning science theories was nascent at best. Secondly, as will be uncovered in the findings, the firm did not have a background in or experts onboard that were trained in educational design to communicate or translate learning science into VR training components. And finally, despite the rich history of business transformation literature, the use of a virtual reality software application as a transformational agent at various levels of the firm was not well established in the embryonic field of virtual reality business use cases.

Consequently, the literature review required extensive work in several directions to address these gaps. The first area of research to explore was learning science as applied to VR applications. Second, in working with the firm, I needed to develop an understanding of how the participation and collaboration might facilitate organizational transformation. And thirdly, the participatory action research involved the development of a modified real-world software application using virtual reality technologies. This application would serve as a case study vehicle for exploring how learning science could impact organizational transformation. However, because this research vehicle involved application development, an in-depth look at software and application development methods needed to be explored and scrutinized.

Learning Science Design for VR

In studying how instructional designers build and develop VR/AR learning modules, I took a multi-stage approach (Battacharya, 2017; Booth et al., 2016). The research on instructional design is rich with theories as is the work on interactive software design and organizational transformation. Therefore, I broke this first stage into two types of sources: tertiary and secondary.

The first step was to look directly at tertiary (Gueudet, 2008; Booth et al. 2016) books and direct studies that would answer the research question. In looking at conceptual frames, the work of Benjamin Bloom's learning outcome taxonomy was critical. Bloom identified several different outcome domains that can be seen in Figure 2 (Bloom et al.,1956). Bloom's work has been updated several times and many versions of the initial committees on pedagogical performance build on his original work. In particular, Nilson's Teaching at its Best (Nilson & Goodson, 2021), Merriam and Baumgartner's Learning in Adulthood (Merriam & Baumgartner, 2020), and Wentzel's Teaching Complex Ideas (Wentzel, 2019) re-enforced the learning outcome domains of cognitive, affective, and psychomotor (O'Neill & Murphy, 2010). Each of these three concepts have an associated 5-6 levels of mastery.

The typical levels of learning mastery are described for real-world, in-person classrooms for pedagogic instruction. There are important differences, however, when applying educational design inside a virtual reality learning environment. Therefore, the next stage of literature research further explored the three domains of Bloom's taxonomy (psychomotor, affective and cognitive) to better understand how these apply to learning in virtual reality.

For example, the psycho-motor domain moves from imitation to the final stage of naturalization, which does not have direct applicability in the virtual world. In looking at the supporting descriptions of these levels of mastery there are no connections to fidelity or deliberate practice (Ericsson & Pool, 2017). Further, it is unclear how fidelity of psychomotor practice would be applied when the transfer of say tying a suture knot, is typically a self-contained automatic VR animation that is triggered by a button push rather than the actual learning of finger dexterity of inserting micro-threads through needles and skin.

There was limited research examining the levels of mastery for the affective domain as they would apply to a virtual experience. As one example, there was no connection to concepts such as the "Uncanny Valley" (Jung & Dieck, 2018), which shows that levels of realism have various effects on engagement and emotional response in an immersive experience. If a VR persona appears too real then research shows some may perceive the VR persona as a threat (Stein & Ohler, 2017). These virtual realism concepts are missing in even the updated digital cognitive and affective taxonomies (Krathwohl, 2002).

Bloom's cognitive taxonomy is used throughout many state standards and curriculum goals, and many schools are also beginning to use VR as a teaching tool (Cureton, 2021; "Teachers, parents to back immersive"). But Bloom's updated digital taxonomy does not refer to virtual reality. In Churches' (2010) digital update to Bloom's taxonomy, the lower levels begin with remembering through to understanding, applying, analyzing, evaluating, and creating respectfully. See Andrew Churches Bloom's digital verbs Figure 16. Yet based on my analysis of over a hundred medical VR journal articles, not a single work of VR in any journal discussing medical VR or surgical VR use a learning feature of 'creating' or 'applying' new or original content as a metric to student mastery. Students in medical VR cannot create patient symptoms or novel tumors or disease therapies to test themselves. All training is pre-programmed in advance. And while there are some articles on the use of Minecraft (a VR children's game;

Sajben et al., 2020; Foerster, 2017), no adult training allows for students to create their own arthroscopic surgery room, their own emergency scenarios, or their own mass causality incidents to name just a few of the studied learning spaces.

In the updated digital taxonomy, there was a movement from nouns to verbs, and with verbs associated activities around those verbs (Church, 2008). For example, in the digital taxonomy, activities for 'creating' included animating, mixing, podcasting, and video blogging to name a few. At the evaluation level, activities included vlogging, commenting, networking, and moderating. Needless to say, none of these activities are supported in any of the dozen VR training platforms that were reviewed. Therefore, the gap in the taxonomy for virtual or mixed reality training does not align with the current taxonomies or activities in digital learning.

At the secondary sources level, I focused on the design elements in VR/AR development that might aid in performance gains for adult learners. Thus, I reviewed the seminal work of Knowles' differentiation of andragogy and pedagogy (LINCS, 2022), and restricted my review of the literature to adult learning. In this phase, I uncovered clusters of research around military simulations and medical device simulations (Salas & Cannon-Bowers, 2001; Graafland et al., 2012; Alexander et al.,2005; Lohre et al.; 2020; Palter & Grantcharov, 2014). Among these was Reiser's (2001) review of the history of instructional design, which points to procedures traced back to World War II and the development of simulations for adult learners. A large amount of work has been studied around "Serious Games" (Abt, 1969), which is the application of game mechanics to adult learning. These studies of simulations from the early 1970's provided a bridge to the more modern application of VR simulation training.

Another set of instructional design frameworks clustered around two predominate instructional approaches: the *direct instruction* approach (Engelmann & Carnine, 2016) which is sometimes termed traditional or objectivist and the more recent *constructivist* approaches (Lave & Wenger, 2020) of social student-focused learning. Constructivists see education as learner initiated, student self-directed, and learning through social scaffolding of community norms and values (Hung et al., 2005). The objectivist approach was teacher-initiated, with instructor-defined communication and elaboration that builds in pre-defined structured communication based on specific standards and learning goals (Engelmann et al.,1988).

Interestingly, both approaches appear to be represented in some of the works around AR and VR training. In fact, as will be discussed later, entire VR platforms and their learning delivery models showed evidence of these two philosophical perspectives. Additionally, some papers touch on direct development assessment approaches including a Kirkpatrick's evaluation model (Mast et al., 2018) and applying Dick and Carey methods (Dick et al., 2005; Nilson & Goodson, 2021) to non-VR yet immersive educational programming. In trying to understand how assessment worked with cognitive abilities, I began to look at how clear the research was on cognitive abilities. This led to further research around encoding, memory, and consolidation around cognitive models.

The cognitive and neurobiological underpinnings of learning are beyond the scope of this work, so the following review is limited to the cognitive underpinnings of multi-modal learning presentations (Moreno & Mayer, 2007). This final phase focused on how the learner encodes auditory and visually complex information. This includes concepts such as dual coding theory (Clark & Paivio, 1991), in which the combination of auditory and visual information promotes enhanced learning, as well as cognitive load (Nilson & Goodson, 2021), which refers to the amount of processing required for a given task, and the von Restorff effect (Hunt, 1995), in which individuals attend to material that differs from other similar material.

These theories had direct relevance to the D3D team. For example, if a VR jet engine training module used both verbal information and imagery to represent information about repairing a jet engine, this might require an understanding of dual coding theory. If in the repair training, so much information was provided that the learner's working memory could not process it all, this could be an issue of cognitive load. If information was presented in a VR training module with various objects that fit the environment, but one object seems out of place, that out of place object might be remembered better than the other objects, and this might be considered a von Restorff effect. Consequently, the application to VR training can be complicated. It is important to understand when different multi-media modalities interfere with learning or too many mental tasks overload (Toy et al., 2020). Similarly, some VR studies have argued that the novelty of the modality may provide an initial learning boost that may fade over time (Merchant et al., 2014; Makransky et al., 2019).

Dynamics of Application Development

The journey of working with the firms' software development team took many twists and turns. In the course of nearly six months, I was directed to help modify four different applications to be part of an academically rigorous case study. First was a series of sales enablement VR applications. These VR sales applications were based around work for a client that provided various kinds of warehouse automation solutions. Then due to a change in the firms' management, I was pointed to technical training of turbo-jet engines. Then as the organization began to focus on community college enterprise recruitment, work was conducted to observe how they began to model immersive recruitment. And finally, a client who was made aware of the case study volunteered their high-voltage personal protective equipment (PPE) training application to be modified. These disparate applications required what Evans calls

Domain Driven Design (Evans & Evans, 2004). The key to this approach is to identify domain experts, develop a common language, and define the boundaries for the logic of the application. This led to further research in interactive design terms and approaches.

In the review of immersive or interactive software design research, there was an interesting overlap of methodologies and language. The term 'agile' is used in both software development as well as instructional design. There are various instructional design models that include ADDIE (Analyze, Design, Development, Implementation, Evaluation; Molenda, 2003), SAM or Successive Approximation Model (Allen & Sites, 2012) and Backward Design (Wiggins & McTighe, 2008). Kennesaw State University's design learning center described SAM as being an agile methodology, in that the developers incrementally develop a minimal viable product in repetitive cycles, similar to agile software developers.

Yet VR and AR learning platforms are dependent on new hardware such as emerging augmented reality glasses and head-mounted displays, whereas agile methods are typically used to develop software on existing stable platforms such as in a personal computer or a smart phone. The alternative to agile methods is waterfall. And waterfall (though slightly out of favor) is used primarily for hardware-dependent software designs with requirements that are well known (Alshamrani et al., 2015). A waterfall design is not incremental, it is heavily requirement-based and does not proffer minimal viable products or rapid prototyping (Saadatmand, 2017). This may to some appear to be a method for building software-based courses with extensive requirements.

Many government agencies such as the military still use the waterfall method because it has a long requirement and testing phase prior to building anything useable (Patanakul & McCarron, 2018). This is needed when hardware requirements exist for a future non-existent platform, say a battleship navigation software system where the battleship is not built yet, but the blueprints are very precise. If your hardware platform has little to no changes, then waterfall development can be extremely effective. But if the hardware deployment is unknown, then the prototyping and feedback phases of the agile method are beneficial as the contingencies are uncovered or evolve (Selzer et al., 2019). Virtual reality is by its nature hardware dependent. Yet unlike personal computers which have two dominant platforms (Windows and Apple or on the smartphone Android and Apple), virtual reality has many various platforms and the war for a dominant platform is on-going and affects which methods to use to develop the virtual reality software.

This battle between methods was not new to anyone in technology development and research was done around software development life cycles (SDLC). As such some have sought a middle ground known as spiral methods (Alshamrani et al., 2015; Boehm et al., 2005). Spiral methods attempt to mitigate the risk (Hijazi et al., 2012) in the SDLC of waterfall with unstable or changing platforms. They do this by approaching the development of the prototype in stages with risk gates at each stage. This is beneficial when it supports parallel spirals of component development (Hijazi et al., 2012) as opposed to the serial method of waterfall SDLC. Yet often the method choice is informed by the developmental external factors.

If you have a stable platform such as a smartphone then the agile method may be preferred, if you have an unknown platform, but stable requirements, the waterfall method may be preferred. But what if you have an unknown platform but fairly stable requirements as in many virtual reality training applications?

This is where VR instructional design appears to have some space for clarity. In a review of various VR training articles and journals (See Figure 5), there is no consolidation or peak on the content for delivering VR learning applications. In many cases, the experiments in VR training had unique hardware systems (Li et al., 2012) and in others the learning platform was only available for one type of VR headset (Palmas & Klinker, 2020). In comparing the hardware and software space created by fluid standards, the question of task performance to technology fit arose.

The collaboration drove much of the research around the how the application would drive success for the organization. DeLone and McLean's (2003) *Model of Information Systems Success* defines how information systems drive organizational success and requires an understanding that information, system, and service quality inputs affect the utility and net benefits of the application and their users. This was contrasted with technology task-fit by for individual performance (Goodhue & Thompson, 1995; McGill & Klobas, 2009). Task-fit looks at technology characteristics and task characteristics to measure utilization. While both models are complementary, this friction of task fit of individual usage with organizational outcomes drove me to look deeply into organizational transformation studies.

Elements of Organizational Transformation

The sources around organizational behavior and management were key to understanding how to categorize and sort specific behaviors the organization was attempting to master. In particular, I needed an understanding of how to differentiate individual learning versus organizational learning (McShane & Glinow, 2010; Argyris, 2000; Senge, 2006). This was critical in order to tease out specific behaviors where there were numerous overlapping theories of organizational dysfunction (Senge, 2006). When looking at organizational change, the literature provided three core lenses: decision making (Marchau et al., 2019), knowledge management (North & Kumta, 2018), and human capital (Kates & Galbraith, 2007).

Given the scope of this project, it was also critical to understand mechanisms in transformation especially in terms of the research questions on dynamics and evidence. This project lends itself best to Action Research, a family of practices that link participatory communities with an orientation of inquiry into a methodology of engagement (Reason & Torbert, 2001). Action Research can be broken down into three objective approaches: participatory action research (Chevalier & Buckles, 2019), cooperative inquiry (Ravitch & Carl, 2021) and continuous improvement (Bryk et al., 2015; Langley et al., 2009). Beyond just theory these provided frameworks take a project about learning science in software applications and potentially create some type of organizational transformation.

However, the measures of the organization's transformation were still not formally or well defined (Ulrich et al.,1993) suggest that a learning organization's importance is in workforce competence, capacity for change, and competitiveness. In terms of organizational management and behavior, Marsick and Watkins (2001) point out in their seminal work that learning is sometimes identified through measurable changes in behavior or it may represent a change in an internal viewpoint that is difficult to quantify. While Marsick & Watkins (2018) developed the Dimensions of Learning Organization Questionnaire, the work in action research that I was entering was a collaborative area between what Carnevale (1990) would suggest is their 87% incidental and 17% formal training space through deliberate interactions. Thus, a search for modeling impact began.

In investigating, there were many topics around successful organizational learning behaviors (Cerasoli et al., 2018). These included psychological safety required for teams to learn (Edmondson, 1999; Detert & Edmondson, 2011), the knowing-doing problem of improving performance by implementing what is already learned (Pfeffer & Sutton, 2000), and Triple-loop learning (Flood & Romm, 2018), a deepness of learning about issues and dilemmas faced and ways that organizations manage them. From the research on organizational learning, three paradigms seemed to particularly important for D3D: the ability to learn new skills, letting go of old tribal ways, and developing better performing habits for a dynamic workplace.

Absorptive capacity (Griffith & Redding, 2003; Easterby-Smith et al., 2008; Camisón & Forés, 2010) refers to the firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends. With multiple touch points from customers via online, face-to-face, and virtual worlds it is unclear whether D3D has learned behaviors, practices, and systems in place to identify valuable knowledge, process it, and then utilize it quickly to attain desired results. The organization has had over 20 years of success in creating interactive experiences. A firm also needs the ability to unlearn (Klammer & Gueldenberg, 2018; Becker, 2005; Akgün et al., 2007) or to discard non-performative or useless tacit knowledge (Fenoglio et al., 2022) that while gained by chance does not accentuate or accelerate the firm's overall ability to reach its long-term goals. Without an unlearning process of identifying un-productive habits and beliefs the firm may not be able to execute with the agility and flexibility needed to succeed in a volatile market.

And finally, the individuals in the organization should have some guidance about how to perform in a turbulent and dynamic market. The shaping of human capital—the knowledge, the skills, and the abilities that employees possess—is an important source of competitive advantage and essential to High Performing Work Processes (Combs et al., 2006; Boxall & Macky, 2009; Messersmith et al., 2011). The essential key is to incorporate behavior and practices that capture their knowledge in working out solutions for clients and partners so that the knowledge can help the organization to scale and accelerate the attainment of its objectives.

Summary

To summarize, three areas of the literature were thoroughly reviewed for this project. Because D3D is pivoting to educational training, I first reviewed critical learning science concepts that could be applied to virtual reality. In this space, I found that this is an emerging field and much of my review was theoretical. This project involves collaboration to develop an updated software application and I therefore reviewed research into methods for software development. Finally, while the goal of the project was to infuse learning science into a software application, the process and collaboration had the possibility of leading to organizational transformation and a review of that literature provided clear concepts and frameworks for consideration.

