A Suite of Devices: Applying the Immersive Flow Learning Outcome Framework to Training Program Immersive Device Acquisitions

Victoria Snow, Maj
United States Air Force
Eglin AFB, FL
Victoria.snow.1@us.af.mil

Dr. Andrew Clayton, Lt Col
United States Air Force - Reserve
Maxwell AFB, AL
Andrew.clayton.7@us.af.mil

ABSTRACT

Immersive learning technology presents an innovative solution for training that potentially offers easily accessible high-fidelity training experiences at a lower cost than traditional methods. However, this technology can also present learning challenges and limitations when not applied purposefully. To avoid these challenges, immersive learning device acquisitions must be results-driven, focusing on desired learning outcomes that drive immersive learning device requirements. As the proliferation of immersive learning devices increases and leaders delve into the world of immersive learning technology, they should be cognizant of both the learning efficiencies and challenges that immersive learning devices can present and aim to find a balance between them.

Leaders must also be aware that the initial innovators required complex solutions, had extensive monetary freedom, and were charged to experiment with the feasibility of immersive technology capabilities. Now that immersive learning devices have shown promise in making training more efficient and effective; leaders must know how to properly write device requirements that fit their training programs because innovation only matters if efficiency and effectiveness improve.

This paper proposes an Immersive Flow Learning Outcome (I-FLO) framework for guiding immersive learning device requirements for training programs. The I-FLO framework consolidates concepts presented by Flow Theory, the Cognitive Affective Model of Immersive Learning (CAMIL), and the Taxonomy for Immersive Experience Design. The framework targets increased efficiency and effectiveness by optimizing the potential learning gains presented by immersive learning devices while mitigating these devices' simultaneous challenges. The I-FLO framework will guide leaders in building efficient and effective immersive training programs that properly cover the spectrum of learning at the appropriate levels.

ABOUT THE AUTHORS

Major Victoria Snow is the Standardization and Evaluation Chief of Trainer Flight Operations assigned to Headquarters Air Force Materiel Command at Eglin Air Force Base. Before this assignment, Major Snow was an instructor pilot at Air Force Rotary Wing Specialized Undergraduate Pilot Training, where she helped set up the Helicopter-Only Pilot Training Next program. Major Snow, a career helicopter pilot, is a command evaluator and instructor pilot who has spent over 1400 hours in the UH-1N, TH-1H, HH-60G, T-6A, and DA-20. She has a bachelor's degree in political science, is a distinguished graduate of Squadron Officer School, and is a member of the Reserve Officer Training Corps Detachment 340 class of 2013.

Dr. Andrew Clayton is an Assistant Professor at Air University, teaching leadership and experiential learning topics. Dr. Clayton also guides AU's past Innovation and Technology Research Task Force and current two-term Immersive Learning and Technology elective. He is a 1999 Purdue University graduate who holds a Masters in Adult Education and Training. Dr. Clayton is certified as a Master Instructor and Distance Learning Instructor and holds a Doctorate in Organizational Leadership with an emphasis in Higher education. He served in the United States Air Force as an active-duty maintenance officer, an academic affairs officer, and an Air Force Reserve Command instructor. Dr. Clayton has served as a master instructor, course director, program manager, and academic advisor for 12 years, spending more than 8,000 hours of classroom instruction at AU.

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INTRODUCTION

It can be tempting for programs entering the world of immersive learning to see the capabilities of immersive learning devices and want to force-fit them into a training program. When applying technology to learning, however, it is important to note that more expensive technology does not necessarily translate into better learning outcomes. To prevent budget constraints from stalling or even terminating the progress made in immersive learning innovation, acquirers must execute due diligence when deciding the required level of immersion.

There are many recent examples of applied immersive learning in industry. In 2017, United Parcel Service (UPS) started using virtual reality (VR) training programs to enhance employee training. Then, in 2020, when the coronavirus impacted industries across the country, UPS saw another need and justification for implementing VR training using the HTC Vive headset, and the results have shown a wide array of training opportunities for more than half a million employees (Viar, 2021). Similarly, in 2018, Walmart leaned forward to better train its employees by introducing VR training. With much success, Walmart's integration of the Oculus GO headset created a turning moment within the company. As a result, Walmart invested in sending four Oculus GO headsets to every Walmart Supercenter to implement more than 17,000 Oculus GO headsets in stores by the end of 2018 (Incao, 2018). The sporting industry has turned to VR as well. Win Reality (Win, 2024) has developed VR baseball training using the VR Oculus 2 headset and the Mixed Reality (MR) Oculus 3 headset. In law enforcement, the Apex Officer interactive VR simulation training system ("Apex Officer," n.d.) is being implemented across several federal, state, and local law enforcement agencies. Through the Apex Officer VR simulation, participants don an HTC Vive headset. They can interact, move freely in a virtual simulation, and practice a wide range of law enforcement skills, such as de-escalation training and active shooter scenarios. Similarly, industries such as the aerospace industry are using the Varjo Extended Realty (XR) and Mixed Reality (MR) headsets to support the United States (U.S.) Marine Corps pilot training and other Department of Defense (DoD) organizations, such as Joint Terminal Attack Control (JTAC) training, are also using XR/MR Vajro headsets.

What process, steps, or framework did each industry use to determine what headset to procure and use within their company or organization to fulfill the learning outcome needed? Why did Walmart choose the Oculus GO headset? What was Win Reality's justification for using the Oculus 2 and Oculus 3 headsets? What immersive elements are needed for DoD pilot training that require the HTC Vive or Varjo headsets?

The common denominator in these examples is the need for more immersive learning and training experiences within these industries. What is quite different with these industry examples is that no device meets all industry needs, requirements, or learning objectives. The examples demonstrate the spectrum of immersive devices from the simple Oculus GO headset, Oculus 2 headset, Oculus 3 headset, and HTC Vive headset to the Extended Reality (XR)/Mixed Reality (MR) Vajro headset. Those examples above provide a snapshot of the complexities of needed learning outcomes and requirements with what devices best meet those needs. Each device provides different levels of immersion, presence, and other elements found in the Immersive Experience Taxonomy chart and part of the Immersive Flow Learning Outcome (I-FLO) framework.

Consequently, immersive learning device capability requirements must be derived from desired learning outcomes with an eye toward the level of immersion most effective for achieving a set of desired outcomes. The I-FLO framework guides device requirements based on desired learning outcomes within a training program. It is a five-step process that applies immersive learning efficiencies and challenges presented by the Cognitive Affective Model of Immersive Learning (CAMIL) to the Flow Theory model of effective learning. I-FLO leverages the immersive element concepts presented by the Taxonomy for Immersive Experience design and presents cost consolidation strategies for training programs. The I-FLO framework ultimately gives leaders a tool to aid in selecting the most effective and efficient immersive devices for their diverse training programs.

