Designing Effective Game-Based and Immersive Virtual Environments for Training

Amanda Bond,
Lead Human Performance Engineer, Cubic Global Defense
Agenda

• Introductions
• Games, Simulation, and Training: Definitions and expectations
• How do I know if my organization could benefit from using immersive/game-based training?
• Designing instruction within an immersive virtual environment
• Designing the immersive virtual environment
• Gamification strategies
Introductions
About Me

Lead Human Performance Engineer, Cubic Simulation Systems, Inc.
15 years as a Human Factors Psychologist/Engineer
Experience across commercial and defense applications in Training, Evaluation, & Design
Microsoft Research Female Academic All-Star: Serious Games
About Cubic Corporation

Company Profile

- 54 years as a publicly traded company
  - NYSE: CUB
- Global Operations
  - 8,000 employees at 130 locations worldwide
- Primary Markets
- Defense
  - Air Combat Training
  - Ground Combat Training
  - Virtual and Gamed Based Training
  - Special Operations & Intelligence
  - Communication Products
  - Cyber Training
  - LVC Training and Performance Assessment
  - Mission Support Services
- Transportation Systems
  - NextCity
  - Automatic Fare Collection
  - Operations Support
  - Maintenance Services

Cubic was founded in 1951 in San Diego, CA, USA
Cubic Simulation Systems, Inc. (CSSI)

Summary
Established in 2012, Cubic Simulation Systems, Inc. (CSSI) is the expert in the industry of effective learning products, solutions and human performance.

CSSI is a cost-competitive leading provider of innovative and effective training, modeling & simulation, and other performance improvement solutions.

CSSI creates challenge-based, collaborative learning solutions that provoke critical thinking, distinctive communication and problem solving through the creation of game based applications containing solo and group content required to achieve complex goals tied to a storyline.

Mission
We create training innovation through advanced products, services and solutions by positioning the latest instructional strategies and technologies for individuals, businesses and governments leading to measurable performance improvement.

Our People
The over 100 employees of CSSI have the following remarkable credentials:
• Over 25% have Advanced Degrees
• 35% have an average of 21 years service in the Military
• Over 45% of the Game Development staff have participated in creating multiple major game titles and collectively shipped 25 titles
• 10% of the entire staff speak more than one language fluently

Mobile Apps * Game-Based Learning * Learning Analytics * Gesture-Based Computing
Games, Simulation, and Training: Definitions and Expectations
Definitions

- Training
- Simulation
- Games
A game is:

- interactive
- Inherently motivating
- rule-governed
- Where an individual progresses to achieve a goal
- The primary purpose is fun
- Games can be live or computer
- Games can be anything from playing cards to laser tag, either real or virtualized
- Skill, strategy, chance, or a combination
- Single-player or multi-player
Definitions

Training is:
• Organized action of teaching (or learning) a particular skill or behavior
• Goal of improving one’s knowledge or performance
• Agnostic of delivery method
• Purposefully assessed (though may not be graded!)
• Includes feedback and opportunity for remediation

Note: Practice doesn’t make perfect: but deliberate practice does!

Deliberate practice is focused on performing the task well, and improving each time through feedback

“Tuba in a closet”
Definitions

A simulation is:
• the imitation of the operation of a real-world system, process, or environment over time
• Often includes a model of the system’s behavior, which is a body of information about the system

A model of behavior allows flexibility in simulation – dynamic simulation rather than linear processes
Definitions

- Training
- Games
- Simulation

Immersive environment
game-based training
## Definitions

<table>
<thead>
<tr>
<th>Educational Games</th>
<th>Virtual Reality</th>
<th>Social Impact Games</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Games</td>
<td>Virtual Worlds</td>
<td>Persuasive Games</td>
</tr>
<tr>
<td>Training Games</td>
<td>Alternative Purpose Games</td>
<td>Games for Change</td>
</tr>
<tr>
<td>Games for Health</td>
<td>Digital Game-Based Learning</td>
<td>Synthetic Learning Environments</td>
</tr>
<tr>
<td>Health Games</td>
<td>Simulations</td>
<td>Game-based [domain]</td>
</tr>
<tr>
<td>Simulation/Simulators</td>
<td>Immersive Learning</td>
<td>Games for Good</td>
</tr>
</tbody>
</table>

A variety of labels are used to describe game-based immersive training, both correct and incorrect.
Definitions

So what does “Immersive” mean?

