



Infestation

THE EVOLUTION BEGINS

**DEVELOPING INNOVATIVE TECHNIQUES
FOR USING MUSEUM-BASED THEATER
AND GAMING TO SUPPORT VISITOR
UNDERSTANDING OF COMPLEX SYSTEMS**

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Liza Pryor, PI

Zdanna King / Evelyn Ronning

Stephanie Long

Trygve Nordberg



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How do you make a theatrical game?

Start with a story that helps you create a world...

- » This is the hardest part—give players something to believe in!
- » Players are more engaged when the WHY is consistent with the story and helps them discover more about this world.



...that's grounded in reality (the Museum, real science)...

- » What's unique about your space?
- » How can you help players feel like museum insiders for the duration of the game?



...and features characters that you care about.

- » Emotional connection helps support the WHY—players care about the story when they care about the people involved.

» We asked our audience to rate their enjoyment of different aspects of the show. The actors (playing the human characters in the show) came out on top, with 95% of those surveyed saying they enjoyed the actors "a lot" or "mostly." The VISTAs received similar ratings. One teenager shared about the cast and characters, "I don't want to go back to school! I want to help them. I love them!"

What's important about games?

In games, it's OK to try and fail and try again.

- » Challenges should be challenges. Remediate places players get stuck, but don't dumb down content or make challenges meaningless.
- » Consider different levels of achievement and/or individual and group win states.



"Soft skills," like collaboration and orientation, are as important as content.

- » Create situations that encourage players to problem-solve collaboratively.
- » As players gain confidence, gradually ramp up the level of audience interaction/participation.

A good game needs a strong story.



- » The story defines the gaming universe and players' expectations, and suggests the game's mechanics.
- » Offer several win/lose states as part of the story's resolution.

» Ongoing evaluation revealed how important win states could be for spurring visitor engagement. Notably, when sharing highlights from their experiences, most visitors first described the shower of VISTAs from the ceiling at the end of the game, or the whooshing of VISTAs through the pneumatic tubes upon solving the mini-challenges.

What's important about theater?



You need a hook.

- » Create a social bond between the audience and the storyteller.
- » A heightened emotional state gets the audience invested in what happens next.



Theater and games require conflict.

- » Your story needs a clear problem to solve or obstacle to overcome.
- » Consider adding an antagonist.



Sets are important.

- » Forcing players to find secret rooms enhances the sense of discovery, both in the museum and in the content.
- » A different ambience for each room adds "stickiness," linking affective experiences to action and content.

» The immersive settings drew delighted responses from visitors and captured their attention. One woman clapped as she entered the Time room; a teen shared, "I want to live here!" about The Variation lab; and one parent reflected, "This is awesome... by far one of the best things at the museum." Floor staff observed non-players trying to follow along, excitedly wondering what was happening. One young non-player offered a staff member \$20 for the code to enter a hidden room he'd discovered and begged to be let in.

What about technology?

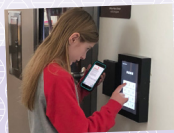
Use technology to deepen the story, not distract.

- » Empower performers to improvise and make decisions.
- » Invest in impactful engineering and technology, then re-use it in different contexts.



Identify aspects of the experience best automated by technology vs. individually cued by a facilitator.

- » Consistent branding, interface, and experience structure can help players quickly identify what they need to do.
- » Facilitators need ways to override and/or assist.



Embed technology in something familiar and consistent with your story.

- » Our game uses an omniscient, personified security system and a supercharged mobile phone.
- » Each interaction feels like a conversation with a friend or adversary.



» We used technology to further learning throughout the experience. One of these technological elements was animation to convey key content during the theatre show. Across evaluations conducted at various design stages, 92% of players reported that they "mostly enjoyed" or enjoyed these animations "a lot".

How do theatrical games support learning?

Emotional investment helps players stick with tricky content or challenges.



The social and participatory nature of the experience encourages a collective sharing and building of knowledge.

- » We encouraged participants to take on roles to collaborate on learning challenges (e.g. holding toolkits, managing phone texts).

Use technology to empower, not distract.

- » We used animations "created" by a character in the show to reinforce conceptual understanding without being repetitive.

» After one testing experience, a man reflected that the humor in the show really helped to connect him to the ideas: "It was amusing. It was nice to have adult humor in the experience and it made me think about evolution. I now understand how evolution works." In surveys, almost all adult visitors shared that getting a refresher on or an introduction to the science content was "enjoyable" or "very enjoyable" and almost all youth and adults from ongoing testing of the game walked away being able to share about key concepts from the experience.

Learn from others as you go!

Playing games feels universal, but audiences are drawn to different elements of game play.

- » Use our list of game elements and accompanying survey to explore how your audiences are drawn to different aspects of gaming.



Some theatre-goers thrive on direct interaction with live actors and fellow audience members, while others may prefer to observe performances.

- » Use our theatre-goer profile document and accompanying survey to understand how your audiences prefer to engage with immersive theatre.

Need to understand how visitors think about tricky concepts? Review some lessons we learned about approachable surveys.

» When you're able to create a story that builds on emotional connections, immersive environments, and the right level of gaming challenges to support learning, people want to come again and again. After one gaming experience, staff overheard a mother talking to her children: "We've seen infestation three times. Are you sure you want to do it again?" "We want to go again," they replied.

How do you make a theatrical game?

Start with a story that helps you create a world...