SECTION THREE – Methodology

Conceptual Framework

In looking at VR instructional design dynamics for a VR digital agency, a conceptual framework was developed (See Figure 6). The framework briefly identifies the theoretical frameworks, tacit theories, methodological approaches, and positionality around the research questions and goals. These relate to and help shape the overall research methodology of data collection, analysis, and synthesis. While this provided a preliminary approach to this complex project, the data collection had two approaches, a direct concept approach and an action data approach.

Direct Concept Collection model

The proposed research has leveraged a method of triangulation (Ravitch & Carl, 2021) or a distinct direct data collection method via qualitative semi-structured interviews (McIntosh & Morse, 2015). The literature review aided in framing the direct questioning context for interviews with subject matter experts inside the partner organization and when available outside experts in VR development firms. The focus here in the direct collection model was on how stakeholders in D3D achieve learning goals for adult learners using learning science to improve outcomes at both the product and organizational level.

Interview Protocols

In working with a partner organization that is a small digital agency, it became apparent that the stakeholders needed a broader spectrum of experience beyond their internal team to understand the standards, objectives, and the state of the art of VR/AR training development around technical training. Therefore, I designed a two-stage process of observing and interviewing the employees and consultants of D3D and interviewing 3rd party developers of educational VR training software. Thus, I split the interview protocol into insiders of the digital agency's VR/AR development team and outsiders who work in the industry of educational or technical VR training applications.

In developing the protocol for team members inside the VR agency, I proceeded with a purposive, semi-structured set of descriptive questions (Kallio et al., 2016; Ravitch & Carl, 2021). As the small inside team was often both resource-constrained and behind schedule in development, the questions focused less on the technical accomplishments and techniques and more on the affective experience of the process. Questions included:

1. *How are you memorializing new understandings of development?*
2. *Can you share your thoughts on how your work has evolved over time?*
3. *Tell me about the time you realized any specific challenge in doing your job well?*

As for the subject matter experts in the industry of VR training application development, I used a snowball approach (Bhattacharya, 2017; Babbie, 2019) with open-ended and informal questions that contrast broad grand tour like queries such as 'What's your typical day' or 'How do you interact with key stakeholders'. The subject matter experts were from a broad array of backgrounds, so the questions attempted to extract the fidelity of their unique experiences.

Questions included:

1. *Walk me through the specification gathering of an initial VR/AR application*
2. *How are learning objectives typically captured prior to coding?*
3. *What are the ways your customers level-set what the technology can do versus what they need?*

Participant Selection Criteria

Throughout the study, I identified three types of participants for the subject matter experts' interviews. The first type were those who work at Digital-3D. These roles included a co-founder, the CEO/CRO, Director of Business Development, two VR programmers, Director of VR Development, a Product Manager, and a Graphic artist. As the team is very small, I also included a 3rd party consultant that is working with D3D. These interviews were limited to the core issues of development and integration of learning objectives.

In addition to individuals within the organization, I also spoke with individuals with content knowledge in order to clearly understand the key concepts associated with the project and most effectively collaborate with D3D. Therefore, the second type of participants were academics that have created and published reports of either technical simulations or other VR educational software. I spoke informally to three medical professors that have published papers on the development and testing of virtual reality training applications. While it would be beneficial to examine not just their software, but to speak to their teams or programmers to see how they integrated knowledge from subject matter experts with their instructional designers and developers, the snowball approach did not garner access to these busy teams.

The third type of participants were professionals in the field that are already developing and delivering VR training to paying customers. These informal conversations occurred at events where I did not have the ability to capture and transcribe. Yet, I have informally spoken to both founders, CEOs, and trainers at these various organizations. These conversations were beneficial to further identify the perspectives on the industry and its challenges despite not having formal notes.

Site observations were virtual or via zoom call as most if not all of the instructional designers work remotely around the world. Additionally, due to the pandemic of COVID-19, it was considered unwise to secure a space to congregate.

Action Data Collection Model

This examination was non-traditional in that it followed a set of participants through a journey of learning and transformation. This represents action research, which has been defined as:

> *... a participatory process concerned with developing practical knowing in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities (Bradbury & Reason, 2008)*

The Action Research collection model used here was a three-phase process (See Figure 7). The first phase was the utilization of Participatory Action Research (Adelman, 1993) that uses a backward design methodology (Wiggins & McTighe, 2008) as a catalyst to engage the D3D development team (see Figure 7a). In the second stage, I helped develop and test basic improvement science concepts through the use of Plan-Do-Study-Act (PDSA) cycles (Vordenberg et al., 2018; Langley et al., 2009) around the results from the PAR interaction of VR software development (see Figure 7b). And in the third phase, the results were communicated (see Figure 7c) to create organizational transformation via Cooperative Inquiry (Bradbury & Reason, 2008). As can be observed in Figure 7 these three phases are interlocked and connected.

Participatory Action and Backward Design

This phase combines backward design into the process of working with a community or team. Backward design starts with defining the desired results or establishing standard outcomes, after which the instructional designer determines the acceptable assessment procedures to capture the outcomes and then develops the content. In this context the need and standards were defined: to implement learning science concepts such as Seductive Details into a VR training application.

Once the standard was defined, the data collection was the process of interacting with the stakeholders and development team responsible for the building and the modification of the VR application. This collection took the form of recorded Zoom calls, note taking, and reflection. Data also included shared files, Google docs, emails, and Slack channel conversation threads.

The process focused on backward design which adhered to an agile software methodology of iterating from the initial standard (i.e., various learning science concepts and variables), then making changes over the discussion of evidence, and then implementing the content within VR. This proceeded into cycles of iterations across several proposed case study projects. While complex and varied in direction and over different mediums, the data collection was rich in context and meaning across the collaboration.

Continuous Improvement Process

The second phase which occurred in parallel with the PAR was that of PDSA cycles to frame the cycles of continuous improvement and interaction. In total there were four different case study projects over the course of five months. The first attempt was to use learning science as a framework with their sales enablement modules using their virtual reality platform. The second attempt was technical training repair of a virtual reality turbo jet engine. The third attempt was their virtual reality recruitment of college students for enterprises. And the fourth was the modification of the PPE (personal protective equipment) training for high voltage scenarios in virtual reality. The Plan, Do, Study and Act (PDSA) cycle forms were captured as bi-monthly initiatives to test to see if the team would use learning science concepts to test adoptions of specific organizational precepts. These precepts were around absorptive capacity, unlearning, and adaptive work processes. Predictions of actions and reflections of those actions were collected and analyzed.

Cooperative Inquiry

The third phase which occurred after the initial few phases of PAR and PDSA cycles was that of cooperative inquiry (See Figure 7d). This is where academics and stakeholders hold the title of co-researchers in that they are both learning how to act to change things (Heron & Reason, 1997). In this third action research initiative there is active discourse around the objectives of the organization. These conversations were primarily held between the co-founder and CEO/CRO during the process of developing the learning science injected training applications.

These conversations differed from the direct approach of data collection utilizing semi-structured interviews protocols. This was in large part due to the interactivity and the level of concerns that often arose around progress, resources, and outcomes for the organization. The discussions on balancing the commitment of staff to an examination in instructional design provided insights to how the leadership viewed the evolution of organizational behaviors. As such much of these interactions were captured in conversational notes, emails, and documents shared during the engagement as well as reflections and input into the PDSA cycle process.

The goal of these various data collection processes was to understand the essential truths in the work of developing a VR training application from various stakeholders in the organization.

Data Analysis

The data analysis had three steps. In the first step, I used keywords and phrases that derived from and supported the research questions. The second step was analyzing linked or cited literature by either seminal papers or by the interviewee's suggestions. The third step was expanding the scope based on coding and insights from the interviews that required greater research context and background to support more cohesive and in-depth coding and analysis.

I used three methods of VR developer transcript analysis. First were transcripts from VR developer meetings that were hand transcribed via Zoom Otter AI. I used a 3-pass method on the transcripts to develop emergent codes, scope, and reduce and refine codes.

Then secondly, there were 1-1 interviews or debriefs with the CEO. These debriefs occurred right before or after meetings with the developer team as well as the outside consultants. These were also transcribed where possible. Here I completed data analysis slightly differently as I engaged in a dialogic spiral as detailed by Paris and Winn (2014). Therefore, as trust was being built and topics took a wider range of subjects, I chunked data in manageable units, clustered the units into categories, and identified where theoretical constructs or patterns existed or were emerging.

Finally, with outside VR developers I used open interviews where requesting and recording a conversation face to face was impractical, and therefore hand notes were primarily used. This was a two step-process. First, I quickly jotted key thoughts and ideas. Then once the person-to-person interview ended, I used a "Brain-dump" (Paul, et al., 2020) of what had just occurred within the conversation. This brain dump was done using computer dictation as stream of consciousness which would allow wider bandwidth of thoughts to emerge from the experience.

Thematic Analysis

Effort was made at taking multiple passes through the data to understand it at a deeper level. This included multiple data readings, data analysis strategies, and creating or scrutinizing themes.

I was mindful in the creation of concepts that emerged from the analysis of the data. First, I read and reviewed the coded data and documented the themes. I then described their meaning and searched to see how the research questions and theories were being addressed. I re-visited the data and recoded where subthemes or codes needed revision. I then explained the relationships of the codes through a story or sense-making narrative. And, finally, I was sure to note or memorialize via memos my evolving understanding (Newcomer et al.,2015).

The Coding Process

Besides note taking, journaling, email correspondence, and Slack threads, I collected all interviews via Zoom Calls when possible. The interviews were initially transcribed by Zoom's use of Otter.ai. As there is some Zoom fatigue at year two of the Pandemic, the questioning was done with an eye to brevity and flexibility. There were a dozen interviews transcribed this way.

My process was to elicit insights into how VR developers or designers approach building software within the technology affordances and constraints of the team (Gaver, 1991; Treem, 2012) and the pandemic. As often is the case, some newer members were silent and some effort was made to be explicit about the advice from the more experienced members of their team (Lave, 1991). On occasion, some D3D members were not at home and were traveling in cars, which added to some of the Zoom transcription errors that were corrected by reviewing the audio as well as reviewing handwritten notes when Zoom was not used.

In processing the transcripts five themes emerged (See Figure 8). Since the questions revolved around past history of success, a theme that incorporated the concept of affordances (Gaver, 1991) based on trade show events or occasions emerged. A second theme arose around Pandemic effects. This was not unexpected due to the fact that each of the participants was well aware of the company's pivot from trade show booths and how VR empowered remote interactions. While affordances of trade shows focused on the event and the activity around the trade show practices, a third theme related but distinct was learning science (Kuhn, 2009; Schunk, 2012). Learning science contextually focused on the characteristics of how and what constitutes a learning science theory and its implementation. Finally, there were two minor themes. The first was emerging market issues or issues of novelty or infancy of VR. Most VR developers are experienced programmers and yet these issues surfaced because the software and hardware are changing and evolving at a rapid pace (Davis & Olliffe, 2022; See Figure 9). The other minor theme was business process management. D3D stakeholders have proven to be very resourceful, using their previous skills in interactive touch, in-booth VR, and video or online tools to engage clients. Yet this nimbleness in the trench foreshadowed questions unanswered on planning and analysis around their many pivots. Each of these themes created a kind of friction between their aspirations to build a community with limited resources and a platform that may not supply the support needed to manage every pivot and new market position.

Validity

Validity refers to the ways that researchers can affirm that their findings are faithful to participants' experiences (Ravitch & Carl, 2021). In working with D3D, there are obstacles to understanding the instructional design elements in VR for adult learners that lead to better learning performance and organizational change. To accomplish this, the research needed multiple sources of data, prolonged participation, dialogic engagement, thick description, and mixed methods including the possibility of a quantitative experiment or case studies via action research.

To reinforce the validity of this study, work was completed to develop thick descriptions and varied methods (Battacharya, 2017). Ravitch and Carl (2021) suggest thick description as research that thoroughly and clearly describes the study's contextual factors, participants, and experiences so as to produce complex interpretations and findings. The research crossed over various aspects, including that of VR training applications, the science of adult learners, and the methods of instructional design. There emerged a richness of research which has provided a broad context that is as deep as it is wide. What keeps the work cohesive and still contextualized is a disciplined focus on the phenomenology (Sokolowski, 2000) of the development and process of developing a single VR technical training application for an experimental case study. While the partner organization is still building the framework of a VR mechanical technical training application platform, third-party developers that have been interviewed have shared access to their VR demonstration software.

SECTION FOUR – The Findings

Introduction

After sifting through the large expanse of instructional design, virtual reality research, technology evaluations, training literature, reviewing over five months of notes from observations of the D3D VR development teams, transcripts from executives, working with consultants, speaking to various outside academics, and evaluating third-party VR developers, I found several sources of tension. These tensions exposed gaps in understanding how to inject learning science into VR instructional design processes and how the organization might transform from those interactions. These tensions will be presented in three domains: discovery of learning science in VR, roles in transition, and developing organizational management at a cutting-edge firm.

Critically, these findings are embedded in the understanding of learning science and learning organizations in the firms and developers that were studied, and in particular at D3D. The language, theories, and conviction or commitment to using learning science and utilizing that knowledge to support the transformation of the organization is challenging for any company.

The following findings and discussion are the result of the iterative participatory action research in the development of learning science theories injected into a VR application. In addition, I was experimenting with an organization in real-time as it metamorphosized due to pressures from a cataclysmic global pandemic.

And within that context, I found a series of dynamic tensions that drove the performance of the firm to deliver services that kept the company afloat, but also provided turmoil and uncertainty in an ever-revolving leadership space. These tensions will be sorted based on the findings though they are very much an interweaved fabric of tight threads and loose strings combined.

These three pillars (discovering learning science, roles in transition, and developing organizational management) are tensions which were overlapping and deeply mixed ideas. Often in at D3D, they were not seen as separate entities or pillars at all. Thus, the challenge in these findings was to untangle the dynamics between learning science in development of VR software, the roles of stakeholders in transition, and the dynamics in the organizational behavior in the creation of that VR software case study.

To provide further details on the three pillars, each pillar has subsections which relate to the literature and are synthesized with the data collected over the course of several months. The findings provide an in-depth look at these issues. In the learning science pillar, there were the conceptual, strategic, and tactical considerations of using learning science to accelerate VR training application performance. In the roles in transition pillar, there were issues of self-leadership and business decisions and how the fluidity of role identity and the business contextual environment shaped outcomes. Within the organizational management pillar, there were high performance work practices and absorptive capacity.

Learning Science Pillar

The learning science pillar is broken down into three distinct constructs: conceptual, strategic, and tactical approaches. These abstract ideas require some context to fuse the workings of an educational VR firm with the theories of learning.

In the first section, I will explain the learning development domain outcomes of Cognitive, Affective, and Psychomotor (Nilson & Goodson, 2010). I will then provide the structural and strategic design of blending actual real-world training across objectivist and constructionist design philosophies with their instructional design implications. And third, I present a coordinated and agreed tactical understanding of the capabilities of the VR software platform, deployment scenarios, and task-fit of the learning medium. These make up three levels of tensions: conceptual, strategic, and tactical which form an integrated stack of VR instructional design gaps and issues between the various stakeholders and the instructional designers of D3D.

Conceptual Construct

There are three learning outcomes in the conceptual domain: cognitive, affective, and psychomotor, which have been refined by numerous learning scientists (e.g., Anderson, 2005; Krathwohl, 2002). In looking at the data there was a lack of development of the outcomes in the training software. In various interactions at D3D, the director of development first looks at software features; the training application is seen as software and not as something where learning science is a critical feature. This can be seen in the below:

> *Yeah, there is a procedure in the D3D DEMO in the arrow area but it's very basic like super basic we did it to showcase the fact of procedure-based learning, not the depth that procedure-based learning could take.* -Director, Interview PDSA cycle 1

What was fascinating from my perspective, was the missing piece of how the software could be harnessed to increase learning performance. Interestingly, across several stakeholders from developers to executives, the suggestion of learning outcomes was not ‘on their radar’, but rather the focus was on conversion of 2D training materials into a 3D immersive experience that would surprise and delight the client.

Cognitive Approaches. In order to improve learning, D3D needs an understanding of the connections and structure of the training material (Bloom et al.,1956). But as we see in the previous quote, the delivery of features is dictated by the software and graphic usability, not the learning outcomes or objectives. Comprehension, application, analysis, and synthesis of learned information lays at the heart of the cognitive domain. If the leadership of educational software lacks that understanding or language, then there is a missed opportunity.