- A sense of “being there,” even when you aren’t
- Promotes better, faster learning
- Attention is focused on the immersed space
  - Encoding is happening for the immersed space
- Feeling of “immersiveness” (“presence”) comes from a variety of factors (Witmer & Singer, 1994):
  - Control
  - Sensory (Visual/auditory/haptic) cues
  - Feedback

The “FlatWorld Wide Area Mixed Reality” demonstration by the United States Army
Definitions

Examples of immersive game-based training

Immersive environments can consist of:
- Virtual art model
- Audio tones/cues/etc.
- Non-player characters
- Simulation model of component behavior
- Varying degrees of realism & complexity
- Haptic devices
- Physical artifacts such as yokes
- Vibratory feedback in input devices such as mice
- Combinations of the above
How do I know if I could Benefit from Immersive/Game-Based Training?
Benefits of Game-Based Training

**Make the time spent in physical simulators more *effective*.**

When trainees learn and practice first in the game, the first time in the simulator, s/he …

• … will spend less time struggling with what to do because they are *already familiar* with the physical environment.
• … will receive instruction *tailored* to their needs in the simulator.

This approach is effective because of *schematic processing*. Since s/he has already developed a foundation for the operational environment and the tasks, they will learn more quickly.

This can decrease the time needed in physical simulators.
Benefits of Game-Based Training

Expose trainees to scenarios that are difficult—or even impossible—to train.

When trainees experience dangerous situations in the game, s/he…

• … can **practice skills and problem-solving techniques** that they would otherwise not be able to do…
  • Fire fighting
  • Complex medical emergencies
  • Unruly, violent passengers
• … can drill emergency scenarios over and over until they are **trained to automaticity**.

The highly realistic, immersive environment encourages **transfer of training**.
Benefits of Game-Based Training

Game-based training can be adaptive based on individual learner performance

Training centers can then:

- Recreate incident conditions for practice of regulations/guidelines
- Make new scenarios to apply learner knowledge in ambiguous situations
- Create complex, reactive, multi-layered scenarios and/or dynamic scenarios – e.g., CRM training

Practice Situational Awareness, teamwork, collaboration, decision-making, communication, etc.
Benefits of Game-Based Training

Obtain in-depth data for analytics

The trainee’s performance can be tracked and analyzed based on performance as well as knowledge…

… to determine gaps in knowledge and skill so that they may be addressed (either by a virtual or real instructor).

… so the instructors will know what they need to spend time on with trainees, making the most of their time.

… to determine what training they need and what they can skip to optimize their time at the training center.
Schemas in Processing

“A schema is a script and/or structure for common occurrences that run on auto-pilot.”

We use schemas for:
• Tackling new problems
• Sensemaking
• Learning

If it sounds like a duck, but doesn’t look like a duck…
Experiential Learning

Caveats:
• The learner must be willing to be actively involved in the experience
• The learner must be able to reflect on the experience
• The learner must possess and use analytical skills to conceptualize the experience
• The learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience

Kolb, 1984

Concrete Experience
Active Experimentation
Reflective Observation
Abstract Conceptualization
Building Expertise

- Expert-Novice differences
- Deliberate practice
- Schema-building
- Deep knowledge

Levels of expertise expressed as mental model maps
Building Expertise

- What is an expert?
  - 10,000 hours (Ericsson, 1990)
  - Office worker: 40 hours week x 52 weeks per year = 2,080 hours/year
    - 5 years of doing variants of the same task to become an expert
    - Note: of deliberate practice
  - U.S.: 80 flight hours a month typical for cabin crew
    - 80 hours x 12 months = 960
    - 10+ years to become an expert
  - How long is the average airline contract?
Increase Training Efficacy