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THEATRICAL GAMES

For most of us, new information doesn't result in a deeper understanding of a topic such as evolution. (Call it the "GI Joe Fallacy": knowing is *not* half the battle.) But deep engagement can help us reframe our existing knowledge and see it differently. And the degree of engagement relates to the likelihood of change.

The development of learning through intrinsic motivation begins with a **hook** (which includes stimulating curiosity and interest), then moves to **opportunities for involvement** (sensory, intellectual and emotional), followed by **conditions for flow** (challenges must be compatible to, and balanced with skills), and **growth of complexity** in consciousness. (Pedretti, 2008)

Two techniques that show promise for engaging learners in deep conceptual thinking in an informal setting are participatory theatre and educational games. They share:

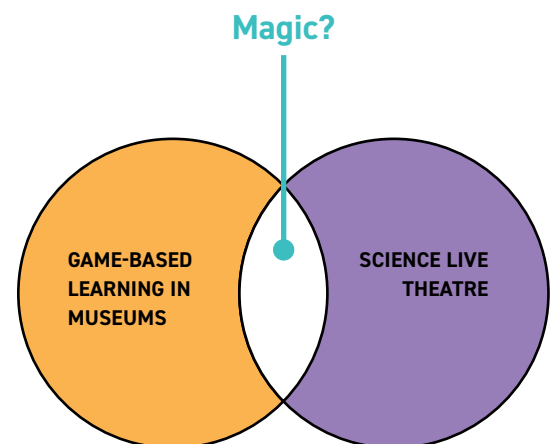
- an emotionally engaging narrative arc;
- opportunities to make sense of systems;
- conflict(s) to resolve;
- challenges and obstacles to overcome;
- and an end state that summarizes or confirms.

The combination of games and theatre—where content is presented within a story context and coupled with a challenge or challenges to overcome (*i.e.* made into a game)—**significantly improves learning**. (Lepper and Cardova, 1992)

A **theatrical game** is an experience, bookended with live or recorded performances, in which the characters and narrative introduced serve to define the "why?" and the appropriate challenges/mechanics for the entire game.

Players interact with the characters throughout the experience and feel physically immersed in the universe set up by the theatrical performance. In a theatrical game, the audience, player, and visitor are all the same thing.

NSF generously funded the Science Museum of Minnesota's exploration of whether or not the theatrical gaming technique could improve visitors' understanding of complex topics requiring conceptual shifts—topics like evolution.



EVOLUTION

Nothing in biology makes sense except in the light of evolution.