Special to VR is how the information will be built in a three-dimensional space, so that it can be connected to previous knowledge and can help expand the individuals' understanding in the future (Ambrose et al., 2010). Ideally, D3D would attempt to provide all six levels of Bloom's cognitive domain (Bloom et al.,1956): remember knowledge, explain the meaning, understand associations and abstractions of the knowledge, break down into usable parts, make new connections, and evaluate the effectiveness or utility of the knowledge.

VR training and simulations often stop at the first two levels of knowledge attainment and comprehension without application of abstraction, analysis, or synthesis. Without these deeper levels of cognitive processing, VR learning may preclude learners from attaining higher levels of mastery.

In reviewing the four case study projects (warehouse automation, jet engine repair and inspection, college recruitment, high voltage equipment training applications), there were no opportunities to break down content into usable parts, understand associations, or make new connections between procedures or tasked behaviors. Each sequence was pre-programmed and serial with no free-form opportunity to be tested or evaluated without cues. In simple terms, there was a lack of evidence that D3D understood or utilized Bloom's Cognitive model of learning outcomes.

Affective Approaches. In the affective domain, the importance and value of the content is determined by the learners' goals. Instructional design that is aware of emotional engagement is more effective and a gateway to learning (Pierre & Oughton, 2007). If the material has no emotional impact or meaning, the learning tends to be less effective.

In an interview with a D3D graphic designer, the process of working with a client was described as starting with 'red boxing' where the development team throws in every element and builds off a creative brief. A series of trials and errors proceeds until the fidelity of the training meets the clients' expectations. In an interview discussion, there was no process to gauge immersion but rather just client feedback to guide the development team to iteratively capture the visual elements. As opposed to focusing on the client's objective *learning* outcomes, D3D delivers only 3D renderings of the content generated by the graphic and interactive developers. In reviewing conversations and documents by D3D, it appears that only visuals around creative briefs and iterative meetings with the client were used to guide the creation of the clients' work.

Essential to VR is how the experience will balance immersion, engagement, and affective responses. If the curriculum is focused on gamification and interactive agents, the designers may not address why this content is needed and why it is important to the learner.

In comparing VR training to real-world training, typically real-world training utilizes a relatable context with practical consequences, as in military or medical training (Diemer et al., 2015; Dubovi, 2022; Flavián et al., 2021). In ideal learning, the consequences should affect both the learner and their immediate contextual environment (Ahn et al., 2022). The learner should understand how correct action can influence systems and people beyond the immediate situation (Miller, 2005). Therefore, providing emotional context, embedding meaning, and linking those values to important cognitive tasks is essential to mastery.

In a review of all the available D3D training modules, no references to the real-world context of the learner were made. There was no statement of why a task done correctly is important or impactful to the organization. In short, D3D prioritized visual fidelity over affective impact of learning.

Psychomotor Approaches. The psychomotor domain includes the kind of motor-skills needed and the level of skill mastery required to excel at the intended role of the learner (Simpson, 1966). Content that is designed to develop and integrate motor skills tends to be retained longer (Bergland & Ekerholt, 2018). Many if not most skill development can be enhanced with movement to anchor and access knowledge attainment.

In discussions with the co-founder of D3D, it was pointed out that they discovered by chance when asking the client for input in a VR demo, that the client remembered how he had to bend down to see under a virtual jet engine. This vicarious learning (Bandura,1965; Myers, 2015) was not based on pre-conceived embodied learning concepts (Macrine & Fugate, 2022) but by trial and error in replication of manual training into virtual reality.

Virtual reality systems today can capture and track gesture and bodily motion. From hand controllers that have inputs and accelerometers to cameras that can capture motion and gestures, VR systems today can record and assess movement around the headset and hand controllers.

Embodied learning where gesture and movement are congruent with both affective and cognitive learning helps increase retention and retrieval (Johnson-Glenberg, 2018). Therefore, while challenging, research supports that developers should seek out every opportunity to convert 2D learning into active 3D spaces where movement helps support comprehension and meaning.

Therefore, regarding the psychomotor domain, D3D achieved some learning objectives, but this was not intentional. In various meetings, discussions and demonstrations, there were opportunities to consider learning outcomes across the cognitive, affective, and psychomotor approaches. In reviewing the data, D3D was preoccupied by focusing on replication of content from 2D to 3D space rather than retention and transfer of content by utilizing the three domains.

Strategic Construct

Organizational systems should be responsive to various goals and instructional approaches that depend on desired outcomes across environmental, cultural, or contextual needs. They need to be responsive to the clients as well as the internal organization's transformations. That is, they may need to adjust their strategy to accommodate changing needs. In order to be strategic with learning science theories, D3D may find new opportunities in various learning approaches.

Objectivist Approaches. The objectivist approach is teacher-initiated, with instructor-defined communication and elaboration that builds in pre-defined structured communication based on specific standards and learning goals (Chen, 2014). This is essential for skill mastery of pre-defined roles.

In a systematic review of all the D3D designed training modules in VR that were made available to me, there was no attempt to build instructor elaboration or to enable gradual release from teacher-initiated instruction to student enablement (Fisher & Frey, 2008). From turbo jet engines to high voltage transformers, to large industrial vehicles, there were few opportunities to enable the learner to display independent mastery of the material.

Again, in reviewing D3D software modules, the two modes of instruction available were automated procedures with animated triggers moving through steps or open space with a complex object that had hot spots that could trigger video animations. None of the software provided open assessment with the ability to test the learner without serial pre-programmed instructional sequences. These sequences could be repeated, one task at a time, but there were no opportunities to allow the learner to have all tools and objects made available and assess if the learner had retained the correct procedure and task order on their own without following a pre-ordained sequence. In open space mode, the instructor would be free to describe, move or x-ray the object to expose its internal workings. Therefore, in this mode the instructor had freedom to speak or move the object, but the lesson would therefore be solely up to the immersed instructor to show or teach how a task was to be completed.

Vital to VR is that some educational environments require or demand this approach. Two large fields of education (medicine and the military) require that specific behavioral modes and communication protocols be followed precisely for optimal outcomes particularly in simulation training (Nicely & Farra, 2015; Akdere et al., 2021; Tiffany & Hoglund, 2016). VR platforms must then support or be flexible to allow clear, consistent, and reproducible instruction and open assessments. The training or education should allow gradual release (Maynes et al., 2010; Fisher & Frey, 2008), but only from the perspective of assessment of meeting standards and goals. Those assessments should acknowledge and make connections to real world execution so that trainees still have the freedom to err and repeat or review procedures and skills that they will need to master. Again, D3D appeared to use an objectivist approach, but stopped short of scaffolding so that the learner was demonstrating independent understanding.

Constructivist Approaches. The constructivist approach is education as learner initiated, student self-directed, and learning through social scaffolding of community norms and values (Singer & Moscovici, 2008; Amineh & Asl, 2015). This is essential for developing social learning and collaboration.

In discussions with D3D development team, the opportunity for clients to develop their own 3D environments similar to Minecraft or Second Life was shunned on several discussions.

First the co-founder felt their value was “How we bring a higher level of fidelity” (Co-founder, PDSA Cycle 2) to the VR product space that can’t be matched by others and might dilute the company’s offering. Second when suggesting opening the platform to others via a software development kit (SDK) such as others in their field have done (e.g., Strivr), the response was that this is “not a priority” (VP Sales, PDSA Cycle 3). Therefore, it is important to note that empowering the trainee or learner to self-construct and self-direct their environment through creative construction was not something they considered valuable yet. However, exploration and interaction were paramount to the D3D software experience, but tools to create as a learner were not prioritized nor available. This differs greatly with other VR educators such as the Optima Classical Academy, where students are expected in the 3D world to build out problems they have learned (V. Jordan, personal communication, September 14, 2022).

Some educational environments while pre-programmed may be suited to student exploration and collaboration. Team cohesion training in extreme or stressful settings can be greatly supported by VR platforms (Lowe et al.,2020; Berndt et al., 2018; Wilkerson et al., 2008). Several platforms in fire-rescue, emergency medical triage, patient care, and military simulations require real-time communication and collaboration in virtual reality training (Vincent et al., 2008; Bhagat et al., 2016; Steward et al., 2019).

Where relevant, VR platforms should provide tools and game mechanics to facilitate communication and task collaboration across individuals and teams (Kirschner et al., 2009; Herrera et al., 2018). Therefore, the VR training or VR education platform should provide affordances for members to develop and share goals and accomplishments as well as resources and evidence in situ.

Examples of VR constructionist approaches include emergency medical triage coordination and 3D Exploratorium's like virtual museums. D3D is not focused on the platform's capabilities. This was supported by various inter-communications with various stakeholders who expressed that 'Sales directs the platform' in opening to new opportunities, rather than having an educational platform that creates new opportunities from features that empower different modes of learning. This sales-centric approach across conceptual and strategic affordances also introduces tactical considerations to address.

Tactical Construct

Learning science has a role to play in the development and deployment of VR training and education. There are two key aspects of tactical approaches that the research exposed. The first issue was how to implement a learning science theory into a 3D temporal space. This was particularly challenging because the developers building the educational software were unfamiliar with the learning science concepts. The second issue was the task-technology fit or how or whether virtual reality as a medium is truly needed to educate or instruct. Not every educational experience requires the use of a head mounted display. These two issues are described in detail below.

Technical Implementation. Decades of research around multi-modal or multimedia instruction informs how educational programs should be developed and deployed (Meyer et al., 2019; Fjørtoft, 2020; Harskamp et al., 2007). This research can also help organizations learn and absorb lessons from the classroom to grow and transform their own knowledge management. Yet because there is no formal VR educational or 3D instructional training standards, many of the VR development firms show a preponderance towards immersion with seductive details (Mayer et al., 2008) over desirable difficulties.

Seductive details are elements in the instructional content and delivery that, while increasing enjoyment and engagement, may often decrease retention and learning by distracting the learner away from the intended lesson (Harp & Maslich, 2016; Moreno & Mayer, 2000). This includes material or procedures that overload working memory, cause attention distraction or schema interference, or create coherence disruption. An example here might include a training session where there is an interesting conversation happening as “background noise”. Learners might attend to the conversation instead of the training, have a hard time blocking out the conversation, or think that both are important and overload their working memory trying to both listen to the conversation and do the training.

It took various approaches to educate and empower the development team to understand and appreciate why seductive details were a wicked VR problem. Seductive details are vestiges of interactive gaming and evidence shows that they do increase immersion and engagement (Makransky et al., 2019). This was evidence for the tension between the surprise and delight goals of trade shows and the new educational objectives. It wasn’t until the 4th case study project around personal protective equipment (PPE) training, that signs of individual initiative appeared, where the development team was actively considering seductive details in their design.

In a PDSA cycle hypothesis, I posed possible alternative learning theories in the experimental PPE case study. I suggested that the development team throw-out seductive details and focus solely on mortality salience priming (Oppenheimer et al., 2007; Zhao et al., 2018; see Figure 14 for potential effects). The lead software developer who had previously built mobile games put his proverbial foot down. As a result, I took a quick poll of the team to see if they cared if seductive details might be replaced with mortality priming. During the weekly development team scrum, he said “No, I need to know if these seductive details affect the outcome" (Lead software developer, PDSA Cycle 4). This indicated that the development team was independently considering the importance of learning science concepts by the end of the project. Once explained, VR interactive developers understood the impact they could make using learning science theories. It is important to note this took several months of deep rich exchanges around various learning science concepts and experimental contexts.

Many approach the VR educational experience with bias from their prior experience in interactive software development. The goal of the VR instructional designer is to educate and meet the standards and objectives of the learning organization. By providing interest, details, and immersion, the instructional designer may be clouding the content with distracting elements (Harp & Mayer, 1998; Wang & Adesope, 2016). Building well-constructed, interesting, and meaningful content is paramount over the surprise and delight of the learner. In contrast, desirable difficulties (Sungkhasettee et al., 2011; Zepeda et al., 2020) are opportunities to increase learning, but often at the expense of participant enjoyment and engagement (Bjork & Bjork, 2011). Desirable difficulties might include quizzing, interleaving, spacing, and varying the learning space. This again shows a tension between surprise and delight engagement and learning objectives, which may not be as enjoyable for participants.

The executive team and development team debated the use of desirable difficulties. In fact, when the concept was introduced to D3D, they began to use it in sales decks as a concept that they were actively investigating. In addition, the CEO/CRO requested several slides and articles that explain the concept. And in fact, the last pilot study with personal protective equipment utilized quizzing and spacing to increase retention (See Figure 10). Yet despite these interactions, the D3D software did not maximize the potential of quizzing, spacing or interleaving. There was no way to export a user's quiz scores to a learning management system or any human capital management software or even to export a simple pdf of completion.

Learning science is clear on what works, but instructional designers especially in VR must build these capabilities of spacing, interleaving, quizzing, and variation of environmental spaces into their platforms. While enjoyment during learning is important, mechanisms like feedforward modalities or learner prediction (Rodríguez et al., 2022; Wensveen et al., 2004), and review quizzes may feel to the learner as troublesome or interruptive, yet they are proven techniques to long term learning and retention (Snyder et al., 2010; Maagaard et al., 2011; Krokos et al., 2016). The platform should make affordances to support the various modalities of assessment and challenging recall with feedback mechanisms through the experience.

In exchanges with management and the development team over the course of many months we discussed over 20 learning science concepts (See Figure 14). Based on the specific context of high voltage PPE training, a new learning science concept was included in the case study. This is survival processing advantage (SPA; Nairne et al., 2011; Burns et al., 2014; Hou & Liu, 2019). SPA is based on the basic concept that when the learner is primed or activated that the learning process affects his or her survival or mortality, that learning will be encoded with greater strength and potentially greater retention (Scofield et al., 2017). One of the key findings in this pillar is that the D3D team began the project with no awareness of learning science concepts and by the end they were independently seeking to incorporate their new knowledge into the software. However, their knowledge is still nascent and a deeper understanding of how learning science educational standards fit various contexts needs to be developed.

Making the Task-Technology Fit. This marriage of educational standards and context leads to the idea of task-technology fit (Howard & Rose, 2019). Tactically, in order for the virtual reality education to meet expectations, the first consideration should be whether the advanced technology is truly essential. VR can be especially effective for instruction. But at what parameters does the technology fit for various learning objectives? After examining VR trainings and talking to D3D engineers and stakeholders as well as outside consultants and other VR firms, I developed a rubric of 5 types of development and deployment characteristics to determine whether VR is best suited for educational training. The rubric covers Movement, Risk, Physics, Components, and Human interaction depth. This rubric is a formulation emerged from the findings of the research.

Complex levels of Movement: Are the interactions with the content embodied (Stolz, 2015)? Is movement required or aided to gain a skill or learn a task? The range of movement in VR is not best suited to the extremes of either fine granularity (e.g., finger dexterity) or large movement (e.g., across courts or fields). Therefore, perfecting specific suture knots with thread and needles may not be best in VR. Nor would learning to swim across a lake. But opening a compartment with a monkey wrench could be effective in VR (Johnson-Glenberg et al., 2021).

In discussions with D3D development teams, many manual movements were automated, (e.g., particularly around screwing in bolts). The decision to animate a bolt fastening was not due to learning objectives but rather due to the number of the bolts needed to assemble a piece of high voltage equipment. And in conversations around medical training clients, D3D expressed doubts that their platform would be successful. So, a balance was made to time and skill specificity. The skill was not tightening a bolt, but rather assembling a panel that required many bolts.

Complex levels of Risk: Does the interaction with the training environment and objects contain an uncertain level of safety (Molka-Danielsen et al., 2015)? Working on an unplugged toaster might not have much risk, whereas working on a power transformer on a telephone pole would have great risk. High risk training tasks are better suited for VR where the risk can be reduced while still engaging in environment.

In collaboration with the D3D team, training in VR was often cited as being safe compared to working with the real objects and environment. These conversations arose both in the sales enablement case study projects and the personal protective equipment training test study. Yet when in discussion with clients that passed on virtualization (e.g., a manufacturer of faucets) there was little fit for risk. It was clear that D3D was using risk as a sales tactic and not considering risk in appropriate task-fit for clients.