Several terms related to immersion, immersive devices, and immersive learning will be referenced throughout this paper. The definitions of these terms are in Appendix A.

IMMERSIVE FLOW LEARNING OUTCOME (I-FLO) FRAMEWORK

Immersive learning device research suggests that the potential learning gains presented by these devices are only realized if the learners have the appropriate skill level to mitigate the simultaneous challenges these devices present (Makransky & Petersen, 2021). To balance learning gains while mitigating challenges, a new framework is needed to determine the required level of immersion for a given set of desired learning outcomes and determine the most appropriate immersive technology requirements. Integrating Flow Theory, the Cognitive Affective Model of Immersive Learning (CAMIL), and Ruscella and Obeid's (2021) Taxonomy for Immersive Experience Design generates a framework for selecting a cost-effective device for training programs desiring to implement immersive learning technologies. The integration of these three frameworks answers three essential questions:

(1) What level of immersion is needed to meet the user's requirements?

(2) How can immersive technology create the optimal flow state for the user?

(3) What level of learning outcome best supports the optimal flow state?

This new integrated framework is termed Immersive Flow Learning Outcome (I-FLO). It synthesizes one psychological learning theory and two conceptual models into a unified immersive flow learning outcome-based framework that can help determine the appropriate use of immersive technology to meet users' needs and requirements for various training and education programs.

Conceptual Theories

The first element of the I-FLO Framework is the foundation of a psychological theory known as Flow Theory. Flow Theory suggests that three conditions must be met for students to enter an optimal state of full engagement with the learning environment. There must be clear goals, immediate feedback, and a balance between challenges and student ability (Taylor & Clayton, 2021). Similarly, Aziz and Ghonsooly (2015) posit that learning occurs when the task is characterized by the skills-challenge balance and the learner's concern, control, and intense focus within the learning moment. Flow Theory explains the interactivity between the learner and the presented content. More specifically, flow theory highlights the learner's various affective states. The amount of challenge to learn or complete a task combined with the learner's skill level will determine the learner's various affective states of mind. These affective states of mind will range from anxiety, worry, apathy, boredom, relaxation, control, arousal, and flow. Since education and training programs aim to transfer knowledge to the learner, they should maximize flow. Flow theory supports the notion that learning is not rooted in the type of technology used in a training or education program but in the level of immersion that will create the most effective state of mind so that the learner can best gain and transfer knowledge.

The second element of I-FLO is the integration of the Cognitive Affective Model of Immersive Learning (CAMIL). CAMIL suggests that instruction effectiveness in immersive environments depends entirely on utilizing instructional methods that take advantage of the medium in which instruction occurs (Makransky & Petersen, 2021). Suppose educators plan to utilize immersive learning devices to conduct instruction. In that case, they must consider the learning advantages afforded by immersive devices and the challenges presented if they wish to achieve desired learning outcomes. Additionally, the CAMIL model shows the importance of immersion and presence using immersive technology. CAMIL theorizes that the type of immersive technology used for learning influences the type and amount of presence and agency a user will obtain. Through presence and agency, knowledge (factual, conceptual, procedural, and transfer) is gained due to affective and cognitive factors. Some of these factors, according to the CAMIL model and Makransky and Petersen (2021), are (1) interest, (2) motivation, (3) self-efficacy, 4) embodiment, (5) cognitive load, and (6) self-regulation. Therefore, CAMIL provides the second concept model for the I-FLO framework and helps define the importance of several affective and cognitive factors that influence learning and experience when introducing immersive technology into a training or education program.

The third conceptual component of I-FLO is the Taxonomy for Immersive Experience Design, which defines the degrees of immersion across a set of criteria. Immersion and presence are two foundational pillars of the Taxonomy for Immersive Experience Design that have an outsized impact on learning outcomes. Ruscella and Obeid (2021) postulate that technology alone is not the answer to making a training or education program more immersive. Instead, the real impact rests with the quality and artistry of the elements found within the learning content. Taxonomy provides more than 1.9 million possibilities (Ruscella & Obeid, 2021) to develop a training or education program to be more immersive, creating a more robust sense of presence for the user. When observing the CAMIL model and the Taxonomy for Immersive Experience Design, we can see how both models are intertwined in answering the above questions.

When all three theories are combined and applied to a program of immersive instruction, the optimal learning flow afforded by immersive devices can be achieved. Ultimately, this framework will guide leaders in determining immersive learning device requirements to keep students in a flow state of learning to achieve desired learning outcomes. This new framework, I-FLO, answers the three questions stated above while guiding technologists, instructional designers, content developers, educators, and other training personnel to the most effective means of creating immersive training experiences with the right technology. This supports the acquisition community in decision-making related to appropriate immersive technology.

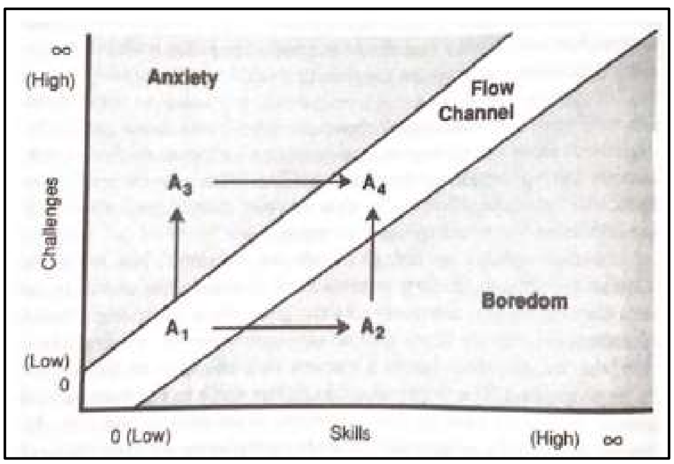

Figure 1. Flow Channel

Flow Theory

Flow theory is the basis for developing the I-FLO framework and aligns with CAMIL and the Taxonomy for Immersive Experience Design. It suggests productive learning results from appropriately matching challenges to student skill levels (see Figure 1). As students enter training, the challenges they are presented with should match their skill levels (A_1). If a learning environment presents too great a challenge for students' skill levels, the students will be driven into an anxious state of learning (A_3). On the contrary, if the challenges of a learning environment do not progress enough to match students' increase in skills, those students will be driven into a state of boredom in training (A_2). If students' increasing skills are consistently matched with increasing challenges, they will maintain engagement and productivity within their learning environment (Taylor & Clayton, 2021). Training programs seeking to employ immersive learning devices should be aware of the challenges presented while learning new material compounded with learning how to learn in an immersive device. The I-FLO framework helps acquirers avoid needlessly increasing the challenge of learning induced by requiring complex and unfamiliar technology that requires mastery to use effectively. As student skill levels increase throughout a training program, immersion can be leveraged to induce unique challenges and prevent boredom. Finding and sustaining a student's optimal flow state throughout a training program ensures the most efficient implementation of training.