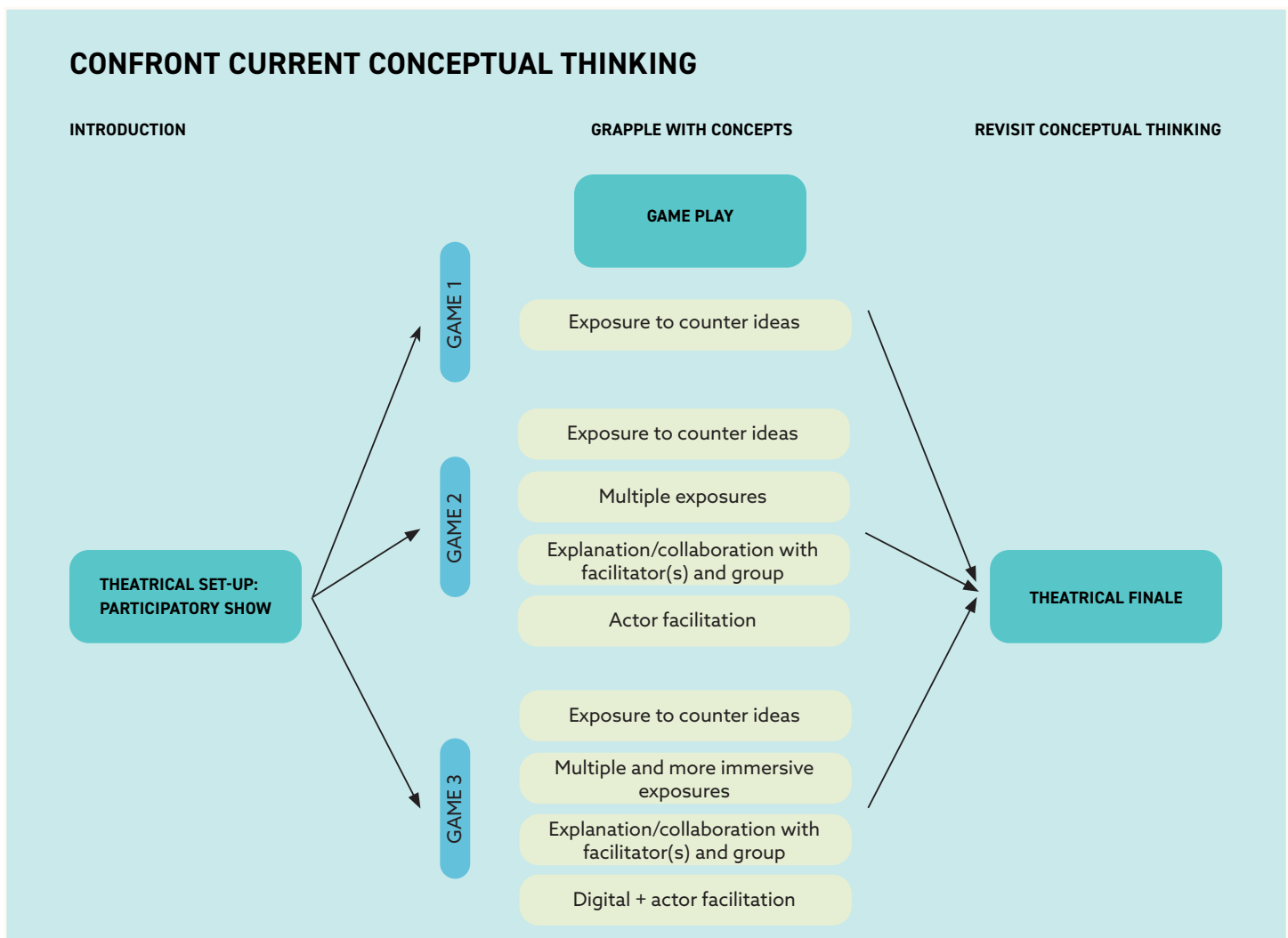
—Dobzhansky, 1973

fewer than 10% of Americans may have a functional understanding of evolution.

“The problem is that even the average graduate level biology student believes that adaptation occurs uniformly across all members of a species

Yet three decades of research have shown a strikingly high prevalence of misconceptions at all educational levels, from elementary school pupils to university science majors. In fact,

in accordance with a species’ needs.” (Shtulman, *Scienceblind*) A working understanding of evolution may be the rare exception rather than the rule (Gregory, 2009). As evolution’s implications become more and more relevant in practical contexts—medicine, agriculture, resource management, etc.—it’s important to support Americans’ understanding of the process. The Science Museum of Minnesota’s mission is to turn on the science: inspire learning. Inform policy. Improve lives. And people with a good understanding of evolution are more likely to accept it, even taking into account religiosity and political views (Weisberg, 2018).

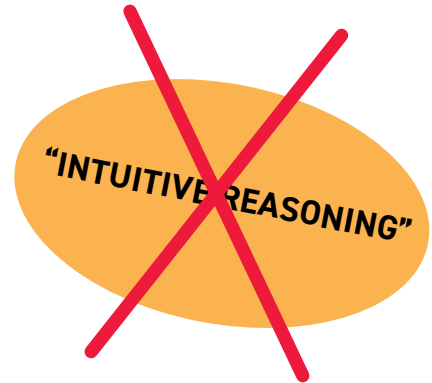
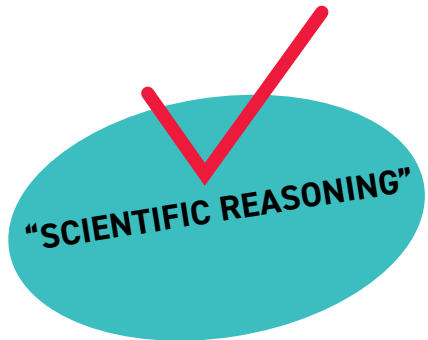


INTUITIVE THEORIES

Humans are hard-wired to create theories about how the world works. Unfortunately, our attempts to explain our observations are often wrong. And bad theories can prevent us from understanding science as it really is. (Think climate change denial, anti-vaccination movements, fears about GMOs, etc.) Many

truths aren't easy to understand because they defy our earliest-developing and most easily accessed ideas about how the world works.

To get the science right, we have to **dismantle those intuitive theories and rebuild them.**



Differences among members of the same species mean that some members will outlive and outbreed others.

VARIATION

Differences among members of the same species are minor and inconsequential.

Organisms inherit a random selection of their parents' traits. They resemble their parents, but also differ in unpredictable ways.

INHERITANCE

Organisms inherit their parents' best traits, the ones that will help them thrive.

Most offspring do not pass their traits on to the next generation. Only some live long enough to reproduce.

SELECTION

Most organisms pass their traits on to the next generation.

Species change over many generations, as small changes accumulate from one generation to the next.

TIME

Species change as quickly as they need to.

Species become more adapted to their environments as organisms with useful traits outnumber those without over many generations.

ADAPTATION

Every organism will be born more adapted to its environment than its parents were at birth.

SO, CAN THEATRICAL GAMES HELP PLAYERS SHIFT FROM INTUITIVE TO SCIENTIFIC THINKING?

To find out, we created a series of experiences, each featuring different combinations of theatrical techniques and game mechanics.



This 90-minute experience—equal parts interactive theater, game, and puzzle room, and entirely one-of-a-kind—begins and ends in the Lab Theater. In between, you’ll discover intriguing secret spaces and beat challenges that test your understanding of evolution. Sounds fun? Of course it does!

GAME 1

“B,” our sentient biosecurity system, is using a scavenger hunt and a series of tasks to learn about humans’ understanding of evolution. Use code phrases, find challenges hiding in plain sight, and—if you’ve been paying attention—trigger delightful surprises for yourself and other visitors. Just don’t let anyone else see how you did it!

GAME 2

Animal breeder Chris is domesticating a strange creature with assistance from you (and the fundamentals of evolution). It’s fun, funny, and perfectly safe... as long as everything goes according to plan. We’re sure it will.

GAME 3

Whoops. While Chris is filling out the accident report and Alex is rebooting the biosecurity system, you have to prove your understanding of evolution to Administrator Jobsworth, earn your VISTA license, round up our fuzzy friends, and save the VISTA research program for another day. And you’ve got just one hour to do it. No problem, right?

GAME DESIGN FEATURES



AND? WHAT HAPPENED?