Complex levels of Physics: Are the objects used in training at a size beyond the norm (i.e., very small or very large; Parker & Saker, 2020)? This can be explained as the *FedEx test*. If the training objects can be easily shipped, then VR may not be a top choice. Molecules and viruses or plane engines and cargo bays would be good examples for VR training simulations that are not easily shipped or handled to be used at training centers.

D3D trainings took advantage of these physics and discussions during demonstrations pointed out the ease of manipulating various large objects. This idea of physics was tacitly added to their sales technique based on their previous customer base. What surprised the D3D management is why manufacturers of small devices such as drains and faucets were not interested in a VR experience. Therefore, D3D was considering some level of physics in their discussions of design and task fit.

Complex levels of Components: Does the training involve complex relationships of many components (Colt et al., 2001)? Do the interactions have multiple layers that are non-obvious? This can be explained as a *Screwdriver test*. If one tool or two tools can disassemble and re-assemble the training objects, then VR may not be necessary. A mouse trap or bread box might not benefit from VR, whereas a solar inverter or a telecom satellite might. Therefore, the complexity in terms of number of steps matter as well.

At different points of development, D3D engineers would cite ease of use for the user. The term "Usability" arose frequently in how they approached their work. Their emphasis was supported around numerous conversations where they attempted a balance between instructional design usability and how they would interpret subject matter experts' intention. Yet in their executives attempt to push VR as a sales tool, they miscalculated the complexity in building complex components as the time it might take to build various offerings was not figured into their pricing structure. Therefore, there was a tension between the simplicity of a software build and the task-fit and necessity of VR.

Complex levels of Human Interactions: Are there complex deliberate interactions between the trainee/student and various objects or individuals (Karwowski, 2012)? Does VR allow for the required domains of 'Human Interaction'? Do the required interactions increase in complexity?

In reviewing why the leadership changed, one element about virtual reality which was alluded to was the richness of complex human interactions. Executives suggested that the pricing for the "VR as Sales" was priced too low initially to cover costs. Yet the company had already built and sold several VR environments to clients, so the cost was not unknown. What was unknown was not the complexity of components, but the complexity of human interactions inside the environments required to deliver the intended persuasive experience. For that reason, D3D should understand how to evaluate the human interactions needed to complete a learning objective.

In looking at dozens of VR modules the interaction can be broken down into two entities: objects and humans (See Figure 11). These variables can then be mapped to determine when VR training is most valuable. The variables included in the map are whether the interactions are human to human or object to human, the complexity of interactions, and the area of scale effect. In reviewing Figure 11, in an event such as visiting a Zoo, there are several variables to consider in determining if the event could benefit from VR. The experience has many objects of focus, but do you miss the smell of animals? The touch of them eating out of your hand? The sudden charge at the fence or window? Do the steps to get you to a zoo outweigh the limits of a less rich sensory VR zoo you can download? Is driving to the zoo more attainable than building a virtual zoo?

Football is a complex human to human interaction with only one significant object: the football or soccer ball. Are the limits to psycho-motor and sensorimotor activity in VR transferable? Does the activity obey the MR-PC rules of movement? Painting a picture is simple with a pencil or paint brush and canvas. Very few personal art scenarios require many people and thousands of objects interacting directly with the human.

Learning Science Pillar Summary

In summing up the learning science findings, the partner organization had accomplished a considerable amount of intuitive learning science acumen without any learning science background. This knowledge likely developed while working with various clients, who brought ideas about how their training should be built in a 3D immersive environment. This learning therefore likely occurred via vicarious learning (Roberts, 2010) from stories and passive observation of the client training or in combination with informal learning (Marsick & Watkins, 2018) by simply trying to replicate 2D learning modules into 3D as part of their job. And thus, the development team absorbed the training intents and insights by doing the replication but following sound pre-conceived non-virtual training practices. While there were many design decisions made that aligned with learning science principles, it was also clear that there was considerable room to grow.

Roles in Transition Pillar

Self-Leadership

In reviewing the interactions across the development cycles of the case study, clues pointed to changes in decision making and individuals speaking up as the engagement progressed. This provided hints at self-leadership (Manz, 1986; Neck & Houghton, 2006; Norris, 2008). Yet, asking what the Dev Team wanted to learn from each project drew blank stares. Initially the Dev team had difficulty defining their learning goals (Stewart et al., 2016) The Co-founder repeatedly suggested he must personally define what the Dev team must do, or they would operate in ambiguity (Crossan & Berdrow, 2003). It was also clear little individual initiative had been taken to organize their collective knowledge in working with client's learning objectives as much of their data was stored in various Google document folders. There appeared to be little self-organized and purposeful or self-directed operationalized community outreach as well (Ancona & Bresman, 2007). Despite the numerous roles and titles, the firm's employees did not appear to have any organizing principles beyond next project's execution.

This apparent chaos reflects the natural need for employee autonomy and general self-efficacy which should lead to self-leadership strategies (Norris, 2008). In developing and seeking leaders in a small or medium enterprise these strategies would be prized. Yet, as mentioned above, the Dev-team had difficulty defining their own learning goals (Stewart et al., 2016) regardless of the learning science or project goals being discussed.

Sales is a critical component at the firm. The newly minted CEO was given that job after several sales successes with the new VR recruitment offering. Self-leadership is a factor in increased sales performance (Panagopoulos & Ogilvie, 2015; Castellano et al., 2021; Singh et al., 2017). For that reason, it is surprising that an organization looking to aid enterprises in pipeline recruitment does not have any pipeline management in terms of developing skills in self-leadership. To keep the leadership pipeline filled and flowing, it is crucial to be aware of the specific requirements of each level, the common problems that managers experience in making a passage, and behaviors or attitudes that show someone is having difficulty with a passage (Charan, et al., 2001).

In observation and discussion at the firm, only specific individuals are allowed to interface with customers. Thus, high performance work processes (HPWP) such as job rotation and multi-skilling are performed ad hoc rather than strategically. This provides challenges to the workforce as the pandemic and their pivot to VR has required existing staff to learn new skills, which may have moderated some of the exploitation threats that would typically arise (Gill, 2009).

HPWP has three basic tenets: development of human capital, enhancing motivation and commitment, and building social capital which add to the organization's performance (Appelbaum et al., 2011). One critical skill found in this set is that of self-leadership (Prussia et al.,1998). Within the canon of self-leadership skills are self-observation and focusing thoughts on natural rewards which have the strongest impacts on job satisfaction, organizational commitment, and innovation (Sesen et al., 2017). When asked what types of recording or memorializing the employees make and share at the firm in terms of self-observation, there was no such activity suggested or offered. Most employees were focused on tasks given to them by management. Without leadership initiating self-leadership skills, leadership can fall into self-leadership derailment and derailed leaders have issues with change, resistance to learn new things, and may overestimate their past successes (Sejeli & Mansor, 2015). This has the potential to lead to a self-fulfilling vicious cycle of failure and incrimination based on poor decision making.

Business Decisions

The firm had hurdles during their pivot from tradeshow booth vendor to immersive education software developer. Thus, the roles at this firm were in flux. This chaotic nature was felt particularly as I was pointed to four different VR applications of the business over the course of this project. Consequently, individuals appeared to be making decisions haphazardly as they went along. Business decision making and organizational learning research may have some explanation for these difficulties. While there are many concepts that overlap, D3D's ability to unlearn may be key in their ability to pivot. A firm's ability to unlearn (Klammer & Gueldenberg, 2018) refers to their ability to discard non-performative or useless tacit tribal knowledge (Fenoglio et al., 2022) that while gained by chance does not accentuate or accelerate the overall firm's ability to reach its long-term goals.

These issues came to light in the subsequent firing of the CEO and the VP of sales. The previous VP of Sales was captured as saying in the last meeting before leaving the firm, "We just need to focus on something and stick with it – based on what we have done before" (VP of sales, PDSA Cycle 1). In an interview with an original co-founder, including learning science in the training software was referred to as being a 'one-off' if it was not going to create a quick win by surprise and delight (Van Buren & Safferstone, 2009) as in their tradeshow booth approaches. This was curious. Why would the idea of using sound learning science concepts in corporate educational software be something done only once? Subsequent documents (See Figure 12) were generated to explain the difference between "Surprise and Delight" software approaches vs "Learn & Assess" software approaches. Regardless, the use of learning science to improve performance was deemed a one-time case study project at the beginning of this project.

Without an unlearning process of identifying un-productive habits and beliefs, the firm may not be able to execute with the agility and flexibility needed to succeed in a volatile market (Salah et al., 2019). The market for VR services is still emerging and taking shape (Damiani et al., 2018). A dependence on quick wins without market intelligence of various factors can take the organization in less fruitful directions.

Not having a system of capturing and assimilating information puts more emphasis on tacit or incidental learning (Cannon et al., 2014; Bandura & Huston, 1961). Accordingly, in looking at how to identify the vicarious and informal learning of the organization, Rebernik and Sirec (2007) describe four types of tacit knowledge: hard-to-pin-down skills, mental models, ways of approaching problems, and organizational routines. Too often knowledge management efforts are limited to creating electronic means to foster knowledge transfer (Lubit, 2001). D3D has the electronic systems of Slack, Google Docs, and the outward interaction with other organizations to acquire tacit knowledge. Yet they have no system to capture tacit knowledge, process it, and share that knowledge.

Communicating this knowledge is especially important for new members of the team. In observing recent meetings with a new employee, onboarding was described as having a "firehose turned on" them while working in the field. But in interviews, it was confirmed across multiple examples the firm had no instructional manual or on-boarding process other than being described as 'trial by fire'.

One means of improving unlearning and tacit knowledge is to increase the organization's absorptive capacity. Absorptive firms use indicators of absorptive capacity: highest academic degree, training, experience in R&D, senior management support, along with alliances, to triangulate data into intelligence (Watkins et al., 2012). There is no way the firm could bring together all the know-how one needs inside a company, so the use of alliances is a good way to garner skills (Noblet et al., 2015). In high-tech sectors, alliances have become the cornerstone of innovation strategies of many companies (West et al., 2014; Sisodiya et al., 2013).

The majority of empirical studies that have been produced show evidence that developing knowledge communities and inter-organizational alliances positively affect corporate performance in terms of growth (Nooteboom et al., 2005). Hence, tribal knowledge while being collected and sorted must be separated from clear objectives and enhanced with a triage of outside evidence that can support any change theory inside the organization. Studies have noted that the firms' interactions and connections with outside organizations would strengthen the absorptive capacity (Lin et al., 2002). It remains to be seen if the firm is taking steps to learn from that outside tacit knowledge (Manning & Bodine, 2012).

One of the surprising findings was that the new sales in VR were created from old accounts. And the new sales initiatives for new accounts for VR for sales enablement was a huge financial miscalculation. The firms' sales have been sustained from their over 20 years of trade show booth and exhibit business where they were able most recently to offer VR as an alternative to their clients' field sales teams in a pandemic world. This pressure to pivot was caused by a need to have reliable and predictable outputs which can limit knowledge exploration (Zahra & George, 2002). When asked what research and analysis was done to decide how the VR for sales was priced, positioned, and deployed little was done to avoid the trap of being grounded in immediate returns, but eventually constraining innovation (Ahuja & Lampert, 2001).

The original CEO used a model from his previous work that worked well and then matched specific features with pricing of the closest software as a service model subscription he was familiar with. Close to a hundred thousand dollars were lost with little sales to cover the expenditure. In considering the roles in transition, it is important to point out that the past models of execution that served the organization well for nearly 20 years did not serve the firm as well in transition, particularly issues around knowledge attainment and knowledge analysis during their transformation.

Summary of Roles in Transition Pillar

To summarize, there were two areas that highlighted D3D's roles in transition, self-leadership opportunities and making key business decisions. In D3D's transition from trade show booth builder to educational software developer, they had missing roles with unaccounted responsibilities across the firm to handle the remote work, shared documents, and collaborative processes with 3rd party consultants and organizations. D3D decisions were on occasion haphazard and not based on recent data or sound research processes and as a consequence, they misdirected money and time to gain market share. Yet despite these challenges, the element of injecting learning science with action research techniques provided a reflective lens that aided transformation of role identities.

Developing Organizational Management Pillar

Knowledge management

Organizational management knowledge gaps appeared at the cutting edge of D3D's innovative service development. The graphic and development team members revealed that there was no formal training program. In speaking to their production team training was described as "people might shadow or follow" or "if they had experience and resources were low, they might be just thrown in" and these were substantiated by confirmations from leadership that no formal training existed within the D3D organization. There was also no clear knowledge management to collect learnings from previous or more experienced employees.

Developing an agile knowledge management process that captures information across front office, production, and engineering by a process of working with disparate clients can help build in those knowledge gaps (Bontis et al., 2002). The key is to utilize cross functional / cross divisional experts (Ancona & Caldwell, 1992; Ancona & Bresman, 2007) both inside and outside the organization with a process to develop a set of understood assets for success of the organization (North & Kumta, 2018; Valentim et al., 2016). Without such direction organizations can suffer from organization dysfunction or succumb to ignoring organizational learning disorders (Snyder & Cummings, 1998; Senge 1990).

Yet assets alone cannot solve or build an agile learning organization. Therefore, there are three pillars that the research indicates are knowledge gaps in the organization. These three gaps are absorptive capacity, unlearning, and high-performance work practices.

Absorptive Capacity

Developing an absorptive capacity platform can be challenging as it is ultimately an intangible asset (Jiménez-Barrionuevo et al. 2011). Absorptive capacity (Cohen & Levinthal, 1990; Griffith & Redding, 2003; Farrell & Coburn, 2017) is the organization's or firm's ability to recognize the value of new information, assimilate it, and apply it to commercial ends.

With multiple touch points from customers via online, face-to-face, and via virtual worlds it would be beneficial to have learned behaviors, practices, and systems in place to identify valuable knowledge, process it, and then utilize it quickly to attain desired results. This can be easier said than done, as there are significant barriers to organizational learning capacity (Schilling & Kluge, 2009).

Organizational sinkholes and silos can form at any organization (Alvesson & Willmott, 2012; Brocke & Mendling, 2018). With more data in the hands of engineers and specialized systems, greater care should be taken to diffuse knowledge outside of select teams (Cannata et al., 2017; Myers, 2015). And yet internal factors of management and structure also have effects on the organization's capacity to learn (Fowler & Mayes,1999). In collaborating with the firm both internal and external factors of impediments to organizational capacity to learn were exposed.

The first factor was at the individual actional-personnel level of absorptive capacity (Schilling & Kluge, 2009). D3D lacks learning science expertise inside the organization despite building educational software. Despite the pivot to developing training software, there had been no one hired in higher educational learning or instructional design.

A firm may ignore the existence of an important knowledge source if it does not have any related experience of this source (Vega-Jurado et al., 2008). So, without any specific understanding of learning science, it was evident that building knowledge in the domain of learning science was deficient. To compound this fact, knowledge acquisition is path-dependent and firms can influence their ability to exploit external knowledge by encouraging individuals' involvement in innovation projects (Schmidt, 2005). Thus, the individuals whose previous experience was in software game development will by nature choose paths of knowledge that are formulated from their previous experience.

Further compounding these issues are issues that stem from having a homogeneous team. By hiring software developers regionally D3D may limit the benefits of diversity of knowledge structures across individuals that parallel the benefits of diversity of knowledge within individuals (Cohen & Levinthal, 1990). Thus, having only young, white, male programmers (who attended the same college) leading the development team and not having cross-functional teams with diverse educational backgrounds can inhibit the development of broader knowledge structures in the firm (Flood & Romm, 1996; Kavadias & Sommer, 2007). Narrow knowledge structures are not conducive to increasing absorptive capacity.

Schilling and Kluge (2009) compare personal barriers with structural-organizational barriers. These barriers are rooted in strategy, technology, culture, and formal rules. Absorptive organizations with systems and mechanisms associated with cross-coordination capabilities, inter-organizational participation, and job-rotation are elements found to primarily enhance absorptive capacity (Jansen et al., 2005; Farley-Ripple et al., 2018).

Management has a role to play in expanding this capacity. The development of not just job rotation, but also quality circles, and assigning projects with problem solving methodology influence absorptive capacity (Vega-Jurado et al., 2008). Yet despite this, D3D leadership chose to shield the development team from outside influences. “It might confuse or startle them” was the approach the co-founder took when new ideas or alternative input was requested of the development or production teams.