• Stizman (2011) Meta Analysis found
  ✓ 20% increase in Self Efficacy (confidence)
  ✓ 11% increase in Declarative knowledge
  ✓ 14% increase in Procedural knowledge
  ✓ 9% increase in Retention

• Other studies show even larger gains in specific domains
  • E.g., Wouters, van Nimwegen, van Oostendorp, & van der Spek, 2013
Return on Investment

Better training **efficacy** means better training **efficiency**

- Operationally:
  - Opportunity for more footpath on expensive simulators
    - Reduce iterations on the simulators to put more trainees through
  - Less wear & tear on existing simulators
  - Standardized training
  - Instructors can focus their valuable time on just the trainee’s specific needs
  - Get trainees to the line faster
  - Trainees can review at their leisure; less likely to fail
Consider the Total Human Cost of Ownership

Consider non-operational and non-course-development costs of the hiring/training

- Hiring cabin crew
- Attrition of cabin crew
- Incidents
- Customer Service impacts
- Travel…
- Lodging….
Designing instruction within an immersive virtual environment
Designing Effective Immersive GBT

First and foremost: What do you **need** to train?
Distinctly different than *want* to train

How do you know?
There are multiple analyses that can be conducted in order to design the best training for the specific domain/task/purpose. Not all analyses are always needed – each uncovers a different type of information.
Training Needs Artifacts

End Result: Training Needs Artifacts

Organizational Goals, Constraints, & Capabilities
Training should support this.

Goals, Constraints, and Capabilities of the Work in Situ
Training should support this.

Job/Duty/Task Analysis
The list of measurable objectives, standards, references, and required KSAs.

Sensory Requirements for Performance
Any VE should support sensory performance requirements.

Requirements for Performing Complex (e.g., Ambiguous, High-Stakes) Decisions
Training should incorporate these requirements.

Current/Desired Performance of Employees
Training should improve the current work state and achieve the desired state.

Desired/Current State of Training
Training should improve the current training state and achieve the desired training state.

Gaps in Training and Performance
New/Updated Training should address performance & training gaps.

Media/Technology Alternatives
Media/Technology selected for training should fit within the constraints provided by the aforementioned analyses.
Task Analysis

Task Analysis:
How a user gets from Point A to Point B

• The procedural step-by-step of a task
• Direct Observation Method
• Protocol Analysis/Talk Aloud Method
• … and many more

What is the correct path from A to B?
<table>
<thead>
<tr>
<th>Task</th>
<th>Action</th>
<th>Component</th>
<th>End State</th>
<th>Reactive</th>
<th>End State</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA: &quot;Cabin Crew prepare all doors and cross check&quot;</td>
<td>Audio</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Raise the Plastic Guard</td>
<td>Lift</td>
<td>L2 Plastic Guard</td>
<td>Up</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm the L2 door</td>
<td>Move</td>
<td>L2 Slide Arming Lever</td>
<td>Armed</td>
<td>L2 Left Girt Bar Indicator</td>
<td>Yellow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L2 Right Girt Bar Indicator</td>
<td>Yellow</td>
</tr>
<tr>
<td>Lower the Plastic Guard</td>
<td>Lower</td>
<td>L2 Plastic guard</td>
<td>Down</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verify Girt Bar Indicators</td>
<td>Verify</td>
<td>L2 Left Girt Bar Indicator</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verify</td>
<td>L2 Right Girt Bar Indicator</td>
<td>Yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cross Check</td>
<td>Navigate</td>
<td>R2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Verify</td>
<td>R2 Slide Arming Lever</td>
<td>Armed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cognitive Task Analysis

Cognitive Task Analysis: How a user *decides how* to get from Point A to Point B

- The cognitive step-by-step decisions and strategies of a task
- Critical Decision Method
- Applied Cognitive Task Analysis Method
- … and many more

How would you decide how to go from Point A to Point B?
Cognitive Task Analysis

Factors include:

- Situational Awareness
- Quantitative Factors
- Qualitative Factors
- Runway Factors
- External Factors
- Internal Factors
- Reason for Missed Approach
  - Too far left or right of the extended runway centerline
  - Too high on glide slope
  - Too low on glide slope
  - ATC-Directed
  - Too fast
  - Other weather-related events

- Quantitative Factors:
  - the pilots must know
  - Will the aircraft be able to safely touch down based on the current position?
    - Aircraft weight
    - Current status of all needed aircraft systems (brakes, thrust reversers)
    - Height above glide slope currently?
    - Current fuel levels (enough for missed approach?)
    - Runway conditions (wet, icy, etc.)
    - Has ATC directed to land and hold short of an intersecting runway?
    - How long is the runway?
    - How much runway is needed?