Cognitive Affective Model of Immersive Learning (CAMIL)

CAMIL outlines the six affective and cognitive factors affected by presence and agency within immersive learning environments and how they ultimately impact potential learning outcomes (factual, conceptual, procedural, and transfer learning). To create a positive learning experience, an immersive learning environment's instructional design should leverage the realism that presence and agency can afford by encouraging high levels of situational interest, intrinsic motivation, self-efficacy, embodiment, and self-regulation while maintaining a manageable cognitive load level (Makransky & Petersen, 2021).

High levels of presence in immersive environments can elevate an experience as "novel and intense" (Makransky & Petersen, 2021, p. 944), which can pique situational interest. Consistent situational interest can develop into individual interest, further driving learner motivation. Additionally, presence positively affects motivation by increasing enjoyment in the activity, while higher agency gives learners a perspective of autonomy and increases a learner's perception of control. This perceived control increases the perceived value of a task and influences enjoyment in the learner (Pekrun, 2006).

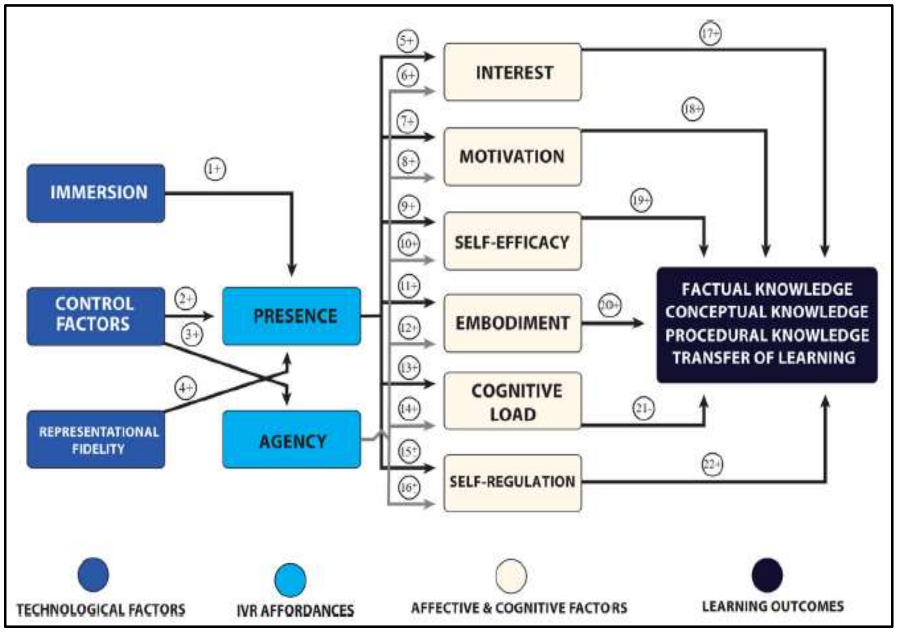

Figure 2. Overview of CAMIL

Both high levels of presence and agency afforded by virtual reality allow users to interpret their experiences as real. This gives learners a sense of accomplishment and a perception of capability (Makransky & Petersen, 2021). Using avatars to create high levels of embodiment enhances self-presence and allows learners to perceive their actions in virtual reality as their own. Watching and controlling the actions of a virtual body cognitively associates actions and ultimately increases knowledge retention (Makransky & Petersen, 2021). Conversely, cognitive load and self-regulation are two potential challenges presented by the high levels of presence and agency in immersive learning environments. Virtual learning environments are associated with high cognitive loads due to the increased presence afforded by a greater field of view and the amount of additional information presented in an entirely virtual environment. It is crucial to consider the effects of a high cognitive load on learners due to the need to filter out irrelevant information in the environment. This requirement to filter extraneous information can distract introductory-level learners unfamiliar with the material (Makransky & Petersen, 2021). Self-regulation must be facilitated by the "instructional design components" (Makransky & Petersen, 2021, p. 947) to help prevent hedonic activities associated with the learning environment's entertaining and engaging aspects rather than the desired reflection on knowledge transfer.

The six factors of the CAMIL influence the feasibility of utilizing immersive learning devices for certain desired learning outcomes (see Figure 2). Makransky and Petersen cite several studies that compare the effectiveness of immersive learning for factual, conceptual, procedural, and transfer of learning. Factual learning encompasses "knowledge of discrete, isolated content elements" (Makransky & Petersen, 2021, p. 948). According to studies by Parong and Mayer (2018) and Meyer et al. (2019), PowerPoint and desktop computer training were more effective than immersive instruction for factual learning outcomes. This encourages the continued use of non-immersive learning to present factual knowledge in training programs. Parong and Mayer (2018) also found no significant difference between PowerPoint and immersive instruction for conceptual knowledge. Conceptual knowledge includes more complex "classifications and categories, principles and generalizations, and theories, models, and structures" (Makransky & Petersen, 2021, p. 948). Procedural knowledge, or the knowledge required to complete a task, is the most targeted learning outcome for immersive instruction (Radianti et al., 2020). Immersive instruction allows early introduction to tasks considered "difficult or dangerous to train in real life" (Makransky & Petersen, 2021, p. 948). For example, a student who learns to fly an aircraft in virtual reality can later implement flying skills in real-world aircraft (Makransky & Petersen, 2021). This is an example of transfer of learning, which occurs in one situation and carries abilities into other situations. Transfer of learning tends to occur in advanced training phases and can be optimized with immersive learning.

In addition to the six factors influencing learning outcomes, CAMIL references the importance of studies by Meyer et al. (2019) that stress the importance of pre-training a subject before utilizing immersive learning devices for instruction. Prior knowledge of a subject positively affects students' application of presence and agency within immersive learning environments. Immersion without pre-training on a subject will misdirect the presence and agency afforded by immersive devices. The students interpret their experiences in a manner that increases knowledge retention, transfer, and self-efficacy. Conversely, students without prior knowledge of a subject receive entertainment value from the presence and agency in immersive environments but lack the knowledge foundation to effectively interpret their experiences (Makransky & Petersen, 2021). This suggests that introductory-level students in a training program should receive a level of pre-training prior to utilizing immersive devices to ensure the students are prepared to take advantage of the presence and agency afforded by immersive learning environments in a manner that positively affects knowledge retention.