Managers can directly affect a firm's absorptive capacity by providing information to potential adopters in the organization (Lenox & King, 2004). Along with sharing data top-down, managers need to coordinate and integrate sharing of acquired knowledge. To better manage the assimilation and exploitation process of knowledge management, firms should invest in coordination systems so that individuals and teams regularly share knowledge and insights (Dabić et al., 2019). The D3D firm used Google Docs and Slack. I was given access to a Slack channel that covered the case study project. But upon analysis, the channel was used only to state completions of tasks and was not used to share any documents that I had created for the team to understand or educate themselves on learning science.

When I asked if there was any hierarchal storage structure of documents or a database, leadership admitted that there was a scattered use of Google Docs and Slack communication. And in discussions with a consultant working with the firm, they did not find any knowledge sharing structures (Lengel & Daft, 1988). In fact, this consultant invited the D3D team to use his tools to collaborate as D3D did not have any beyond Google Docs. In the process of the participatory research, I found no operational structure of change initiatives or hierarchy of consolidated files to share with hybrid workers (LeMahieu et al., 2017).

Absorptive capability contributes positively to innovation performance with the use of collaborative networks (Benhayoun et al., 2020). In the creation of D3D Network, D3D is beginning to expand its network of knowledge-based communities. But this is only after not doing so with both its technical VR training and its VR sales enablement products which still have paying customers. The firms' interactions and connections with outside organizations would strengthen the absorptive capacity (Lin et al., 2002) of the firm. Therefore, while they are beginning to build outreach in the D3D Network educational recruitment service, this is more a process of sales prospecting than that of building and nourishing knowledge communities. And where there is evidence that this is an outreach to community colleges to connect D3D to students looking for connections to large enterprise recruiters, the knowledge is tacit and incidental to the prospecting. Consequently, there is no evidence that the incidental knowledge acquired is being operationalized for the diffusion benefits of the entire staff. On the contrary, in pre-development team discussions with leadership, the staff was compartmentalized to focus only on task driven work.

To better manage knowledge management, firms should invest in coordination systems so that individuals and teams regularly share knowledge and insights. (Dabić et al., 2019). Yet beyond individual Google Doc folders and various private Slack channels the firm D3D has yet to develop a coordinated process of acquisition and assimilation of knowledge from its interactions with various organizations and firms. In 1-1 interviews both production staff and leadership confirmed that beyond discussions or post-mortem after meetings no known system or person tracks, stores, sorts, collates and shares organizational learnings. This included a disclosure that the firm had spent a large sum on leads with no customer relationship management (CRM) to track or manage any leads generated. This stated coordination is not a simple organizational act, coordination is not a trivial issue (Grant, 1996). Therefore, the firm or any organization must begin to look at ways to operationalize better work processes and leverage intellectual capital it is developing with various internal and external stakeholders.

High-Performance Work Practices of Intellectual Capital

The shaping of human capital—the knowledge, skills, and abilities that employees possess—is an important source of competitive advantage and essential to HPWP (Combs et al., 2006).

The present essential aspect of what Combs et al. suggest is to incorporate behavior and practices that capture workers' knowledge in building out solutions for clients and partners. This is key not only so that the knowledge can help the organization to meet its objectives but doing so engrains the HPWP pillars of skill-, motivation-, and opportunity-enhancing outcomes (Obeidat et al., 2016).

In looking at the broad array of HPWP employee behaviors, D3D found ways to not include three types of opportunities for participation: in decision making (via self-directed teams and offline committees), enhancing the capacity for participation (via upskilling, multiskilling practices such as job rotation), and providing incentives for participation (via compensation practices (Kalleberg et al., 2006). This differs greatly when discussions of how to treat the development team and production teams at the firm. The Co-founder suggested they must 'always define what the dev team must do' rather than get their feedback so that they did not operate in ambiguity (Crossan & Berdrow, 2003).

Delineating the task is important, as giving ambiguous instructions with ambitious goals may be considered an "employee exploitation" oriented perspective on HPWP (Kroon et al., 2009). At the firm, the CRO confided that the dev team has been taught to wait for orders and requirements around projects in a top-down fashion (Bolman & Deal, 1991). Because the organization was founded around booth and physical effects in which teams took orders based on precise prescribed elements, they did not see how their new position as VR design thought leaders might change the way they behave organizationally.

Summary of Developing Organizational Management Pillar

To conclude on the development of organizational management findings, there were three spaces for growth which included knowledge management, absorptive capacity, and high-performance work practices. D3D had limited processes and systems to collect, collate, and disseminate acquired knowledge. D3D possessed a lack of diversity and missed chances of intentional cross-functional teamwork combined with no process to collaborate and build knowledge which hindered performance. The original D3D top-down management style hindered or stopped self-directed teams, up-skilling, and incentives for employees to grow and learn. Nevertheless, D3D’s new CEO had made changes, purchasing a CRM and had begun reaching out to diverse constituents across the educational field to strengthen the organizations ties to various educational NGO's.

SECTION FIVE Recommendations & Discussion

Recommendations

The challenge in VR training development is the construction and interaction of the classroom or learning environment. Prior to immersive virtual reality applications for learning, a teacher or professor could, with some imagination and a room full of willing students, use any number of approaches to develop and to deliver the curriculum. Most classrooms have desks, pencils, paper, and a whiteboard or chalkboard, all of which can be moved and rearranged. The teacher could create a project-based lesson, or the teacher could present material in a step-by-step way building in an incremental fashion and then test the students on comprehension. The options to design are wide and broad. But once you include advanced software, multiple hardware devices, network connectivity, and the non-trivial requisite resources of software programmers, VR developers, and graphic artists, the decision complexity to develop and deploy learning applications grows exponentially. This can be seen in samples of screenshots of various VR training programs in Figure 13.

The partner organization has responded to a pandemic that shifted their focus from delivering surprise and delight for the clients' trade show booths for many years to immersive interactive virtual reality training software and services. This agility and the ability to do so with existing clients supports their earnest desire to deliver exceptional results whether that be in immersive exhibits or in 3D software technical training. Nevertheless, evidence, observation, and analysis provide three areas where Goldsmith (2008) might add *What got you here, won't get you there*.

Therefore, based on the insights gathered over nearly 6 months of participatory action research, there are three areas where the organization might want to focus on to improve and accelerate their new set of services in virtual reality. These are the development of learning science modules, network improvement communities, and sense-making structural operations. The goals or outcomes for these recommendations are to place the partner organization into the forefront of virtual reality enterprise training and recruitment services.

Learning Science Modules

Currently the partner organization does not have formal training for employees. If the partner organization wants to lead in this space, developing training in learning science would empower the team to learn learning science skills and would aid in their leadership in that space. These modules would be part of an internal training program that, upon sections of completion, would be pushed to outside online learning communities such as Linkedin Learning, Udemy, and Plurasight to name a few (See Appendix for Logic Model). This would establish their leadership in defining how learning science intersects with virtual reality training.

The learning modules would cover how learning science can be incorporated via VR/AR or immersive 3D technologies. The 3D-based lessons would include the four levels of learning covered in the literary review: Conceptual (Cognitive, Affective, & Psychomotor), Strategic (Objectivist, Constructivist, & Realist), and Tactical (Theory Application & Task-Fit). By providing lessons for all interactive immersive designers, they would be accomplishing two feats. First, they would be developing expertise in-house. Thus, by creating immersive learning experiences on say Bloom's taxonomy, they would be moving through Blooms' taxonomy themselves. They could also utilize Kolb's learning cycle (Konak et al., 2014; Abdulwahed & Nagy, 2009) by providing lessons that begin with concrete experiences, reflective observation, abstract conceptualization and finally with active experimentation. Therefore, simply by the prescribed activity theory (Scanlon & Issroff, 2005) the team would be developing both their own skills and knowledge by creating a product that would ultimately help others as well as promote the organization.

The best way to gain knowledge in educational theory would be by creating content that expands their outreach and develops inbound leads and recruitment. One of D3D's strongest competitors (Strivr) was founded in 2015 and has over 45 videos on YouTube. Several of their YouTube videos have over three thousand views. Alternately, the firm has 17 videos with 15 subscribers on YouTube covering 5 years of a company that has been in business for over 22 years. Their Facebook page was created in 2019 and has 556 followers on it so far. This leads us to the second recommendation which is the development of networked improvement communities.

Networked Improvement Communities

Networked Improvement Communities (NIC's) are a concept developed by the Carnegie Foundation for the Advancement of Teaching in the USA (LeMahieu et al., 2017). The idea is based on the concepts of quality and continuous improvement of programs. As the firm is moving into educational VR software design and development as well as VR recruitment from educational institutions, it would be logical to lead in that space.

The idea of NICs is a combination of "improvement science" and "Network science" (LeMahieu et al., 2017). Improvement science dates back to theorists such as Deming and Ackoff (Ackoff, 1993) and their use of using incremental and measurable improvement to complex systems. The Institute of Healthcare Improvement association describes the science of improvement science as:

> *The science of improvement is an applied science that emphasizes innovation, rapid-cycle testing in the field, and spread in order to generate learning about what changes, in*

which contexts, produce improvements. It is characterized by the combination of expert subject knowledge with improvement methods and tools.

Network Science is broad, but in terms of its application here, the focus is on information spreading (Rogers, 1962, Granovetter, 1973) and social capital (Lin, 2002; Putnam, 1994). The science is about using social networks and links in those networks to exchange value between nodes or groups. In essence, it is about spreading information inside targeted social networks or communities. The challenge for the firm D3D is that the market space is not well defined and there are several spaces that their work falls into. As such, they are in the enviable position to help define the market at the intersection of virtual reality software design, human capital management, and learning science. Effectively, this is a blue ocean strategy (Kim & Mauborgne, 2005) and one that also brings additional challenges as the market is still forming and congealing (Van Kuiken, 2022).

The firm should begin to build a community around those three pillars: learning science, virtual reality software design, and human capital management. This would entail a three-step process. The first would involve creating events that bring specialists and academics around these three pillars together in webinars, in-person seminars, or break-outs at large conferences. Having a cross functional event brings value in and of itself, as participants and speakers confront issues in education, software, and human resource training together and discuss how to add value.

The next step would be in parallel in order to begin adding value to the events with research and lessons gleaned from the learning modules being built to train the internal teams. As in this study where the participatory action research was powered by an experimental case study, the firm would continue to work with academics and enterprises looking to find value in cutting edge VR software applications. These modules and lessons would be part of specific events where the academics would be able to discuss or in some instances enable participants to experience and become trained in their system.

Finally, the firm should begin to create social network touchpoints and collaboration learning spaces where learners and academics can post, coordinate and assimilate information around the three pillars of learning science, interactive software design, and human capital management. At first this may be a specialized blog that simply requires registration, but as resources build and content expands this could be a learning management platform that combines VR modules with lessons and community boards.

By combining leaders in learning science, with experts in interactive software design, and executives in human capital management, the firm has the opportunity to create value and a market where few competitors exist. Currently there are companies creating soft skill VR training as well as many digital agencies that have created varied VR training and VR corporate marketing applications, but none have cornered or created a community around learning science, interactive software design, and human capital management.

If the digital agency can accomplish the creation of a new uncontested market space, they may be able to truly expand the 22-year-old organization. But the essential key is the exchange of value between the networks. Each network must find value in the coordination and participation of the networked improvement community (Joshi et al., 2021; Russell et al., 2017). Community members must not see the opportunity to participate with the firm as transactional or simply as a vehicle to sell more of D3D's products and services. The partner organization should attempt to develop standards in the VR educational software space that helps businesses and educational institutions with delivering the next generation of immersive training and education.

Sense-Making Structural Operations

Sense-making is a process of gathering information to bring about a comprehension of the tasks and operations that a group, team, or organization needs to accomplish (Weick, 1993). If the partner organization takes the first two recommendations and acts on them, they may still experience barriers to organizational learning (Schilling & Kluge, 2009), including turfism and silos (Wilken & Walker, 2004). From the evidence of the way the organization works, it appears that often members are not necessarily communicating and getting appropriate feedback. One example is when the former CEO did not work with the development team to come up with accurate man-hours and costs. Therefore, there should be an organizational skill set that needs to be exercised that works across data silos, work out process sinkholes, and uncover forgotten organizational work-around skeletons in the closet.

Additionally, in conversations with the current CEO, it was revealed that the process of working on the experimental case study of injecting learning science into their product had begun to change the organization in what the teams understood were their responsibilities. In fact, I noticed several examples of emerging self-leadership (Manz, 1986). These glimmers of self-leadership should be nurtured. A set of procedures should be developed and implemented that were part of the participatory research. Thus, the action research methods of working at the application, team, and organizational levels of collaboration, communication, and participation should continue. This backward triple spiral can be used not just as a research process, but also for continued organizational transformation. To do this the organization should continue the action research process that was developed around the development of the updated application at the partner organization. This action research process is not in and of itself a 'one-off' project, but rather a continual process of improvement.

The organizational skill of sense-making has far-reaching effects for the improvement of the firm (Krush et al., 2013). Several trainable compensatory strategies of sensemaking include self-reflection, forecasting, and information integration. These are built into a model of continuous improvement and cooperative inquiry that I developed in this project using action research methods. Based on preliminary qualitative findings of this study these methods appear to have had some impact. The following is a recommendation based on that model.

I recommend using what I call the Backward Triple Spiral (See Figure 7) in which the organization should begin small and at the bottom of the organizational hierarchy but not from the design perspective of surprise and delight, but rather what is the desired standard of operational outcomes. When the outcomes are defined, the systems that will capture that outcome or standard of proficiency should be considered. Only then can work begin to design the core features and content that the educational application requires. The challenge is slowly working in a parallel process of agile development on both the educational application and with the organizational management or structure of the enterprise.

The art of communicating the sensemaking dependencies may be more easily aligned and captured through the use of continuous improvement and cooperative inquiry (Chouinard & Cousins, 2014), than building an application or platform that was not evaluated fully in terms of outcomes or results. This may be particularly useful if learning science ideas and concepts need to be absorbed by the team of engineers. Learning science is very much a results-oriented endeavor to detect ways to increase acquisition, comprehension, retention, and transfer. If teams of engineers are to develop educational software, then the application of learning science must be continuous and intentional.

There are three spiral processes (Farr et al., 2005; Nilsson & Wilson, 2012; Oriogun, 2000). As described, an agile method of developing an application that utilizes learning science begins in the first phase. The first spiral begins with a Backward design (Wiggins & McTighe, 2008) where the organization must identify the desired results first, then design the assessment instrument to capture the results, and then develop the content.

From here the cross-functional team builds the program injecting learning science concepts. In this second phase (See Figure 7b) D3D would follow with the second spiral of Plan, Do, Study, Act cycles forecasting outcomes of the process using an X-Team (Ancona & Bresman, 2007) configuration of cross-functional members and team participants that are connected throughout the organization and even outside the organization as well.

Note the PDSA cycle is not to take the place of the iterative agile method or quality control methods of the application build cycle spiral, but rather to analyze how the team is incorporating learning science both at the application level as well as the team level. The key is whether the learning science is being understood by the team and whether the teams are processing and diffusing the ideas more broadly.

The third phase and spiral are that of cooperative inquiry where team members solicit outside exchanges of feedback and a continual process of sensemaking to way-find how the application can have direct effects on the organization. This is where continuous improvement and learning science work to integrate at the organizational level. Cooperative inquiry (Susman & Everad, 1978) includes stages of diagnosis, action planning, action taking, evaluation and identifying patterns (See Figure 7d). This spiral process continues just as the first and second spirals continue. But rather than focus on the program or application and its direct constituents with stated outcomes, the third spiral focuses on organizational sensemaking, developing actionable narratives and charismatic routines (Chen, 2012). The goal with this third spiral is that the lessons at the team level and their interactions can be exchanged with the other parts of the organization. This third spiral is looking at the organization outside-in (Bodine & Manning, 2012), in that the lessons and learning are outcome based not solely around how the organization sees itself but how the partners and customers see the organization in its transformation of harnessing learning science and sharing those insights with the world.

By developing learning modules and developing network improvement communities the continuous cycles of the backward triple spirals allow for a cycle that propels the organization into a space of leadership at the intersection of advanced education, interactive design, and human capital management.