- Qualitative Factors:
  - the pilots consider
  - Maintaining operational schedule
  - Commuting
  - Passengers with missed connections
  - Internal Factors
  - the pilots consider
  - Failure to see the runway at decision height (poor visibility)
Sensory Task Analysis: How a user detects their environment as they are getting from Point A to Point B

- Identifies sensory and perceptual cues in each stage of task completion
  - voluntary and involuntary
- E.g., visual cues in the environment for course of action decisions
- Can be employed embedded with other cognitive task analysis methods
## Sensory Task Analysis

<table>
<thead>
<tr>
<th>Task</th>
<th>Cue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency evacuation – slide raft fully inflated</td>
<td>See Slide Raft fully inflate</td>
</tr>
<tr>
<td>Emergency evacuation – slide raft fully inflated</td>
<td>Hear Slide Raft fully inflate</td>
</tr>
<tr>
<td>Manual door opening – door fully open</td>
<td>Hear Gust Lock engaging</td>
</tr>
<tr>
<td>Emergency ditching – door status</td>
<td>See water level below door sill</td>
</tr>
<tr>
<td>Decompression</td>
<td>See cabin lights turn on</td>
</tr>
<tr>
<td>Lavatory Fire – feel if door is hot or not</td>
<td>Feel heat</td>
</tr>
</tbody>
</table>

Which cues are critical to the task and decision-making? Which cues must be exact in the environment? Which cues can be approximated (e.g., feeling heat)?
Assessment

• What do you need to assess?
  • How a user gets from point A to Point B and
  • How a user knows they’re successfully getting from Point A to Point B
• Measures of Performance
• Measures of Efficacy
• Etc.
Assessment in a Virtual Environment is both \textit{implied} and \textit{overt}

I.e., if a learner is prompted to “Call the Flight Deck from ML3 Station”, if the user can successfully perform this task, we know:

- The user can \textbf{locate} ML3
- The user can \textbf{locate} ML3 Station
- The user can \textbf{locate} the cabin interphone
- The user can \textbf{identify} the purpose of the Cabin Interphone
- The user can \textbf{identify} how to use the buttons on the interphone
- The use can correctly \textbf{perform} a phone call to the Flight Deck using the interphone
Zone of Proximal Development and Progressive Game Difficulty

Diagram showing the relationship between task difficulty, individual skill level, and levels of anxiety/frustration and boredom in the context of gameplay balance and development.
Scaffolding Instruction

Techniques:

- Levels of “hints”
- Practice levels (training wheels)
- Non-player character help
- Tutorial walk-throughs
- Use judiciously
Feedback

• Deliberate practice requires feedback for improvement

• Feedback types
  • Naturalistic – realistic, true-to-life
  • Instructional – warnings, cautions, messages, scores, hints

• Both important, but they should be carefully constructed

• Balance between not enough and too little
  • Sometimes it’s better to stop someone, sometimes it’s better to continue on the lesson
Design Based on Analysis

- Identify Training System Requirements
- Cost-Benefit Analysis (if required)
- Identify Game Characteristics (play, story, etc.)
- Organize Instructional Content
- Sequence Instruction
- Identify Learning Strategies/Prescriptions
- Generate Learning Objectives/
- Identify Administrative Training Needs
Designing the immersive virtual environment
Platform Design

• What kind of technology will you use?
  • What kind of technology is best suited to the training?
• Deployment strategies
  • Mobile
    • Phone vs. Tablet
    • iOS or Android or Windows
  • Online or offline
  • Live
  • Synchronous/Asynchronous
• Impacts: game engine/3D modeling, scalability, lesson/content size, design, input/output devices…
Fidelity Design