CAMIL's findings suggest that not just the level of immersion affects learning outcomes in immersive environments but also how well the instruction design utilizes the advantages of presence and agency in immersive environments. Does the instruction design pique interest and motivation by leveraging self-efficacy and embodiment while appropriately balancing cognitive load and self-regulation requirements? As part of instructional design, pre-training requirements are also essential to ensure training effectiveness. It is crucial to identify desired learning outcomes to fully take advantage of presence and agency in immersive environments to maximize the six affective and cognitive factors that drive learning outcomes.

Taxonomy for Immersive Experience Design

J.J. Ruscella and Dr. Mohammad Obeid (2021), from *Access VR*, created *A Taxonomy for Immersive Experience Design* (see Figure 3) to guide designers in creating immersive learning programs. It ranks ten immersion elements across varying degrees of immersive experience that each element can exhibit. Each element of immersion relates to an aspect of immersive device technology that can be adjusted based on the user requirements. Therefore, these criteria should be used by training program managers when determining the appropriate combination of immersion levels deemed necessary to achieve training goals. (Ruscella & Obeid, 2021).

The overarching definitions of each element are listed below (Ruscella & Obeid, 2021):

(1) Interactivity: User's level of engagement with the environment
(2) Embodiment: Gap between the user and the experience
(3) Co-Participation: Maximum number of users at a given time
(4) Story: Context and narrative journey
(5) Dynamics: User's ability to influence the outcome
(6) Gamification: Rules or outcomes that induce play or competition
(7) Immersive Technology: Types of technology used
(8) Meta Control: User's control over the environment
(9) Didactic Capacity: Degrees of learning within the experience
(10) Data: User-specific data recorded and how it is used

DEGREES	INTERACTIVITY	EMBODIMENT	CO-PARTICIPATION	STORY	DYNAMICS	GAMIFICATION	IMMERSIVE TECH	META CONTROL	DIDACTIC CAPACITY	DATA
0	Passive	Detached	Single-Player	None	Pre-determined	None	None	None	Elemental	Anonymous
1	Interactive	Watcher	One-on-One	Setting	Choice	Instruction	Augmented Reality (AR)	Journey	Explicit	Identity
2	Problem Solving	First-Person Point-of-View	Group	Pre-Created	Free Will	External Process	360° Media	Character	Implicit	In-Game
3	Physicalized	Movement	MMO	Choose Your Own	Convo-Reality	Reinforcement	Virtual Reality (VR)	World Editor	Recall	Personalized
4	Interpersonal	Human-to-Human Interaction	Secondary Perspective	Interactive Story	Adjustable Point-of-View	Reward System	Extended/Mixed Reality (XR/MR)	World Builder	Synthesis	Biometrics

Figure 3. Taxonomy for Immersive Experience Design

See Appendix B for definitions of each degree within the ten elements of the Taxonomy for Immersive Experience Design (Ruscella & Obeid, 2021).

It is especially important to note that only one factor of immersive learning references the type of immersive technology being utilized. This emphasizes the weight that immersive environment design holds regarding its influence on the learning experience, as nine of the ten immersion elements are environmental rather than hardware. The I-FLO framework considers this by implementing a Degree of Immersion range as the driving factor behind requirements for each Desired Learning Outcome instead of defining required technology.

The I-FLO Framework

The I-FLO framework for selecting the appropriate suite of devices for a training program applies the studies cited by CAMIL regarding the effectiveness of immersive learning devices for each learning outcome to Flow Theory's Flow Channel diagram. It considers the importance of pre-training to ensure experience interpretation that results in knowledge transfer. The key to optimizing learning outcomes is to balance anxiety and boredom within the flow channel to challenge students to match their skill levels appropriately. As students progress past the factual and conceptual phases of learning and into procedural and transfer states of learning, an increase in immersion can be leveraged to keep students engaged in the flow channel.

Applying the full framework to a training program is a five-step process that begins with identifying desired learning outcomes for each training stage using the descriptive statements by Krathwohl (2002), outlined in Table 1 below, from the article *A Revision of Bloom's Taxonomy: An Overview.*

Table 1. Structure of the Knowledge Dimension

The Knowledge Dimension	Description
Factual Learning	"Basic elements that students must know to be acquainted with a discipline or solve problems in it" (Krathwohl, 2002, p. 214).
Conceptual Learning	"The interrelationships among the basic elements within a larger structure that enable them to function together" (Krathwohl, 2002, p. 214).
Procedural Learning	"How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, methods" (Krathwohl, 2002, p. 214).
Transfer (Metacognitive) Learning	"Knowledge of cognition in general as well as awareness and knowledge of one's cognition" (Krathwohl, 2002, p.214).

Once the desired learning outcome(s) is/are identified for each stage of training, managers can utilize the Immersive Flow Learning Outcome Framework (Figure 4) to identify the degree of immersion range that will keep students in the flow channel during each stage of instruction. The resulting degree of immersion range provides a target to aim for when determining immersion element requirements. For example, training devices that provide an average degree of immersion between 0 and 1 reflect the appropriate immersion level for factual knowledge.

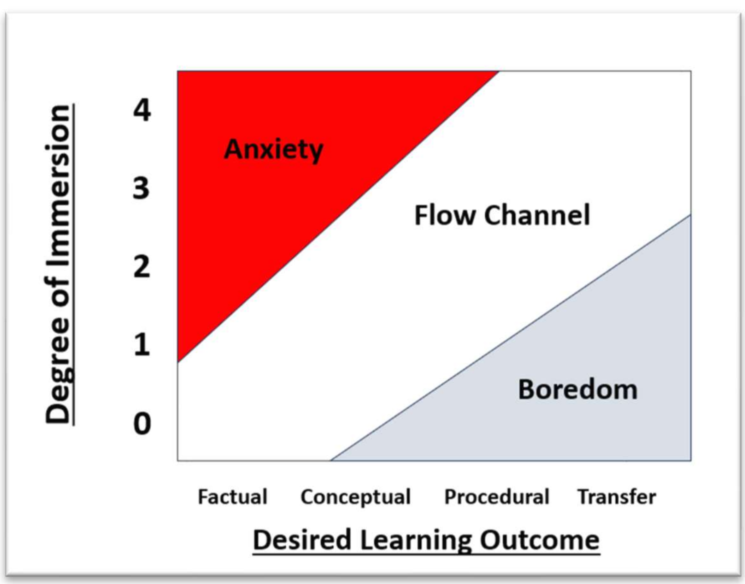

Figure 4. Immersive Flow Learning Outcome (I-FLO)

Program managers should then select degrees of immersion for each element on the Taxonomy for Immersive Experience Design table (Figure 3), resulting in an average degree of immersion within the degree of immersion range identified for the corresponding desired learning outcome. Since the resulting degree of immersion is based on an average of all elements selected, the user may omit elements as necessary or select multiple immersion characteristics within each element on the Taxonomy for Immersive Experience Design table.