As can be seen in Figure 15, the 3 key change ideas are development of VR based Learning Modules, Network Improvement Communities, and Sense-Making Structural Operations. Each of these work towards developing feedback, coordinating with experts and compensating or acknowledging corrective feedback from both inside and outside the firm. This requires hiring of learning scientists and utilizing VR to train emerging leaders both as project leads in the development of VR modules as well as the content itself in the VR learning modules. Finally, D3D needs to create opportunities for growth both individually and organizationally by creating both in-person and online events.

Limitations

The research findings provide the skeleton or frameworks across learning science to provide clear points of reference to aid in the change drivers detailed in Figure 15. Yet much work still needs to be completed. Standards around virtual reality and learning outcomes requires more work, for example on how to develop Bloom's taxonomy so that it might work with augmented or virtual reality learning opportunities. Standards also need to be considered around how organization transformation can be aided by immersive training. These are the early days of virtual and augmented reality both in terms of learning science and organizational transformation.

Conclusion

In review, the organization does not have to incorporate the development science modules, the networked improvement communities, or sense-making structural operations in order to continue to be successful. Yet, it is clear from this project that learning science can be applied to transform D3D via their core VR training application. The learning science elements of conceptual, strategic, and tactical approaches have been sorted, compared to, and integrated with advanced immersive learning tools and services. The dynamics of the process that would facilitate the continuous change or improvement have been documented. And over the pages of this research project, evidence has surfaced that would support indications of organizational transformation. It is in that light that the firm could use the findings and recommendations from this project to expand and accelerate their cutting-edge firm with learning science and organizational transformation.

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Appendix

Figure 1. VR/AR Commercial Headsets

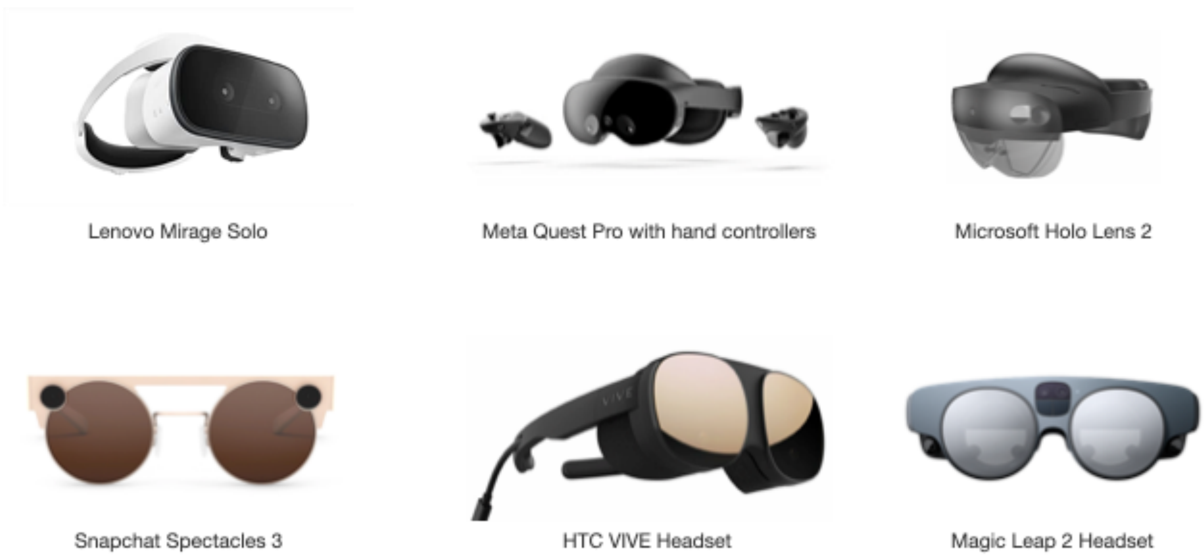


Figure 2. Blooms Taxonomy
Sources: Bloom et al. (1956); Dave (1970); Anderson et al. (2001)