• What is fidelity?
  • Measure of **realism** for any representation, or model, of the real world
  • Fidelity has a linear relationship with cost
  • **Diminishing returns on fidelity cost!**

• Types of Fidelity:
  • Functional Fidelity
  • Psychological-Cognitive Fidelity
  • Task Fidelity
  • Physical Fidelity
    • Visual-Audio Fidelity
    • Motion Fidelity
    • Equipment Fidelity
Fidelity Design

• Functional Fidelity:
  • Degree to which a device replicates the actual environment; how real the simulation appears and feels
  • Parameters: time, role accountability & responsibility, environment behavior and consequence, reactions to tasks and inputs by the learner
• High functional fidelity doesn’t necessarily mean high physical fidelity
  • E.g., Microsoft Xplane with a game controller
Fidelity Design

- Psychological-Cognitive Fidelity
  - Degree to which the simulation and associated devices replicate the cognitive and psychological factors
  - Parameters: stress, fatigue, workload, noise, heat
- Psychological-cognitive fidelity does not require true-to-life stimuli...
  - Show a timer
  - Use a haptic vest
  - Noise
  - Ice buckets
  - Lab coats
Fidelity Design

• Task Fidelity
  • Replicating tasks, procedures, and maneuvers the learner performs
  • Parameters: ensuring steps and required elements are true to life checklists, using the right equipment, communications, traversing space, etc.

• Task fidelity does not require any other components
  • Role playing has high task fidelity (live and games)
Fidelity Design

• **Physical Fidelity**
  • Degree to which the device looks, feels, and sounds like the actual environment
  • Parameters: The actual environment visual displays, controls, and audio as well as the physics models
• **Visual-Audio Fidelity**
  • Replicating the visual and auditory environment
• **Kinesthetic/Haptic Fidelity**
  • Replicating the motion or tactile cues in the live environment
• **Equipment Fidelity**
  • Replicating the actual equipment via hardware, software, or both
**Fidelity Design**

- Approximate some Kinesthetic & Equipment Fidelity using a Virtual Environment
  - See the hardware move, how to use it
  - See the physicality of specific tasks
Character Avatars

- Use as mentors
- Use as character avatar instrumental to training
- Use as non-player characters

Considerations:
- Are there image standards?
- Are there branding considerations?
- How likely would this be to change?
Why all the details?

- Intuition is really experience in disguise.
- Schemas:
  - Match real-world expectations
  - If something doesn’t fit, why?

Decision-makers ask “what’s going on here?” before they ask “what do I do?”
Special Considerations

• Wearables
  • Wearables work well for 3D rooms, but limits deployment
  • Physical considerations of trainees

• Simulator Sickness
  • Can happen in those not used to immersive environments
  • Vast majority of effects can be overcome by good design
    • Feedback, animation, navigation, etc.

• Accessibility
  • What are the considerations of the population for accessibility via language, learning disability, physical disability, etc.?
Gamification Strategies
Gamification

• Not all games are simulations, and not all simulations are games

• What makes a game?
  • Story
  • Flow
  • Motivation
    • Individual Intrinsic
    • Individual Extrinsic
    • Social
Why Not Stick with Simulation?

• Games support and improve training outcomes
  • People who have game-based training play to train, AND play again for fun
  • Presents information as part of a meaningful, scaffolded experience
  • Games naturally support other reward mechanisms for performance: awards, leader boards, etc.

• Simulations don’t provide corrective feedback
• Training can be boring, and can limit learning
• Games are fun and motivating and memorable, but do not provide adequate instruction

Game-based training in Immersive Environments is the best of all three worlds
Flow

Game Flow

Anxiety / Frustration
Level of Potential Development / Achievement
Zone of Proximal Development / Cognitive Coordination Balance
Actual Developmental / Skill Level

Individual's Skill Level
Gamification Strategies

• Games should go from easy to hard, like training
• Start with fundamentals, then add more scenarios
• Build in difficulty and nuance