Cost considerations must then be carefully analyzed for potential applications of cost optimization strategies. If immersive learning devices are only used for one stage of training, leaders can span degrees of immersion to draft requirements that will allow for cost comparisons. For example, suppose a law enforcement training program plans to utilize immersive devices for the sole purpose of teaching recruits how to conduct a traffic stop. In that case, the desired learning outcome is transferring knowledge to a real-world scenario. The I-FLO framework suggests a 3-4 Degree of Immersion range to keep students in the flow state for knowledge transfer. In this case, the program manager should draft at least two sets of requirements within the 3-4 Degrees of Immersion range that meet their training needs. This will allow for cost comparisons between the varying device capabilities.

In the instance where the utilization of immersive learning devices will span the entirety of a training program, program managers should be aware of two optimization strategies that offer potential cost savings:

1) Different Training Stages with Same Desired Learning Outcomes: Sometimes, utilizing the same instructional medium across varied curricula can incur cost savings. As students progress through a training program, new concepts are often presented with introductory-level desired learning outcomes. Using pilot training as an example, students begin with factual learning of aircraft dimensions and limitations. They then proceed to conceptual learning encompassing aerodynamics and how aircraft systems work. Following this, they progress to procedural learning to start the aircraft. Lastly, they conduct transfer learning, where they learn how to apply what they have learned to conduct basic maneuvers in the aircraft. As new concepts are presented, students may flow back through these phases, beginning with factual learning. For example, a flight student learning to fly in formation will begin again with factual learning of formation positions and spacing. Then, proceed through the conceptual and procedural phases, and eventually transfer learning phases to put all the numbers, positions, maneuvers, and procedures into motion to fly a formation flight. Program managers should identify these different training stages with the same Desired Learning Outcomes to appropriately identify which elements of the Taxonomy for Immersive Experience Design will meet all training requirements. This will allow devices to be utilized across the entire training program for stages with similar Desired Learning Outcomes.

2) Overlapping Degrees of Immersion: Sometimes, utilizing the same instructional medium across varied Desired Learning Outcomes can incur cost savings. This cost optimization involves consolidating device utilization across training stages with different Desired Learning Outcomes but overlapping degrees of immersion technologies as depicted in Figure 5. Considerations regarding initial device development costs, such as unique software design or part design labor, should be made. For example, the cost of an immersion-level-2 device may be justified for conceptual learning if that device can also be used for procedural training.

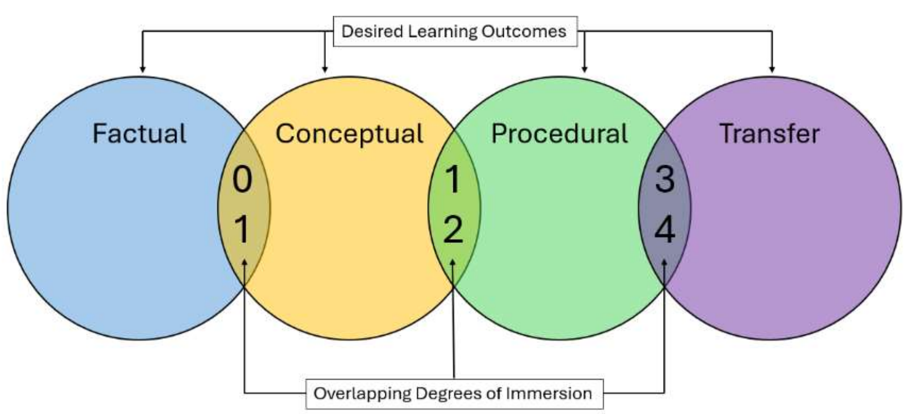

Figure 5. Overlapping Degrees of Immersion

The final step requires the acquirers to draft immersive learning device requirements based on the results of steps one through four. These requirements should give a target degree of immersion for each training device. They should detail the degrees of immersion required to achieve the desired learning outcomes using immersive element degree descriptions from the Taxonomy for Immersive Experience Design. The specificity of initial requirements for each device will depend on the training event requirements but should be defined as device capabilities rather than technical limitations. For example, for a device that requires a look-through capability to see physical maps while flying in virtual reality, acquirers should define this need. However, they should not be so specific to limit how that capability is met. This will allow for a greater variety of potential solutions for requirements. Lastly, the number of devices required for each level will depend on the size of classes, the timeframe for instruction, and the number of individuals each device can accommodate at a given time. This will appropriately guide developers in the creation of training devices meeting the required levels of immersion within a training program.

Example Application of I-FLO

To better provide an understanding of the I-FLO framework, we will use a current and relevant military example from undergraduate helicopter pilot training. In 2020, the United States Air Force charged pilot training units with implementing immersive learning in the undergraduate pilot training syllabus. They deemed this project Pilot Training Next. Pilot training units developed immersive device requirements based on previous training plans, conversations with the industry about device capabilities, and small group tryout trial and error. Applying the I-FLO framework could have determined these instances' most effective and efficient immersive learning device requirements. The following is how the I-FLO framework can be applied to a training program, using a sample undergraduate helicopter pilot training syllabus to demonstrate the process:

Step 1) Identify the Desired Learning Outcome for the targeted stage(s) of the training program.

In this example, the I-FLO framework is applied to all stages within the sample syllabus that can either be replaced or supplemented by immersive learning devices (see Table 2). One specific example is "Aircraft Start/Shutdown" training, a substage of "Preflight/Postflight" training. For this substage of training, students receive instruction on the proper procedures for starting the aircraft before a flight and shutting it down afterward. Students must also be able to follow start/shutdown procedure checklists and execute the proper procedures in a simulated aircraft environment. Conducting this training in an immersive learning environment allows the student to accomplish a specific task or series of tasks safely before conducting these tasks in the physical aircraft. This meets the definition of procedural learning. The "Step 1, Desired Learning Outcome" column in Table 2 shows the results of this analysis completed for all 33 substages of training. This will aid in determining which stages should utilize computer-based desktop training and which stages should leverage immersive learning devices.