Expert advice and many rounds of play-testing and observation yielded **three clear imperatives** about theatrical gaming in general.

Start with a story that helps you create a world.

This is the hardest part. Make sure that the overall scenario you're presenting to players is internally consistent and gives them something to believe in. Players are more engaged when the reasons behind whatever you ask them to do flow naturally from the story and help them discover more about the world you've created.

Stay grounded in reality, even when you're asking players to join you on a flight of fancy.

We're a science museum, not a commercial escape room, so even our silliest experiences

are built on real scientific discoveries. What's unique about your space or identity?

And how can you make players feel like insiders for the duration of the game?

Feature characters that your audience cares about.

Emotional connection helps support learning and willing suspension of disbelief. Players care about your story when they care about the people involved.

But did we achieve our goal? Did players demonstrate a better understanding of evolution? And how can you create your own theatrical game? Check out the rest of this packet to find out!

What's important about theater?

You need a hook.

- » Create a social bond between the audience and the storyteller.
- » A heightened emotional state gets the audience invested in what happens next.



Theater and games require conflict.

- » Your story needs a clear problem to solve or obstacle to overcome.
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Sets are important.

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- » A different ambiance for each room adds “stickiness,” linking affective experiences to action and content.



The immersive settings drew delighted responses from visitors and captured their attention. One woman clapped as she entered the Time room; a teen shared, “I want to live here!” about The Variation lab; and one parent reflected, “This is awesome...by far one of the best things at the museum.” Floor staff observed non-players trying to follow along, excitedly wondering what was happening. One young non-player offered a staff member \$20 for the code to enter a hidden room he’d discovered and begged to be let in.



THEATRICAL GAMES

We've identified some **best practices** for storytelling and theatre that support the creation and production of theatrical games in informal learning institutions such as the Science Museum of Minnesota.

START WITH STORY

Stories are personal, but they provide a shared experience. They create a social bond between the audience and the storyteller.

Creating a universe for a theatrical game is crucial. A concrete story defines the game world and the parameters for game play expectations. A strong story also establishes the social contract between players and performers.

In *INFESTATION: The Evolution Begins*, a 25-minute interactive play featuring live and pre-recorded performances sets up the challenge for players to overcome. Players who continue on with Game 3 return to the theater after completing the small-group challenges for a performance that includes one last obstacle to overcome, a fun content summary, and the story's resolution. In between, while players are dispersed throughout the building, they interact with the same characters via text messages that contain clues and helpful hints. Players believe they are engaging with actors/characters and love this aspect of the game.

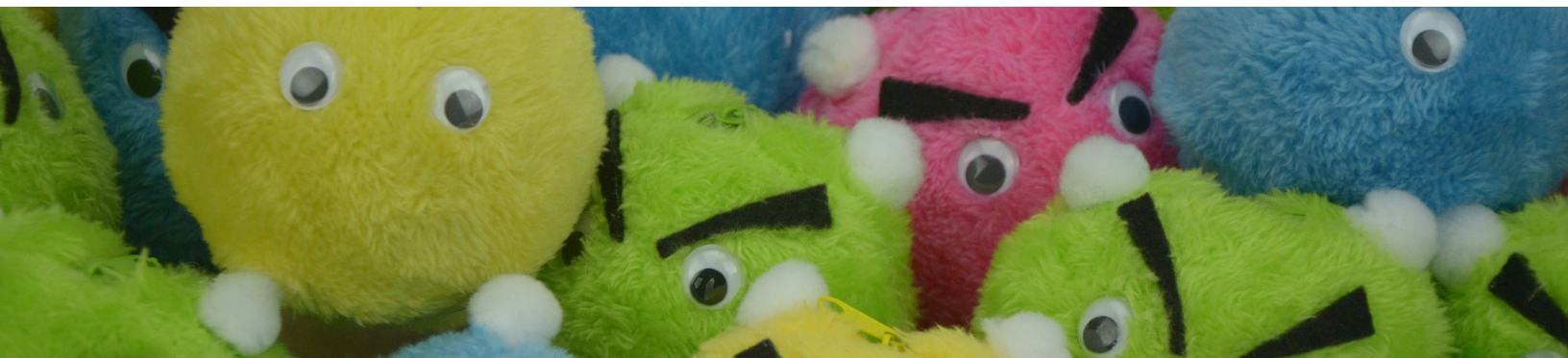
Write for the stage, not the page.

—Truman Capote

FIND A HOOK

A hook grabs the audience's attention. A provocative statement, question, or environment is a hook to engage visitors and a cue that something interesting is about to happen.

INFESTATION uses physical hooks to immerse players in the game universe even before the theatrical performance begins. The audience goes through a fictional decontamination process when entering the Lab Theater. This simple technique starts to define a world and gets visitors wondering why decontamination is necessary and what happens next. Once inside the theater, they see VISTA creatures moving around in cages and hear cooing and growling noises. Before an actor utters a single line, players are wondering, "What are those?"



IMMERSION

Sets are important!

An immersive setting helps reinforce the story world. In *INFESTATION*, the Lab Theater is a set for the actors and the game-players, too. Forcing players to “decontaminate,” “get licensed,” or discover secret rooms enhances the sense of discovery—both in the Museum, and in the content. A distinct ambiance for each element of the theatrical game adds “stickiness,” linking affective experiences to action and content.

POSE A QUESTION

Theatre and stories are all about questions. A good story has you asking, “What happens next?” We gather around the fire or the watercooler to share stories or speculate about “Who killed JR?” because we crave opportunities to pose and resolve interesting questions.