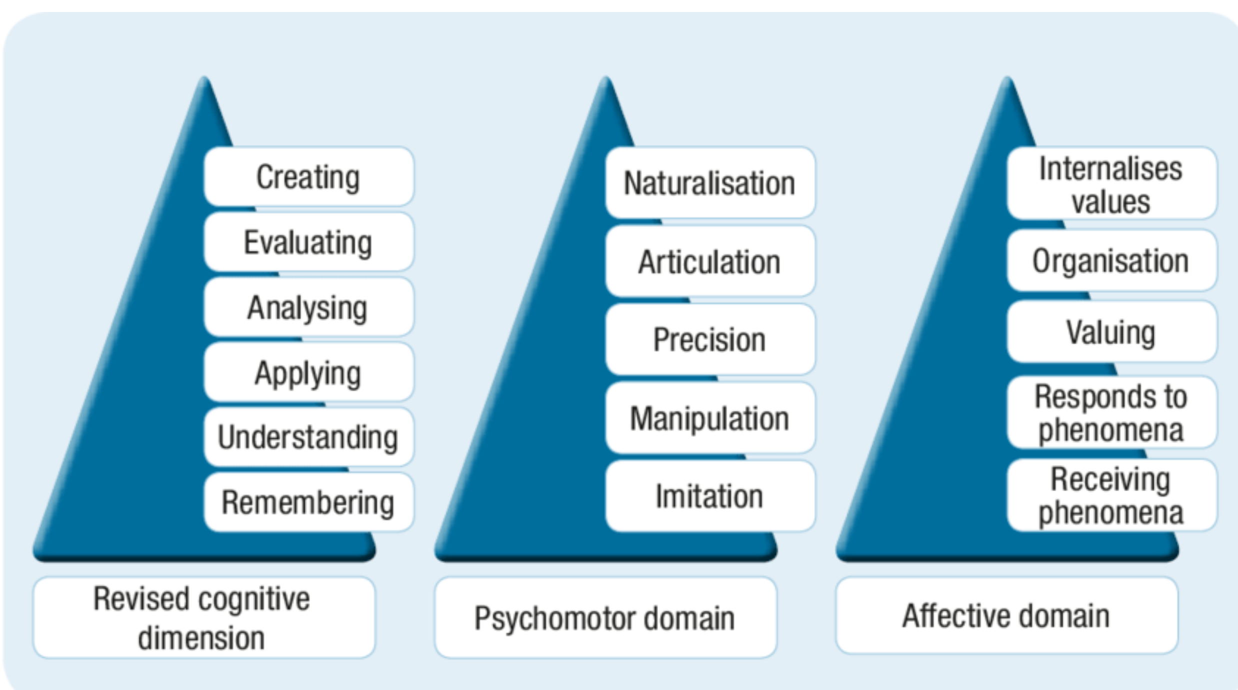


Figure 3. Exhibition Industry Revenue

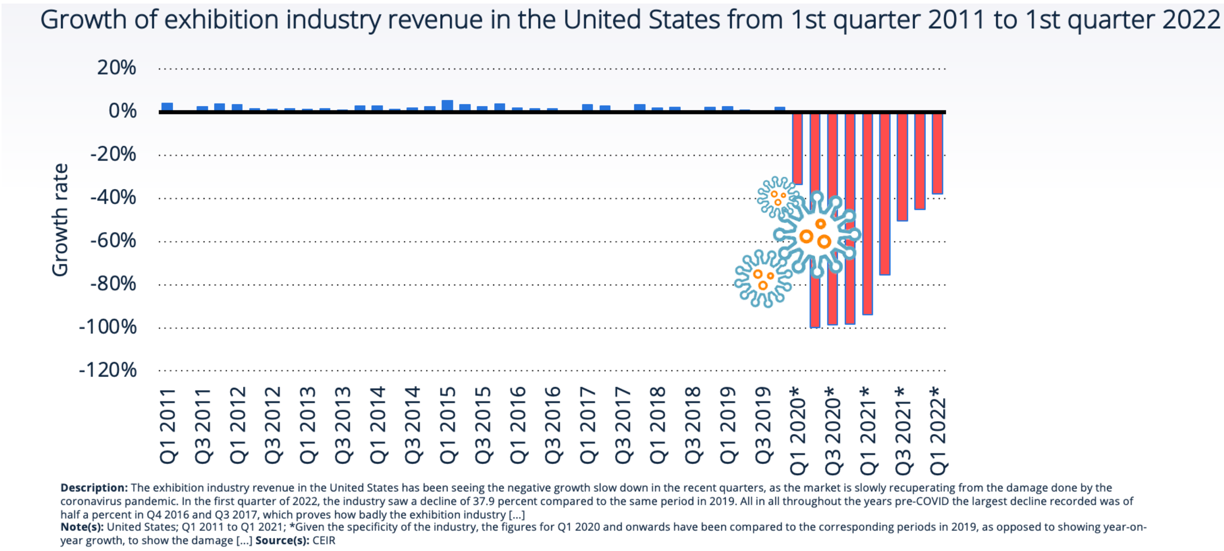


Figure 4. Predicted AR/VR Growth

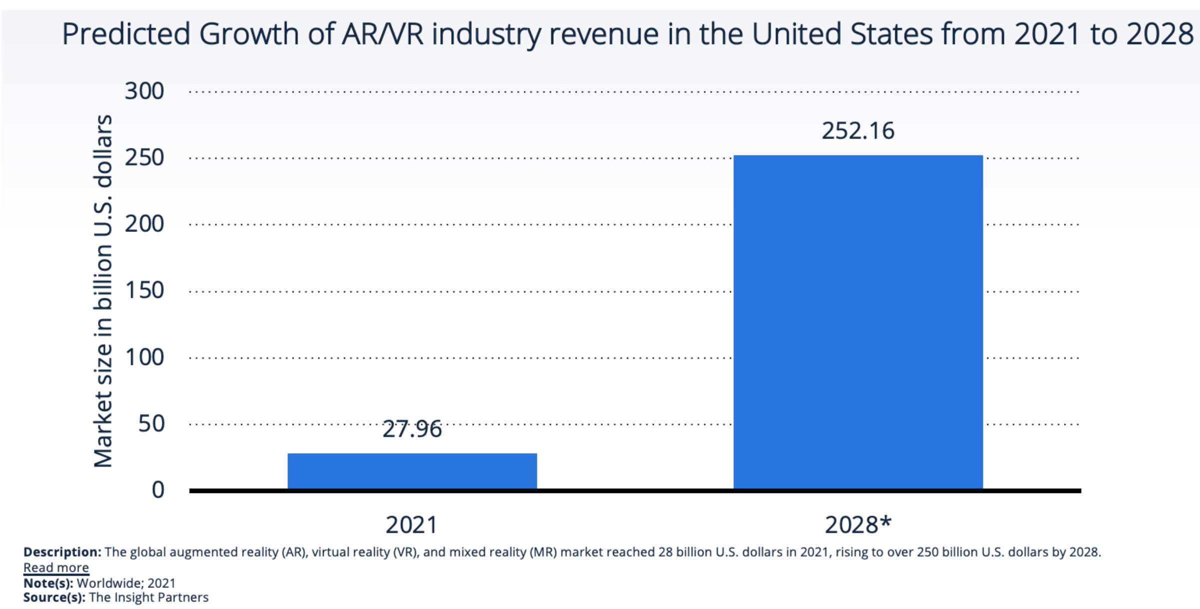


Figure 5. VR Training over Time Google Trends

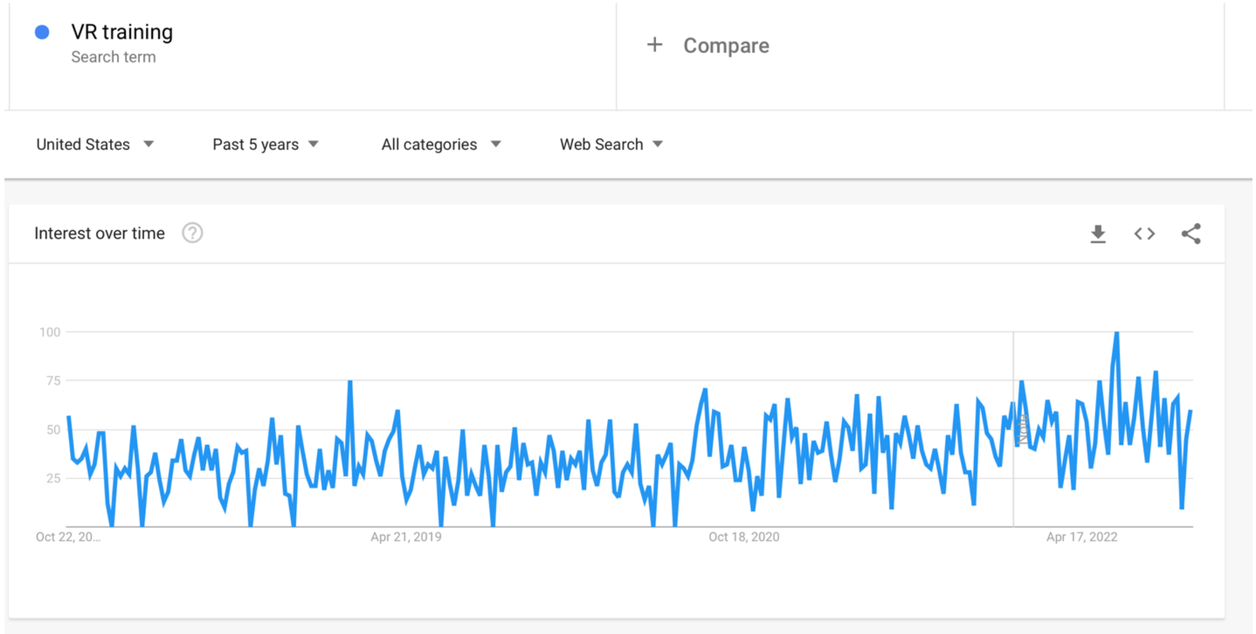


Figure 6. Theoretical Frameworks

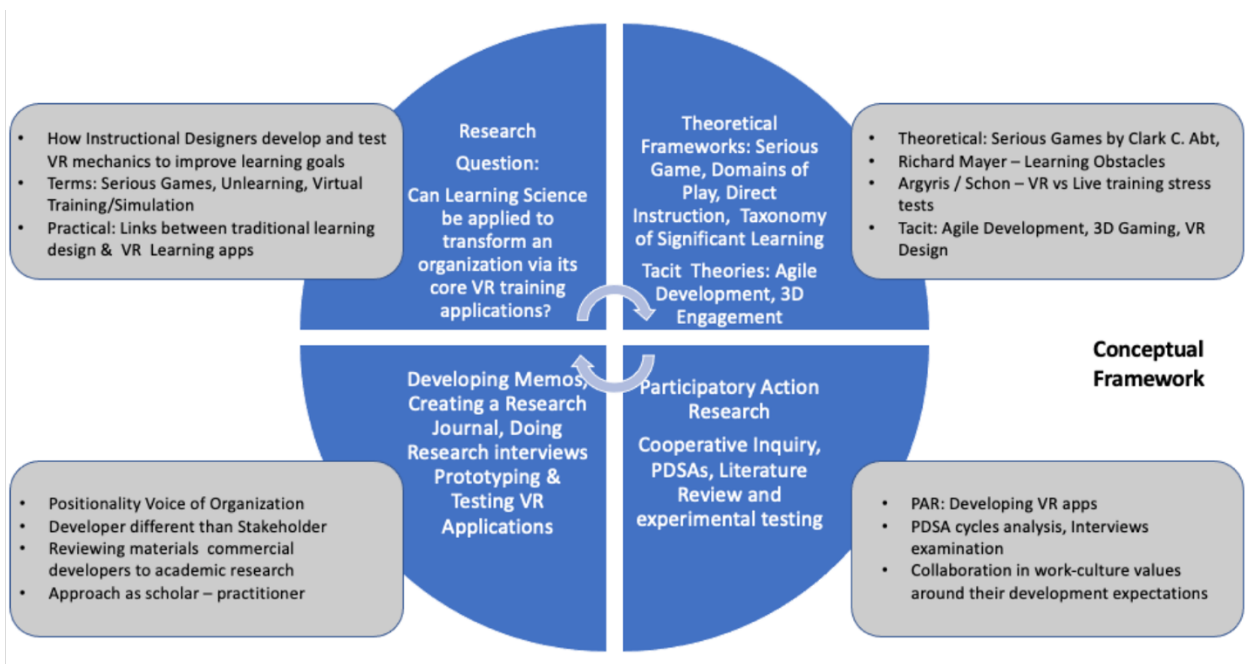


Figure 7. Backward Triple Spiral Data Collection Method

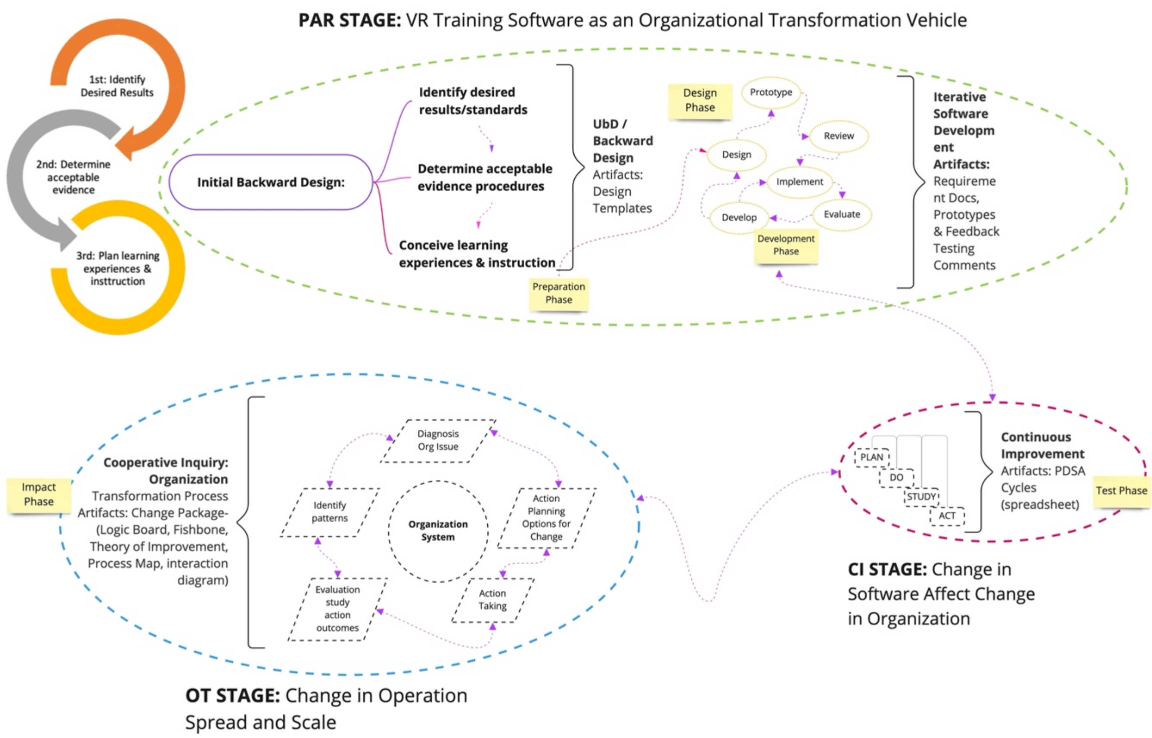


Figure 7a. Participatory Action Research Stage

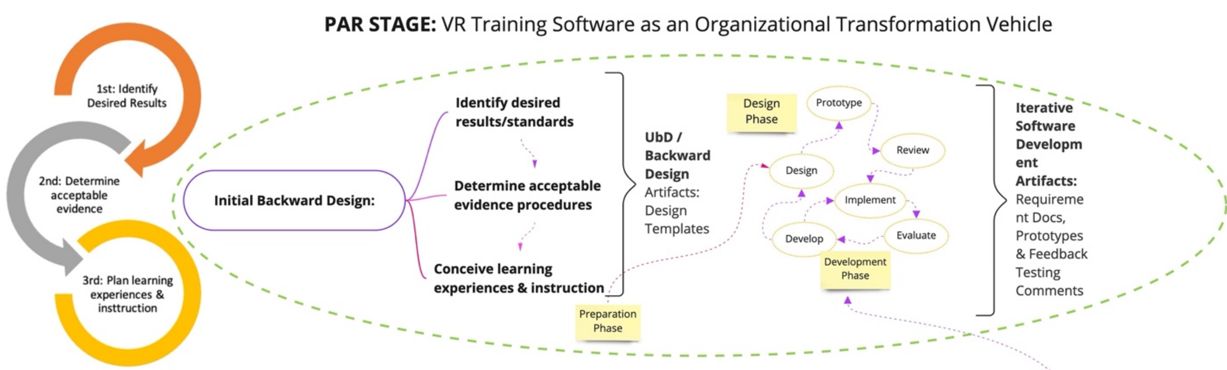


Figure 7b. Continuous Improvement Stage

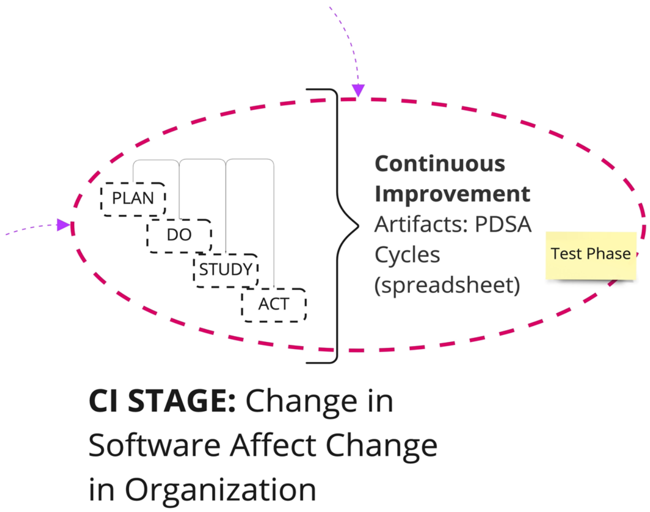


Figure 7c. Cooperative Inquiry Stage

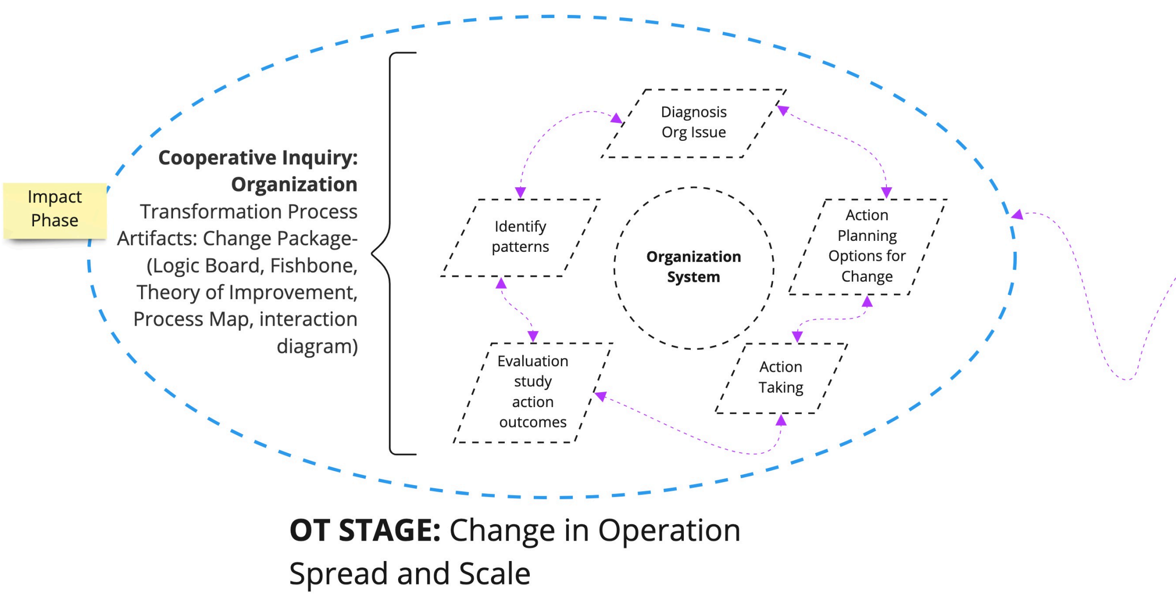


Figure 7d. Alternative Cooperative Inquiry Stage

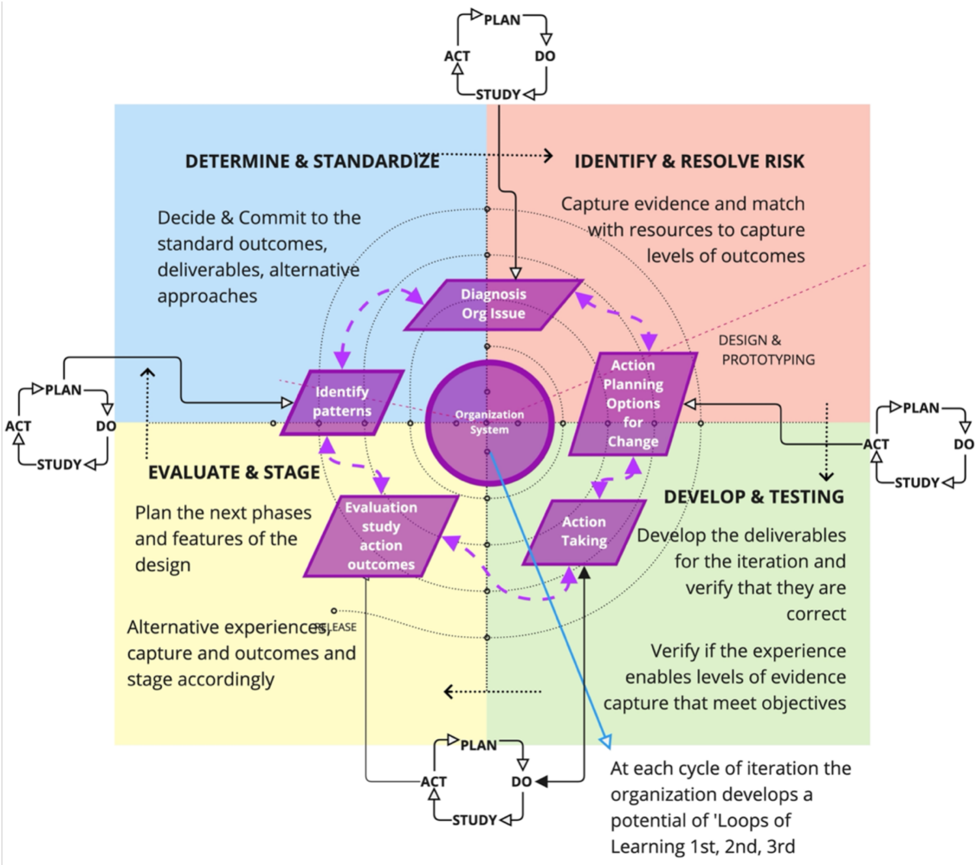


Figure 8. Emerging Themes

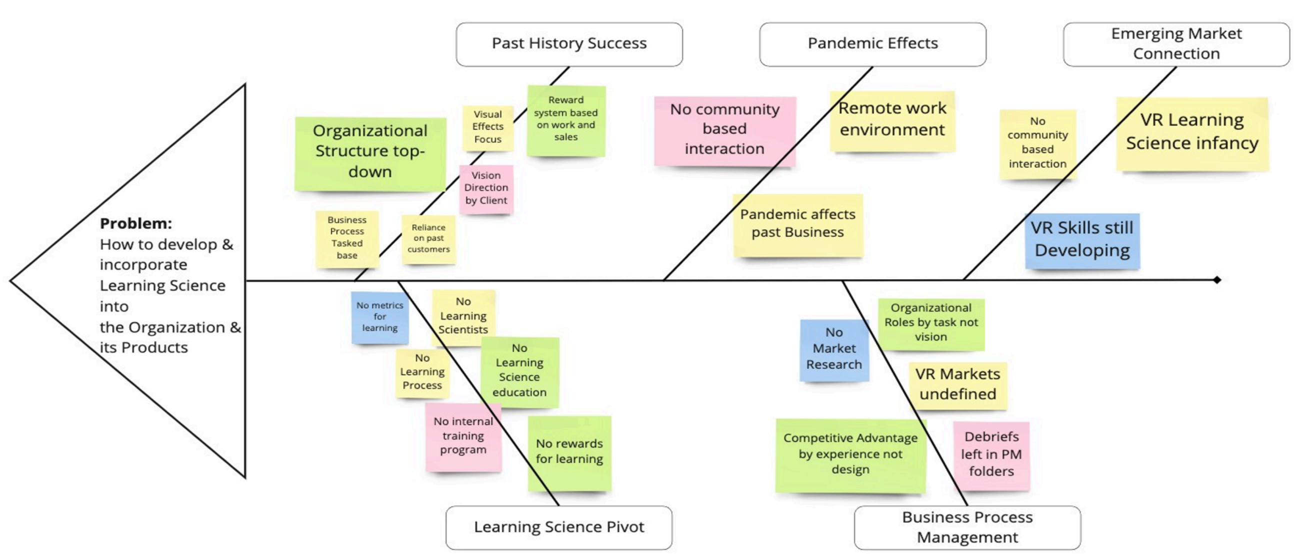


Figure 9. Hype Cycle

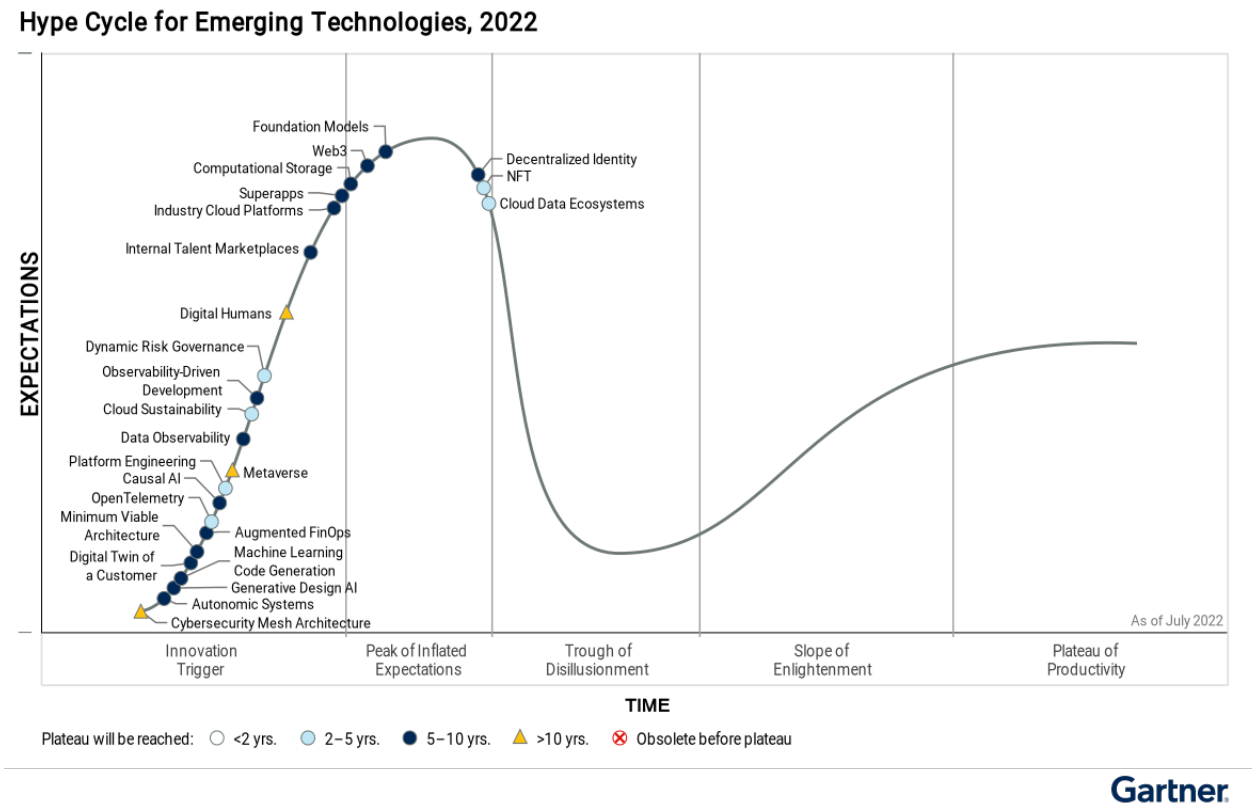


Figure 10. Case Study Environment Prototypes

Figure 11. MR-PC-H Technology Fit Diagram

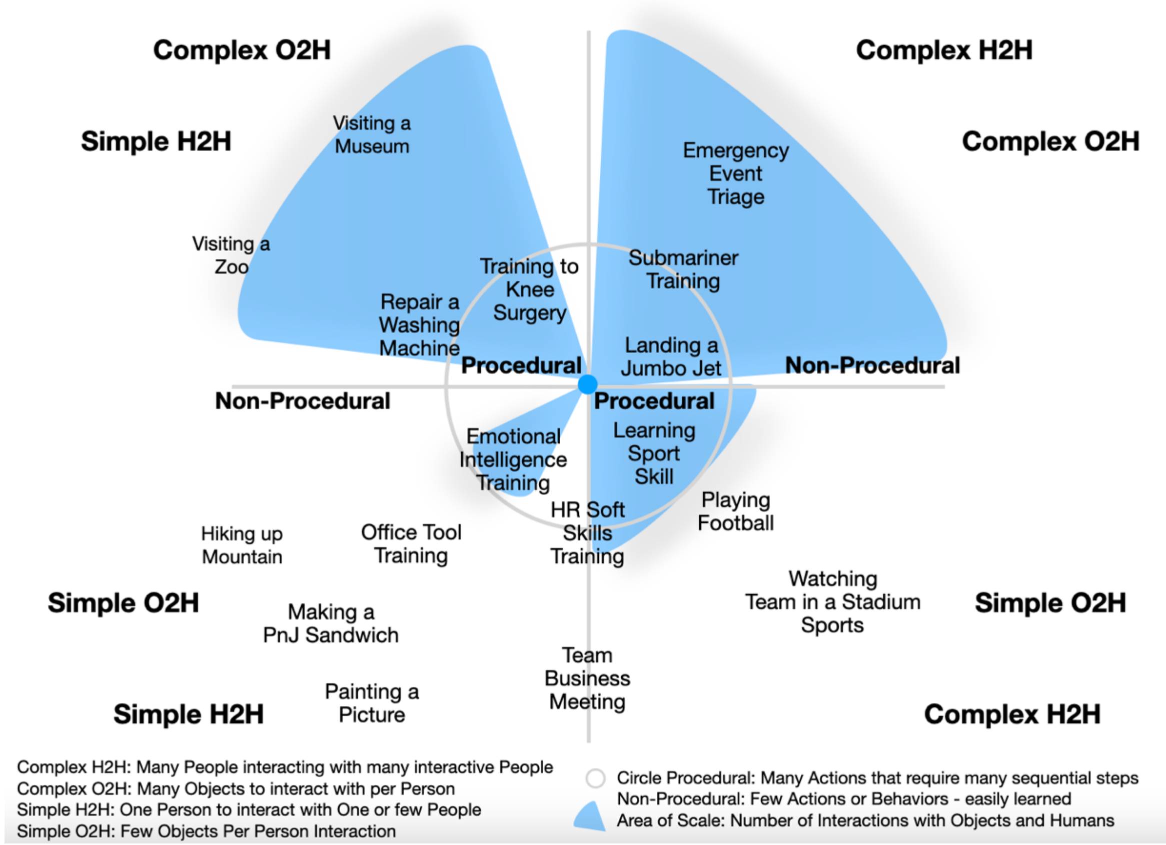


Figure 12. VR for Events/Effects vs VR for Corporate Training vs VR for Selling Table

Practices, Methods, Outcomes	**VR for Events and Effects**	**VR for Corporate Training**	**VR for Selling**
Objective	Surprise and Delight	Educate and Assess	Persuade and Close
Output	Customer Facing Experiences	Internal Business Facing Training	Prospect Facing Engagement
Model	Exploratorium	Immersive Learning Lab	Product / Service Sales Portal
Typical Usage	Events, one-off experiences curated by specific needs of Client / Facilitator to impress and delight generally to be used as a Marketing vehicle	Reusable Learning Modules designed to deliver Training for Sales, Training for Technical skills, Training for HR, or Educating Customers	Reusable Sales Modules to use to enable sales agents to close deals with Prospects

Non-VR Alternative	Conference Booth, Museum, Amusement Park, Corporate/Campus Entrance	Classroom, Learning Lab, Field Training center	Retail Space, Showroom, Demonstration Center
Measurement Methods	Qualitative: Video time-series of capturing participants exploring with or without Facilitator, creating thematic maps of interactions and use of questionnaire of satisfaction	Quantitative: Control group and experimental group, with defined content inside VR vs outside VR. Pre-Posttest to assess learning objectives attainment	Quantitative: Control Group/Experimental Group VR/Non-VR Customer Willingness to use VR
Metrics	Satisfaction, Remembrance, basic questions of did they enjoy experience and what did they remember most.	Educational goals and standards of structured content retained and transferred, change in new learned behavior linked to business goals	Time to Close, Cost of Sale, Sales Revenue, Service Obtainable Market expansion
Experience	Participant explores space and discovers unique interactions around branded content	Participant is immersed into a series of experiences with structured content, which includes feedback and testing	Prospect is immersed into a sales experience based on needs or objections
Alternative Uses	Live Event augmentation, Customer Education, Recruitment, Sales	Sales Tool, Recruitment, Retention, Compliance, Customer Support, Marketing…	Education of new employees,