Table 2. I-FLO Applied to a Sample Undergraduate Helicopter Training Program

Training Stage	Training Substage	Step 1 Desired Learning Outcome	Step 2 Degree of Immersion Range	Step 3 Required Average Degree of Immersion
Initial Academics	Introduction to Professional Flying	Factual	0-1	0.3
	Flight Publications	Factual	0-1	0.3
	National Airspace	Factual	0-1	0.7
	Weather	Factual	0-1	0.7
	Introduction to Aircraft	Factual	0-1	0.3
	Aircraft Systems	Conceptual	0-2	1.3
	Aerodynamics	Conceptual	0-2	1.3
	Crew Resource Management	Conceptual	0-2	0.7
Preflight/Postflight	Aircraft Preflight Inspection	Procedural	1-4	1.8
	Ramp & Refueling Procedures	Procedural	1-4	1.8
	Aircraft Start/Shutdown	Procedural	1-4	2.1
Contact Maneuvers	Contact Maneuver Academics	Factual	0-1	0.3
	Airfield Operations	Conceptual	0-2	1.3
	Perform Contact Maneuvers	Transfer	3-4	3.7
Emergency Procedures	Malfunction Analysis Academics	Factual	0-1	0.3
	Malfunction Corrective Procedures	Procedural	1-4	2.1
	Perform In-Flight Emergency Procedures	Transfer	3-4	3.8

Instruments	Instrument Academics	Factual	0-1	0.3
	Instrument Navigation, Approaches, Departures, & Holding	Conceptual	1-4	1.3
	Instrument Maneuvers (Takeoffs, Turns, Climbs, Descents)	Procedural	1-4	2.1
	Perform Instrument Flight	Transfer	3-4	3.7
Day Mission	Remote Operations Academics	Factual	0-1	0.3
	Landing Site Reconnaissance Procedures	Procedural	1-4	2.1
	Perform Remote Site Operations	Transfer	3-4	3.7
	Low-Level Operations Academics	Factual	0-1	0.3
	Route Navigation & Site Planning	Conceptual	0-2	1.3
	Perform Low-Level Flight & Maneuvers	Transfer	3-4	3.8
	Introduction to Formation Procedures	Procedural	1-4	1.3
	Perform Formation Flight & Maneuvers	Transfer	3-4	3.8
Night Mission	Night Academics	Factual	0-1	0.3
	Night Vision Device Familiarization	Conceptual	0-2	0.7
	Perform Mission Operations at Night	Transfer	3-4	3.8

Step 2) Utilize the I-FLO framework to identify the Degree of Immersion range.

The I-FLO framework designates a degree of immersion range that maintains the learning flow for each desired learning outcome. Figure 6 demonstrates how to identify the appropriate degree of immersion range for each desired learning outcome, using procedural knowledge as an example. The "Step 2, Degree of Immersion Range" Column in Table 2 shows the results of this analysis completed for all four desired learning outcomes across the curriculum's sample stages.

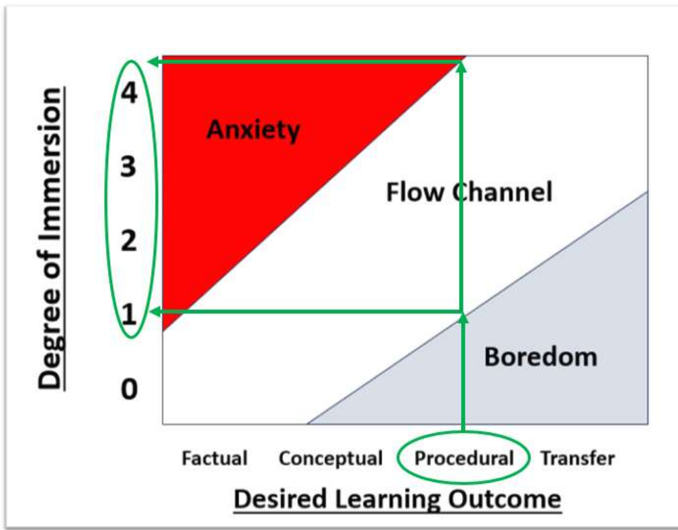

Figure 6. I-FLO Framework Applied to Procedural Learning

Step 3) Identify the elements of immersion on the Taxonomy for Immersive Experience Design that will result in an average degree in the targeted degree of immersion range.

Figure 7 depicts the results of implementing step 3 for the "Aircraft Start/Shutdown" substage as an example. A degree of immersion is selected for each element as it applies to a student conducting aircraft start and shutdown procedures. This substage of training requires a physical representation of the student to align with and train muscle movements, meaning it needs a physicalized avatar. The embodiment demands the ability to move arms and legs at a minimum. The story element remains in a single setting, as the training occurs in a stationary environment within the cockpit. It is only intended for one student at a time, making it single player. Since students need to execute procedures independently and learn from their mistakes, the design demands free will and reinforcement capabilities. For determining immersive technology, either virtual reality or extended/mixed reality could meet the requirements; since this substage is early in training, virtual reality is selected to allow for ease of access to devices for new students. Students should not have meta-control to edit their journey, character, or environment to ensure they do not modify the procedures they are being taught. Instructional capacity for this substage demands a synthesis between the student and what they have previously learned to conduct proper start/shutdown procedures within the immersive environment. Lastly, in-game data collection can be leveraged for this substage to identify improperly executed procedures upon completion of the training.

DEGREES	INTERACTIVITY	EMBODIMENT	CO-PARTICIPATION	STORY	DYNAMICS	GAMIFICATION	IMMERSIVE TECH	META CONTROL	DIDACTIC CAPACITY	DATA	
0	Passive	Detached	Single-Player	None	Pre-determined	None	None	None	Elemental	Anonymous	
1	Interactive	Watcher	One-on-One	Setting	Choice	Instruction	Augmented Reality (AR)	Journey	Explicit	Identity	
2	Problem Solving	First-Person Point-of-View	Group	Pre-Created	Free Will	External Process	360° Media	Character	Implicit	In-Game	
3	Physicalized	Movement	MMO	Choose Your Own	Convo-Reality	Reinforcement	Virtual Reality (VR)	World Editor	Recall	Personalized	
4	Interpersonal	Human-to-Human Interaction	Secondary Perspective	Interactive Story	Adjustable Point-of-View	Reward System	Extended/Mixed Reality (XR/MR)	World Builder	Synthesis	Biometrics	
Degree of Immersion (DOI) Total	3	3	0	1	2	3	3	0	4	2	= 21

Average DOI = DOI Total ÷ # of Elements
= 21 ÷ 10
= 2.1

Figure 7. Immersive Elements for Aircraft Start/Shutdown Training Example

To find the average degree of immersion required by a training stage, add the degrees selected for all elements and divide that number by ten. For this example, the total degrees of all ten immersive elements equal twenty-one. The average resultant degree of immersion for the "Aircraft Start/Shutdown" substage is 2.1. This appropriately falls within the 1-4 degree of immersion range for procedural learning. The "Step 3, Required Average Degree of Immersion" column in Table 2 shows the results of this analysis for each substage of training and will aid in the cost consideration analysis in Step 4.

Step 4) Analyze cost considerations and determine the need for cost comparisons or device consolidation strategies. Costs should be determined based on the requirements to yield efficient and effective learning outcomes; successful learning is where true efficiency is achieved. The I-FLO framework intends to implement efficiencies through flow learning. This is why steps one through three apply learning theories to establish immersive learning device requirements before applying cost considerations and consolidation strategies. For the sample helicopter training program above, the results of step 3 can be analyzed through the lens of both cost optimization strategies.