In *INFESTATION*, we pose our questions at the top of the show: Will the character Chris be successful teaching us and her sibling, Alex, about evolution? Will Alex derail the presentation? Will we all become certified VISTA handlers before the villain, Jobsworth, shuts the experiment down?

START AT 40% EMOTION

A conflict or heightened emotional state captures the audience.

Chris’s presentation is almost immediately interrupted by Jobsworth, who threatens to shut down the training and the experiment. And shortly after that, Chris’s sibling Alex appears—adding another level of conflict—which instantly raises the stakes and the emotions.

USE HUMOR AND OTHER POSITIVE EMOTIONS

Feelings can change how people take in factual information. When people laugh, or otherwise engage positively, they can explore and change their minds.

INFESTATION is a comedy featuring actors with professional improvisational experience. But it still addresses the “Five Fs”: flaws, failures, frustrations, firsts, and fears—universal feelings and experiences that are part of humanity’s collective lived experience and allow the audience to immediately connect with the characters and become part of their journey(s). This is serious fun.

CONFLICT IS CRUCIAL

A story needs a clear problem to solve or obstacle to overcome.

Who doesn’t love to hate a foil? Consider adding an antagonist. While play-testing *INFESTATION*, we added a villain—Jobsworth—and discovered our audience was highly motivated to “beat” him. Making the central emotional conflict of the experience character-driven yielded a bigger, better win state.

BE LIKE AN ONION

A story is more than the sum of its basic parts (beginning, middle, end). A story or show should be layered with reveals. Take the audience on a narrative journey.

In *INFESTATION*, the evolution content is gradually revealed, step-by-step, via the VISTA acronym. Players aren’t overwhelmed by too much content at once. Different levels of player achievement are also important reveals and part of the narrative arc—audience members “win” stickers at the end of the 25-minute show and then a button (with googly eyes!) for successfully finishing the hidden rooms and returning the VISTAs to the Lab Theater. Swag is a good motivator!

BUILD TO CRESCENDO

The story builds to a moment of absolute change.

INFESTATION's 25-minute performance ends with a cliffhanger: the VISTA creatures escape the Lab Theater and are running amok in the Museum. The audience has to solve a puzzle to break out of the locked-down Lab Theater and start the distributed puzzle-room challenges. The mission is clear: players must simultaneously earn their VISTA handler certification by solving each room **and** return the VISTAs to the Lab. They're no longer watching a performance; they're part of the story themselves.

What's important about games?

In games, it's OK to try and fail and try again.

- » Challenges should be challenges. Remediate places players get stuck, but don't dumb down content or make challenges meaningless.
- » Consider different levels of achievement and/or individual and group win states.



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- » Create situations that encourage players to problem-solve collaboratively.
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Ongoing evaluation revealed how important win states could be for spurring visitor engagement. Notably, when sharing highlights from their experiences, most visitors first described the shower of VISTAs from the ceiling at the end of the game, or the whooshing of VISTAs through the pneumatic tubes upon solving the mini-challenges.

WHAT DO YOU NEED TO KNOW ABOUT GAMES?

We identified some **best practices** for game development specific to the creation and production of theatrical games in informal learning institutions such as the Science Museum of Minnesota.

Games aren't just filler in education. They have the ability to introduce, reinforce, or even assess learning of a given topic.

—Kara Carrero

A GOOD GAME NEEDS A STRONG STORY

Create an immersive, energetic, story-driven set of challenges that propel players into hidden and secret corners of the Museum while reinforcing content.

A theatrical game requires rigorous internal consistency. The story defines the game universe and player expectations, suggests the game's mechanics, and supports win/lose states and experience resolution. As you develop an experience like this, keep asking yourself "Why?" What is motivating the characters? The players? Does a challenge or its solution make sense in this world?

RESIST THE TEMPTATION TO CREATE "EARLY ASSURED SUCCESS"

In games, it's OK to try and fail and try again. Challenges should be challenging.

Prototype and play-test your theatrical game with different groups of people. Gradually ramp up the level of participation or knowledge required to complete challenges. By all means, remediate the places where players consistently get stuck, but don't "dumb down" content or make challenges meaningless. When obstacles are balanced by skills and knowledge, players are deeply engaged.

EMBRACE YOUR SOFTER SIDE

"Soft skills," like collaboration and orientation, are as important as content.

Create situations that encourage players to problem-solve, communicate, take on different roles, share proficiencies and insights, and develop other "21st century science skills."

BE SOCIAL

Theatrical games are social experiences on a variety of levels.

By nature, these experiences combine lots of different social groups: big ones, small ones, singles, families, friends, strangers. Pay attention to those dynamics, and devise efficient and seamless ways to get the audience, whatever its composition, to work together or to divide into teams. Remember, too, that as the story unfolds, players experience it both collectively and individually. Can you create situations that allow for both competition and collaboration?

THERE ARE LOTS OF WAYS TO "WIN"

A game needs a win/lose state. In a theatrical game, the players must be part of the resolution with the characters. Consider different levels of achievement and/or individual and group win/lose states.

INFESTATION has several configurations and win/lose states that accommodate time constraints and/or group composition and help scaffold conceptual shift around the idea of evolution.