Measurement Time	Days / Weeks to scan/analyze hours of recorded video interactions	Less than a day to setup and test	Less than a day to setup and test. Internal Metrics should cover and report, follow-up to customer can be via email.
Impact Scalability	To test impact takes time to scan, measure, and then track to see if any business goal of recruitment or purchase was generated.	Easily scaled and tested for immediate results, follow-up can be tested at timed intervals	Depending on response rate may take days or weeks
Target Customers	Marketing, Recruitment	Sales, Operations, HR, Customer Support, Marketing	Sales Operations and Sales Management
Target Buyer Persona	Field Marketing Executives, HR Recruitment ex. Director of Recruiting, CHRO, VP Field Marketing	HR Education, Training Specialists ex. VP Training and Development, CLO	Head of Sales, National or Regional Sales Management
Customer Expectations	Wow experiences that people remember	Transfer of key skills and knowledge	Speed Sales and Close deals

Figure 13. Screenshots of VR environments of D3D

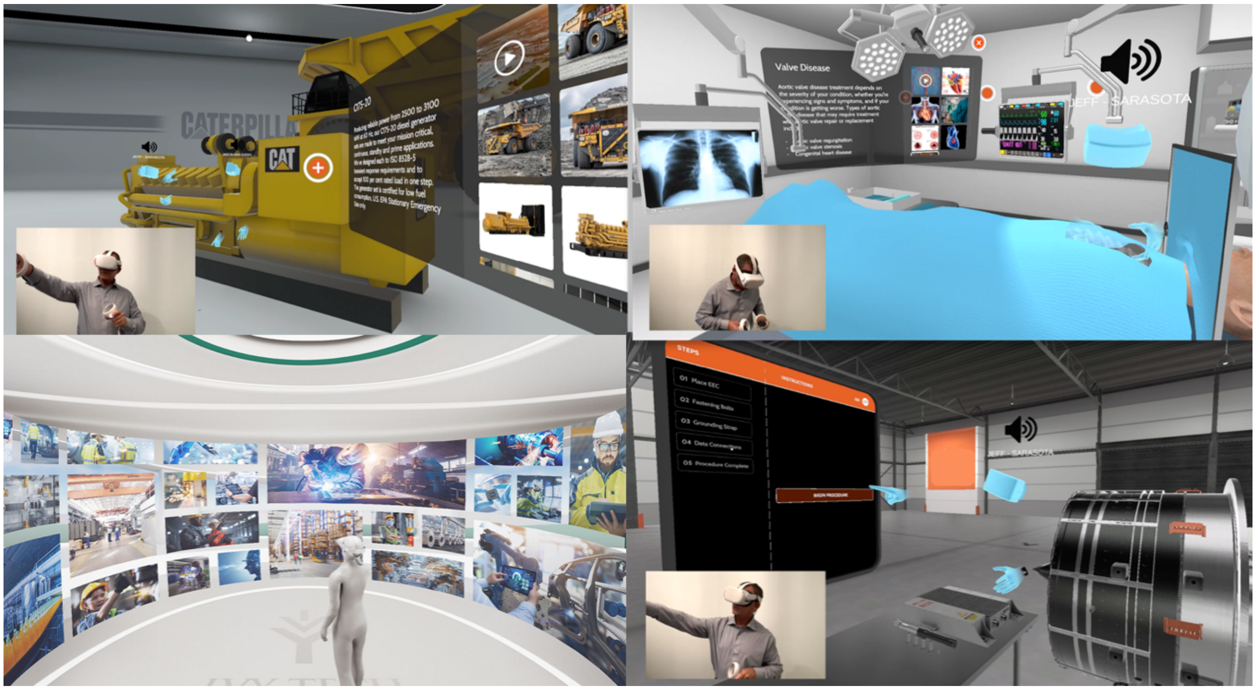


Figure 14. Learning Science Theories

Learning Science Theory	VR Training Feature	Predicted Behavioral Outcome	PPE Example
Seductive Details	**Quirky objects & animations**	**Decrease retention/transfer**	**Fly paper dangling from ceiling with buzzing**
Embodied Cognition	Non-Congruent Gesture	Decrease retention/transfer	Moving hand controller in a circle to lift a jacket
Disfluency	Harder to read text curved, embedded,	Increased retention/transfer	Using a Magnify glass to read fine print
Self-explanation principle	Self-Talks aloud to explain actions	Increased retention/transfer	Trainee asked to talk out loud
Yerkes-Dodson Law	**Simulate 'explosion' arousal/stress**	**U shaped ability to recall procedures**	**Gas leak in room, water leak, sparks**
Frame of Reference	Rate the Trainer first, then do	Increased retention/transfer	Watch virtual person do the procedure and rate it
Irreverent Speech	**Background A/V**	**decreased retention/transfer**	**Audio People on fake Walkie giving out orders or comments**
Split Attention Effects	Variable Media Streams of Instruction	decreased retention/transfer	Video Pop-up, Audio and subtitles

Homuncular Flexibility		Different POV's inc. NPC's	Increased retention/transfer	Character in Room switch to their POV
Proprioceptive		Zeroing in on corrective movement	Increased retention/transfer	make moving objects speed variable
Feed Forwards		Give a clue future logic	Increased retention/transfer	Pop-up hints
Retrieval Practice		Quizzing	Increased retention/transfer	Quiz at end of PPE
Spacing		Time delayed recall	Increased retention/transfer	Space out garment meaning or order
Interleaving		Cross Content learning	Increased retention/transfer	Cross-train with transformer build
Ego-Depletion		difficult pre-process	decreased retention/transfer	
Survival Processing Advantage		**A/V fear survival hyper-focus**	**Increased retention/transfer**	**outline of last VR trainees**

Figure 15. SMART AIM Change Diagram

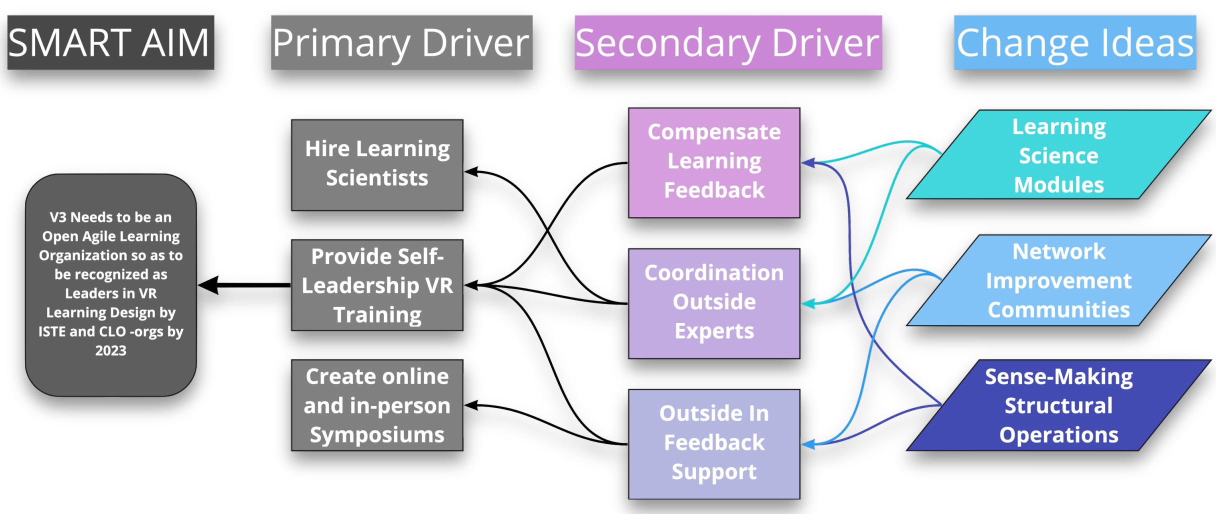
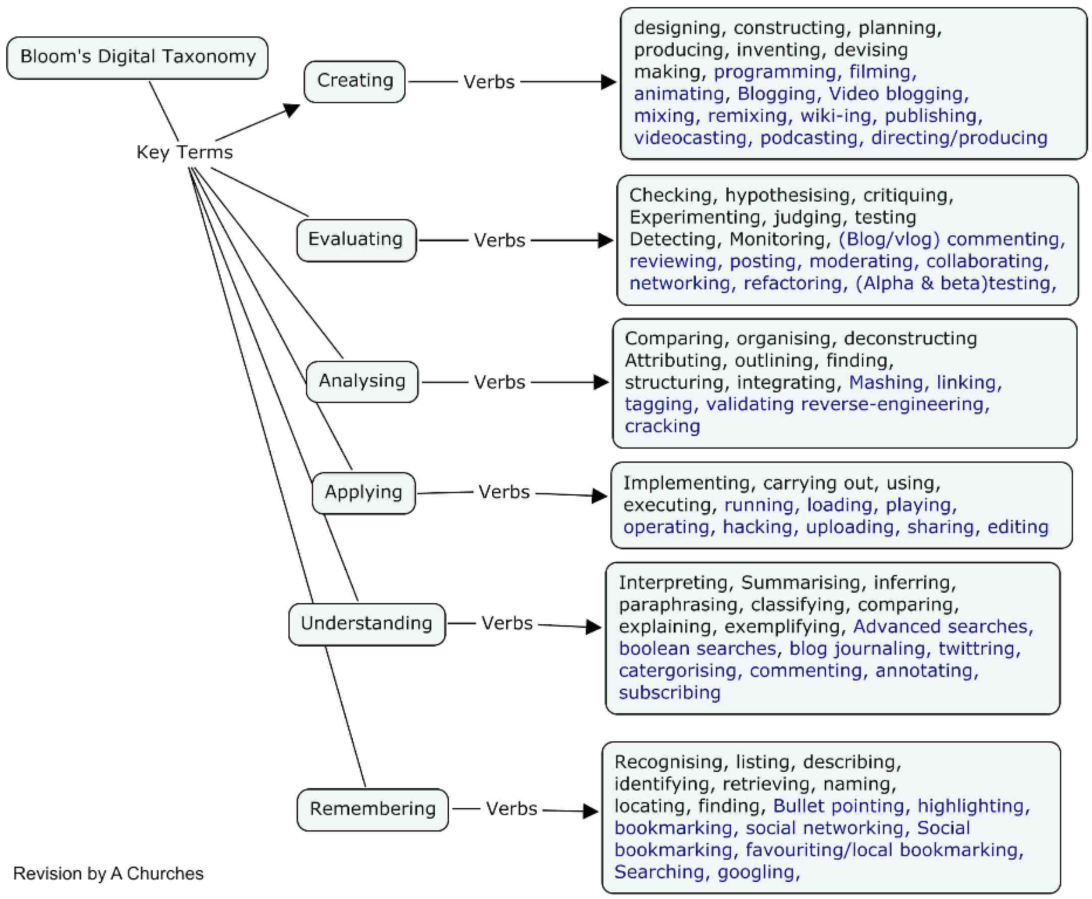


Figure 16 Bloom's revised digital verbs from A. Church

Bloom's revised digital taxonomy map



Drawing 3: Mind map of Bloom's Revised Digital Taxonomy

Key:

Elements colour in black are recognised and existing verbs, Elements coloured in blue are new digital verbs