Across the training program are groupings of substages with similar average degrees of immersion (ADOI). This is because there are different training stages with the same desired learning outcomes, yielding similar immersive element requirements. Additionally, overlapping degrees of immersion yield similar ADOI results, as in the case of factual learning of "Weather" and conceptual learning of "Crew Resource Management," yielding ADOIs of 0.7. Of the 32 substages of training, nine scored a 0.3 ADOI, four scored a 0.7 ADOI, six scored a 1.3 ADOI, two scored a 1.8 ADOI, four scored a 2.1 ADOI, three scored a 3.7 ADOI, and four score a 3.8 ADOI.

Once substages with similar learning outcomes are grouped, further cost efficiencies come from consolidating overlapping degrees of immersion. Substages with 0.3 and 0.7 ADOIs can be consolidated into a level 0.7 device. Additionally, CAMIL suggests that factual learning is best relayed via PowerPoint or desktop trainers (Makransky & Petersen, 2021). Cost efficiencies can be realized using PowerPoint or a desktop trainer rather than an immersive device for the substages with 0.3 and 0.7 ADOIs. Substages with 1.3 and 1.8 ADOIs can be consolidated into a level 1.8 device; likewise, substages with 3.7 and 3.8 ADOIs can be consolidated into a level 3.8 device. This leaves a requirement for one more device to cover substages with 2.1 ADOIs.

Step 5) Draft immersive learning device requirements detailing the degrees of immersion required to achieve the desired learning outcomes.
Based on step 4, this sample training program requires an immersive device suite covering the immersive spectrum from 1.8 to 3.8. Consolidation strategies suggest the acquisition of three devices that meet the following immersion and training requirements:

- **ADOI level 1.8 device** that has problem-solving level interactivity enables watcher level embodiment, group participation, choose your story style, an adjustable point of view, instruction level gamification, employing 360-degree media, journey level meta-control, and enables implicit learning, with no requirement for data collection. This device should accommodate conceptual-level learning of aircraft systems, aerodynamics, airfield operations, instrument navigation, approaches, departures and holding, route navigation and site planning, and formation procedures.

- **ADOI level 2.1 device** that is physicalized allows movement in a single-player environment, is based in a single setting that allows free will level decision making, with reinforcement level gamification within virtual reality (VR), synthesis level didactic capacity, and in-game data collection, with no requirement for meta control. This device should accommodate procedural-level learning of aircraft start and shutdown, malfunction corrective procedures, instrument maneuvers, and landing site reconnaissance procedures.

- **ADOI level 3.8 device** that is interpersonal, allows for movement, enables secondary perspective participation by instructors, presents an interactive story and adjustable point of view, gamifies instruction through reinforcement, is implemented in mixed reality (MR), allows for world builder inputs by instructors, requires synthesis of learning, and collects or utilizes biometric data. This device should accommodate transfer-level learning of full flight representations for contact maneuvers, in-flight emergency procedures, remote site operations, low-level flight, formation maneuvers, and night vision goggle flight.

Further specific requirements can then be added. For example, procedural training on aircraft preflight requirements may include “the ability to represent the physical aircraft, the ability to manipulate aircraft switches with true representation of all switch position effects, and the ability to induce, represent, and react to all aircraft start and shutdown engine malfunctions and corrective actions to such, to include ‘hot start,’ ‘hung start,’ and ‘no start’ malfunctions.” More complex training events will require more in-depth requirement specifications, such as “the ability switch between the representation of a night vision goggle environment while looking through simulated night vision goggles and a night environment while looking outside a simulated night vision goggle field of view and inside the simulated aircraft.” Although eye-tracking capabilities may be how this requirement is translated into a device, it is important to emphasize that it is the desired training result, not the type of technology used. This list should guide program managers in communicating the immersive device requirements that will optimize learning within their training programs.

LIMITATIONS WITH THE I-FLO FRAMEWORK

The I-FLO framework encompasses one psychological learning theory and two conceptual models into a unified immersive flow learning outcome-based framework. Integrating these learning theories and models into one framework comes with limitations that require further examination.

The first limitation is the learning curve for new technologies. The spectrum of immersive experiences can range from virtual to augmented to mixed reality, all of which can be classified under the term extended reality. How one defines these aspects of extended reality can also be challenging. When does one determine that the immersive experience device has created an augmented to mixed reality to a fully immersed virtual reality experience? Similarly, as devices become more advanced, the spectrum range becomes even more blurred, making it more difficult for the instructional system designer, educator, trainer, or instructor to determine the spectrum needed from the headset to create the immersive experience. A great example of this advancement in technology devices is the Apple Vision Pro headset and the function of the “digital crown,” which allows the user to transition their experience while in the headset from a virtual reality experience to a mixed reality experience. This type of functionality adjusts how virtual or augmented you want an experience to be, complicates the analysis within the I-FLO framework, and simultaneously requires the educator, trainer, or instructor to stay abreast of advances in the technology and the characterization and description within the spectrum of extended reality.

The second limitation resides in the need for specialized instructor training. In the truest sense, the I-FLO framework is supported by the Learning Experience Design (LXD) concept. LXD is not a new concept but differs from the traditional Instructional System Design (ISD) process. ISD is a formal educational process to determine, develop, and analyze the learning outcomes of a training program, course, or lesson. LXD, however, is a fluid process that emphasizes the learner's experiences within a lesson, course, or program. LXD requires multiple disciplines and fields of study, such as psychology, educational learning theories, experiential models, and frameworks, which are not typically part of instructor training or certification. As a result, the I-FLO framework may require ISD personnel, educators, instructors, and trainers to develop additional skills outside of the traditional instructional system design process and more skills on how participants are immersed in the experiences within a lesson, course, or training program.

The learning curve of new technologies and the need for specialized instructor training are the two most significant limitations of the I-FLO framework. Other limitations to the I-FLO framework include cost and resource allocation of the immersive technology devices. Procurement of such devices can be cumbersome due to contracting and acquisition requirements and sustainability costs that are always associated with immersive technology equipment. Additionally, assessing the result of an immersive experience can be challenging as the assessment of the transfer of knowledge can be difficult, especially when the learning moment is experienced with some form of immersive technology. Differentiating between a cognitive and an affective learning moment is challenging, and the analysis can be subjective or objective depending on the educator or trainer's lens. Is the analysis more rooted in the ISD process, or is the analysis rooted more in the LXD analysis? These are just a few other limitations that should be considered when applying the I-FLO framework.