- The simplest, most accessible game is a scavenger hunt—finding the last station triggers delightful surprises that other visitors can see, but only players can activate. This one requires a minimal time commitment, minimal facilitation, and minimal interaction with other players.
- “Winning” the games built into the interactive performance involves solving riddles/puzzles

to complete phase-one VISTA training and escape the Lab Theater. This game has a group win state, but still offers opportunities for individual levels of participation.

- Becoming a “certified VISTA handler” requires finding four hidden rooms, completing challenges in each one, rescuing and returning the VISTAs to the Lab Theater, and a final group challenge/narrative resolution. In this game, your little group can compete against all the other little groups, but there are opportunities for each player to serve a role and there’s a group win at the finale.

GAME 1

SECRET MISSION

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- 3 stand-alone mini-games
- Minimal time commitment
- Uses the “B” character
- Always available to visitors





GAME 2

THEATER SHOW

Animal breeder Chris is domesticating a strange new creature with assistance from you (and the fundamentals of evolution). It's fun, funny, and perfectly safe... as long as everything goes according to plan. We're sure it will.

FOUR CHARACTERS

- Two live actors
- Two pre-recorded characters

Characters played by live actors have gender-neutral names and can be played by any actor in the Science Live company who has learned the part(s).



MEET THEM:



Chris

- Aspiring scientist
- Older sibling
- Lawful good

Trying to deliver a serious lecture about the famous Russian fox experiment, a new variation on that experiment, and the relationship between artificial selection and evolution.

Alex

- YouTube star wannabe
- Younger sibling
- Tech wizard
- Chaotic neutral

Wants to improve Chris's presentation and gain more YouTube channel subscribers.





Jobsworth

- Institutional bureaucrat
- Creepy obsession with rules
- Does taxes for fun?
- Lawful evil

Appears at inconvenient times, via Skype, to oversee/threaten the VISTA project. Wants to shut the whole experiment down.

"B"

- Omnipotent AI system
- Keeps museum safe & secure
- Lawful neutral?

Cannot disobey security protocols. Communicates through audio and an on-screen avatar.



VISTAS

- Experimental creatures
- Prone to escape

Exhibit varying degrees of "friendliness," among other traits. Friendly ones wiggle like puppies; unfriendly ones hang back like angry cats.

GAME 3

WHAT'S IN THE CHALLENGE ROOMS?

VARIATION

- Dr. Eva Looshun's office
- Real specimens

First, see the man in the sunglasses. Then consider some familiar animals. Can you tell a pigeon from a non-pigeon? Is a gray squirrel always gray? Be quick, but careful: if you make a mistake, Jobsworth requires a time-wasting review, and there's another team right behind you!



INHERITANCE

- Officer Harry Tense's office
- Secret screen

Can you tell acquired from inherited traits? Use your RFID cards and special glasses to complete this challenge and send the VISTAs back to the Lab Theater. Everyone will want to know what you're doing, but only you can see the screen.

SELECTION

- Dr. Robin Featherly's "holodeck"
- *Avis annuli* launcher

Were you paying attention when Alex and Chris "selected" VISTAs? Good, because now you have to make predictions about a population of birds. And Jobsworth is watching the clock!



TIME

- Dr. Tim Chronus' time chamber
- Rotating table/projections

This one's all about following the directions. And time traveling over many generations. And drawing really, really fast. But get your final answer right, or who knows when you'll end up?

BACK TO THE LAB THEATER

There's one last challenge and a fun surprise. Really, that's all we're going to tell you.

DEFEAT JOBSWORTH, RESCUE THE VISTAS,
AND EARN SOME FUN SWAG.



What about technology?

Use technology to deepen the story, not distract.

- >> Empower performers to improvise and make decisions.
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Identify aspects of the experience best automated by technology vs. individually cued by a facilitator.

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WHAT DO YOU NEED TO KNOW ABOUT TECHNOLOGY?

Technology is obviously a big deal in theatrical games. Live theater cues, wayfinding, access, challenge tracking, experience reset, facilitation and assistance... There's a lot to consider.

In general:

USE TECHNOLOGY IN WAYS CONSISTENT WITH YOUR STORY WORLD.

In *INFESTATION*, Alex uses a super-charged mobile phone to control show cues and to text clues to players. Our omniscient, anthropomorphized security system, "B," is figuratively tied into all the Museum infrastructure, and so can appear anywhere and know anything.

IDENTIFY ASPECTS OF THE EXPERIENCE BEST AUTOMATED BY TECHNOLOGY VS. CUED BY A FACILITATOR.

People are your most valuable resource. Simple wayfinding and access are good candidates for automation, especially because technology can control access to hidden spaces, allow a facilitator to track each team's progress, and eliminate or reduce "traffic jams" caused by teams moving at different speeds. But make sure that players and facilitators aren't too "locked in"—they need to be able to improvise and make decisions.

EMBED TECHNOLOGY IN SOMETHING FAMILIAR AND CONSISTENT WITH YOUR STORY.