• E.g.,: For Cabin Crew, Ditch = Crew Systems + Doors Arming/Disarming + Door Opening + Door Emergency Assessment + Slides + Evacuation + Slide/Raft Disconnect + Survival + Medical

• https://www.youtube.com/watch?v=mCis7kkOrTk
Goals

• Providing meaningful benchmarking goals tied to performance
  • Specific goals are the best
  • Directs attention on the task
  • Consistency

• Difficult goals = increase in effort and better performance

• Stimulate prior knowledge and skill

• Satisfying!
Mini-Games

- Use mini-games as rewards mechanisms
  - Fun
  - Add rewards/bonuses
- But still provide meaningful training
- Way to mix types of games within a single game
  - E.g., add a casual game to an immersive game
  - Target multiple audiences
# Game Types & Game Play

## Example Game Genres for Specific Learning Outcomes

<table>
<thead>
<tr>
<th>Learning Outcome</th>
<th>Game Genre</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skill-and-drill</strong></td>
<td>Fighting /First person shooter</td>
<td>Relies on patterns and repetition; player initiates action.</td>
</tr>
<tr>
<td><strong>Declarative knowledge, facts, statements</strong></td>
<td>Classic arcade-style, puzzle</td>
<td>Simpler gameplay, makes use of both pattern matching and recall abilities.</td>
</tr>
<tr>
<td><strong>Scientific concepts, problem solving</strong></td>
<td>Action-Adventure</td>
<td>Objective-driven nature and use of puzzles promote creative problem-solving. Problem-solving helps players create an understand connections between concepts (Spires, Rowe, Mott, &amp; Lester, 2011).</td>
</tr>
<tr>
<td><strong>Complex relationships, decision-making</strong></td>
<td>Real-time strategy (RTS)</td>
<td>Gameplay relies on resource management and complex system reactions, which provides analogous practice for this outcome.</td>
</tr>
<tr>
<td><strong>Metacognitive (dynamic, complex) knowledge</strong></td>
<td>Traditional and sandbox role-playing games (RPGs)</td>
<td>Requires planning and forethought at the crux of gameplay. Branching narratives and interactions with non-player characters (NPCs) with quest systems can encourage deeper processing and teach more complex topics.</td>
</tr>
</tbody>
</table>
Individual Intrinsic & Extrinsic Motivation

- **Intrinsic Motivation**
  - Individual motivational factors based on values
  - What are your learners’ values?
    - Pride, company loyalty, feelings of self-value

- **Extrinsic Motivation**
  - Doing something for external gain
Individual Intrinsic Motivation Examples

- Scoring
  - Stars, points, etc.
- Badges
  - Reward incremental process
  - Reward good training behavior
  - Think: 2 stars vs. 3 stars
- Sense of Goal achievement (job well done)
Individual Extrinsic Motivation Examples

• Rewards tied to points/success metrics
  • Bonuses, prizes, etc.
• Leveling up
• Bonuses, freebies, equipment that helps the gameplay
  • Make sure this ties to the learning!
• Content
  • Mini games, choose your sound track, “hidden” levels, etc.
Social Motivation

- Leaderboards
- Gameplay with others of that level
  - Relevant in multiplayer
- “Share” to get bragging rights
- Competition factor

Dr. Sheldon Cooper, character on the CBS show *The Big Bang Theory*, who is fiercely competitive and delights in besting others, saying “Bazinga!” when he has.
Use Multiple Motivational Factors

• Kaplan University found motivations for non-traditional learners based on their unique factors rewarding good learning behavior
  • raised the time students spent in class by 17%
  • increased the percentage of students who chose more challenging coursework by 85%
  • raised the prevalence of higher grades by 9%
  • Badges, leaderboards: Teamwork, Dedication, Problem-Solving, etc.
Wrapup

• Game-based training is a powerful and cost-effective training tool when designed well from the ground up
• Solutions aren’t one-size fits all and should be custom for your organization
• First, determine what you need to train
• Next, design the training itself – content and instructional strategy
• Then, design the virtual environment to provide the critical cues you need and deploy on the best devices
• Finally, design gamification strategies to complement the learning
• But always center on the learner
Thank you!

Questions? Comments? Follow-up?

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