CONCLUSION

As educators continue integrating immersive learning devices into training programs, consideration must be given to how students effectively learn within immersive environments. In this regard, the I-FLO framework guides the development of requirements for immersive learning devices while realizing that the instructional design and the quality of the virtual learning environment are more important than the type of immersive technology. It also brings attention to the fact that pre-training, both on immersive device operation and the learning subjects, is key in ensuring students realize more from the experience beyond simply having fun. I-FLO establishes the need to target the right level of engagement with students to keep them out of boredom and frustration by achieving a flow state of learning. Additionally, I-FLO provides a step-by-step process to determine the right level of immersion for a training program by providing program developers a way to prioritize desired learning outcomes. This allows the outcomes to determine the level of immersion needed. The desired results will drive asset acquisitions through this framework, and optimized training efficiency and effectiveness will propel valuable innovation.

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APPENDIX A

Term	Definition
Immersive Learning	Instruction or training conducted within simulated environments. Common mediums used to harness these simulated environments are virtual reality, augmented reality, mixed reality, and extended reality.
Presence	The perception of "'being there'" (Makransky & Petersen, 2021, p. 942). Makransky & Petersen posture that the level of presence within an immersive environment is determined by three factors: "(1) the extent of sensory information presented, (2) the amount of control one has over the sensors in the environment, and (3) the degree to which one can modify the environment and its objects (2021).
Agency	The perception of control. Within an immersive environment an individual's agency is based on the amount of control they have over their own actions and over the environment (Makransky & Petersen, 2021).
Interest	The "relationship between an individual and a specific topic or content area" (Makransky & Petersen, 2021, p. 944).
Intrinsic Motivation	The internal drive to participate in an activity for the sake of satisfaction from the activity itself, rather than the results of completing the activity (Makransky & Petersen, 2021).
Self-efficacy	The belief in one's own ability to accomplish a task (Makransky & Petersen, 2021).
Embodiment	A perception of controlling one's own body. In the immersive environment this is dependent on the user's ability to see, control, and even feel bodily movement and/or sensations (Makransky & Petersen, 2021).
Cognitive Load	The amount of information needing to be processed. It consists of both intrinsic and extraneous cognitive load. Intrinsic cognitive load is determined by the learner's prior knowledge and experience. Extraneous cognitive load is determined by the way information is presented within the learning environment (Makransky & Petersen, 2021).
Self-regulation	Simply defined as self-control. Within an immersive learning environment, self-regulation refers to the user's ability to ignore distractions and impulses in favor of focusing on the intended learning tasks (Makransky & Petersen, 2021).

APPENDIX B

Taxonomy for Immersive Experience Design (Ruscella & Obeid, 2021)

Interactivity	**Passive**	The participant has no ability to interact with or influence the experience, such as an audience member watching a movie
	Interactive	The participant has the ability to trigger actions in the experience
	Problem Solving	The participant has the ability to resolve challenges within the experience
	Physicalized	The participant has a physical representation, or avatar, that is engaged in the experience
	Interpersonal	The participant is able to communicate with or relate to someone or something else within the experience
Embodiment	**Detached**	The participant has an external voyeuristic view of the experience
	Watcher	The participant is within the experience with a bird's eye view, and their role is merely an observer
	First-Person Point of View	The participant views the experience from a first-person perspective. They are living the experience but they cannot control their movement
	Movement	The participant has a locomotion ability which enhances their sense of personal will
	Human-to-Human Interaction	Participants can explore relationships with other participants, as avatars, within the experience
Co-Participation	**Single-Player**	The participant is alone with no other real person contact
	One-on-One	Two participants are able to interact with each other, alone
	Group	More than two participants can experience the environment at the same time
	MMO	Participants interact in a large, online experience, playing synchronously in a story-driven world
	Secondary Perspective	An external point of view on the experience that allows for indirect participation
Story	**No Story**	The experience has no context
	Setting	The experience relies upon story aspects to establish a context for time and place
	Pre-Created	The story is like a movie or a television show that the participant has no influence over
	Choose Your Own	The experience allows the participant to make individual choices that shape the direction of the story
	Interactive Story	The participant is the protagonist within the story, can influence events, and can make independent choices that will determine the outcome
Dynamics	**Pre-determined**	The participant is unable to influence the outcomes of the experience
	Choice	The participant can make a decision when faced with one or more possibilities
	Free Will	The participant perceives either a real or imagined unfettered ability to choose their own experience
	Convo-Reality	The participant can engage in interpersonal communication, can develop deeper relationships, and can live through conflict-driven situations
	Adjustable Point of View	The participant has the ability to shift between and influence the environment from multiple characters or perspectives

Gamification	**No Gamification**	Nothing instructs or induces play or competition
	Instruction	The participant has a set of guidelines to follow in in the experience
	External Process	The participant is given a set of rules as a means to succeed
	Reinforcement	The participant is given cues that encourage participation and reinforce moments of success or failure
	Reward System	There is a score or reward(s) for passing levels or accomplishing goals
Immersive Technology	**None**	No immersive technology is used
	Augmented Reality (AR)	Participant's view is augmented by computer-generated imagery, superimposed on top of the real world
	360 Media	Immersive videos allow participants to be surrounded by a photo-realistic environment, typically involving three degrees of freedom (3DoF) of motion
	Virtual Reality (VR)	An artificial, computer-generated environment surrounds the participant and engages their audio, visual, and at times haptic, senses (usually involves 6DoF of motion)
	Extended/Mixed Reality (XR)	Combinations of these technologies that can include more than one of these types in unison and/or an interaction between the real and virtual world
Meta-Control	**No Meta-Control**	The participant has no control over the experience
	Journey	The participant can choose events to participate in
	Character	The user can customize their character or avatar
	World Editor	The participant can edit the levels and existing assets of the environment they inhabit
	World Builder	The participant can affect the global functionality of the world and impact other participants' experiences
Didactic Capacity	**Elemental**	No knowledge is conveyed beyond the functionality of the experience
	Explicit	Learning is direct and instructional, as is present in a typical classroom lecture
	Implicit	Learning is derived and discovered, where assumptions and connections are formed
	Recall	Prior information is required to succeed or proceed in the experience
	Synthesis	Participant incorporates multiple concepts, ideas, and functionalities to solve a problem within the experience
Data	**Anonymous**	All data collected by the experience is anonymized and cannot be related back to its participants
	Identity	The experience asks for credentials from the participant, like a participant name and password, and data collected by the experience can be related to that participant
	In-Game	Data collected is based on the participant's decisions throughout the experience
	Personalization	The experience applies background and demographic information about its participants and adapts itself to those characteristics
	Biometrics	Real-time data is collected about the participant's body through specialized hardware, e.g., eye tracking, blood pressure tracker, etc.