Instead of asking players to download and learn a new app under pressure, Game 3 offers

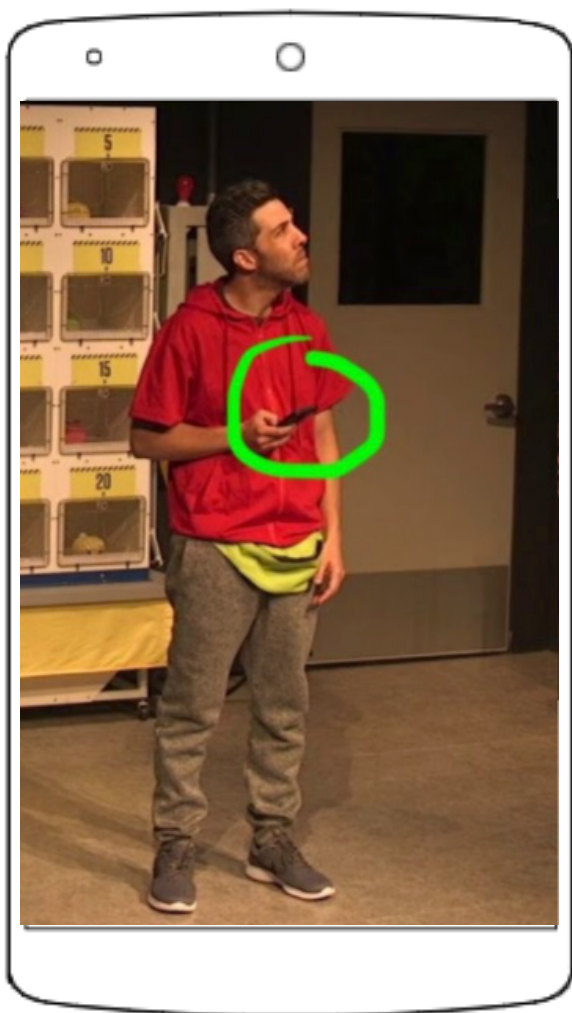
instructions and wayfinding via text (SMS). It fits our universe: Alex is already closely identified with a phone. Most visitors know how to text. Players can use their own devices or borrow ours, and that adds another layer of immersion: each interaction feels like a real-time conversation with a friend or adversary.

The test of the machine is the satisfaction it gives you. There isn't any other test. If the machine produces tranquility, it's right. If it disturbs you, it's wrong, until either the machine or your mind is changed.

—Robert M. Pirsig

INVEST IN TECHNOLOGY AND ENGINEERING WITH IMPACT, AND THEN RE-USE IN DIFFERENT CONTEXTS.

If you discover a meaningful payoff, repetition can help anchor players and remind them of the overall goal. Consistent branding, interface, and experience structure—like the access panel and challenge sequence in each of *INFESTATION*'s hidden rooms—can help players quickly identify where they are and what they need to do. And each hidden room challenge ends with a similar payoff—the VISTA vacuum tube—which is fun and reminds players about the ultimate goal of the game.



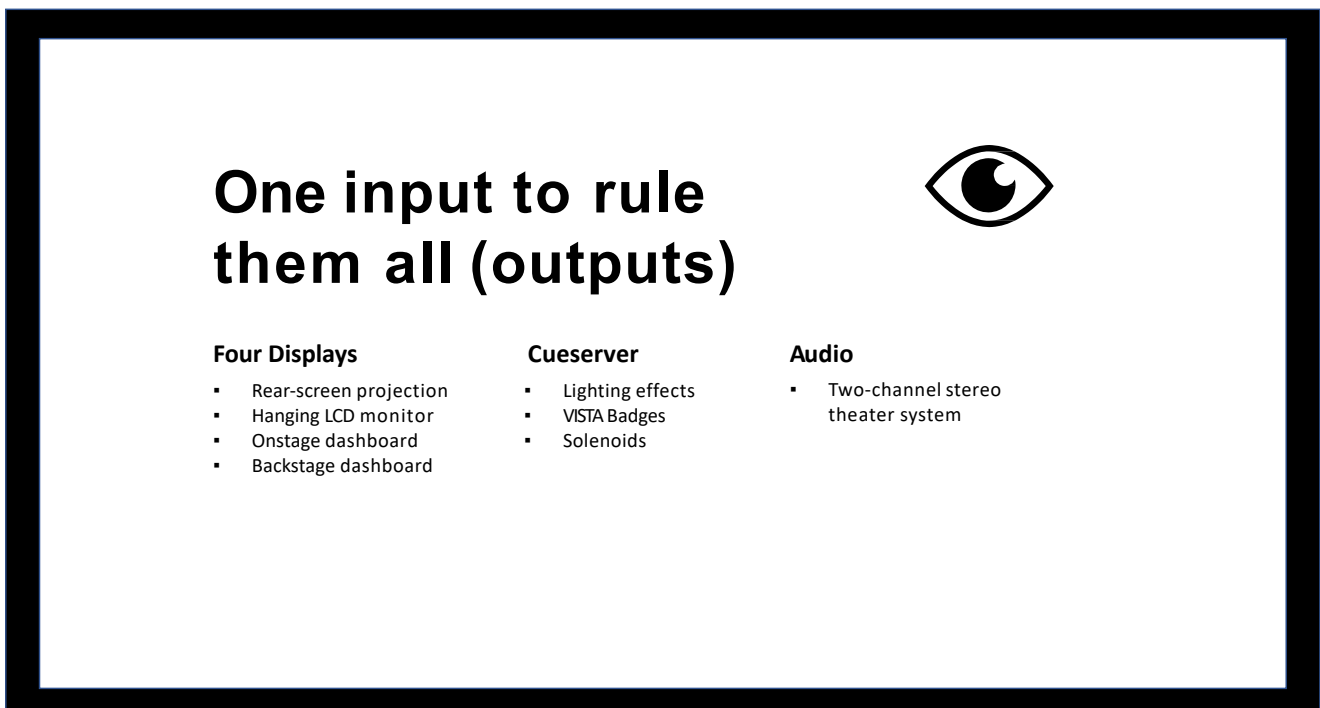
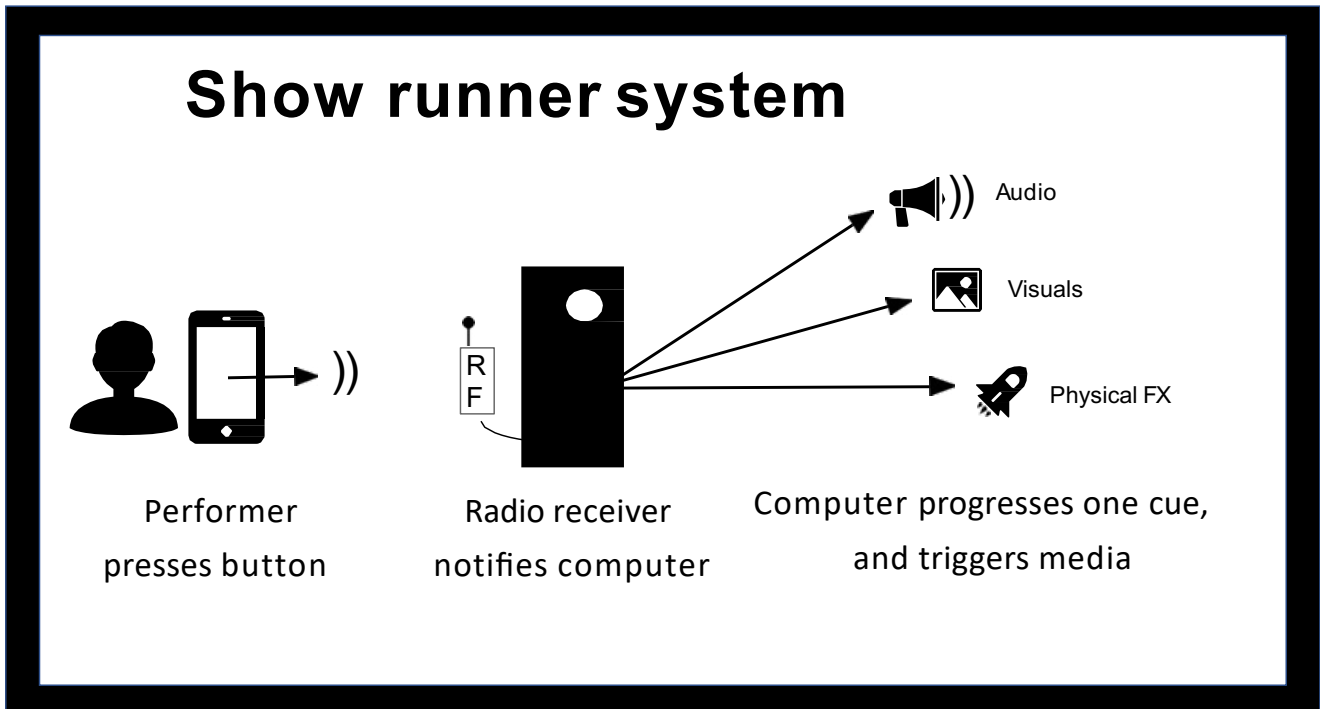
Alex's phone—almost a character in itself—allows the actors to “perform” all the tech/lighting/media cues the show requires.

With a finished script, a need to run shows 2–3 times per day, and no dedicated staff to run live tech and lighting, we focused on empowering the actors to control all the theater media and lighting cues themselves. They needed a way to do this while onstage in front of a live audience without breaking audience immersion.

We found a solution in the tech-savvy personality of “Alex.” For most of the show, Alex holds a “smartphone” with an RF transceiver embedded in it. At 84 points during a show, the performer presses the phone button to send a signal to a backstage radio receiver. The radio connects to a computer running custom software that advances a single cue in a cue list, triggering all audio, visual, and physical media associated with that moment in the script. This gives actors complete control over timing, which is vital for comedic effect and improvisation with a live audience.

The media cues vary greatly: animations, sound effects, music, video, physical effects, onstage signage, and real-time evolutionary digital simulations. The cues also vary in complexity—

from a single sound effect to a full blackout of the theater along with timed mechanical and sound effects that surround the audience.



DIGITAL NURSERY

In order to accurately show the number of generations required for the artificial selection experiment, we created an onstage physical device—Alex's Amazing Population Popper 2000™—connected to a digital VISTA Nursery. This system, invented by Alex, “digitizes” the VISTAs and accelerates selection and reproduction to show gene frequency shift over generations in a short amount of time. VISTAs appear as abstract, on-screen circles that “bump” into

each other to create the next generation. As the population grows and generations pass, the audience watches the overall friendliness of the VISTA population transition from mostly red (less friendly) to mostly blue (more friendly).

This visualization uses all programmatic animation, simulating actual random mutation as realistically as possible. This means each audience sees a brand new simulation unfold before them in each show.

“...a sophisticated device that can digitize and un-digitize simple organisms for the purpose of rapid reproduction. We can use it to watch the VISTA population change on screen instead of getting all Nature Channel and trying to watch them do their private business in the real world...”



GAME RAMP-UP

- All ages and levels of knowledge
- Can't assume any players are gamers
- Most have never played an escape room
- Start simple: group quizzes, shout-outs
- Present first escape room-style puzzle at the end of the show
- Game 2 ends with a cliffhanger!

INFESTATION ALERT

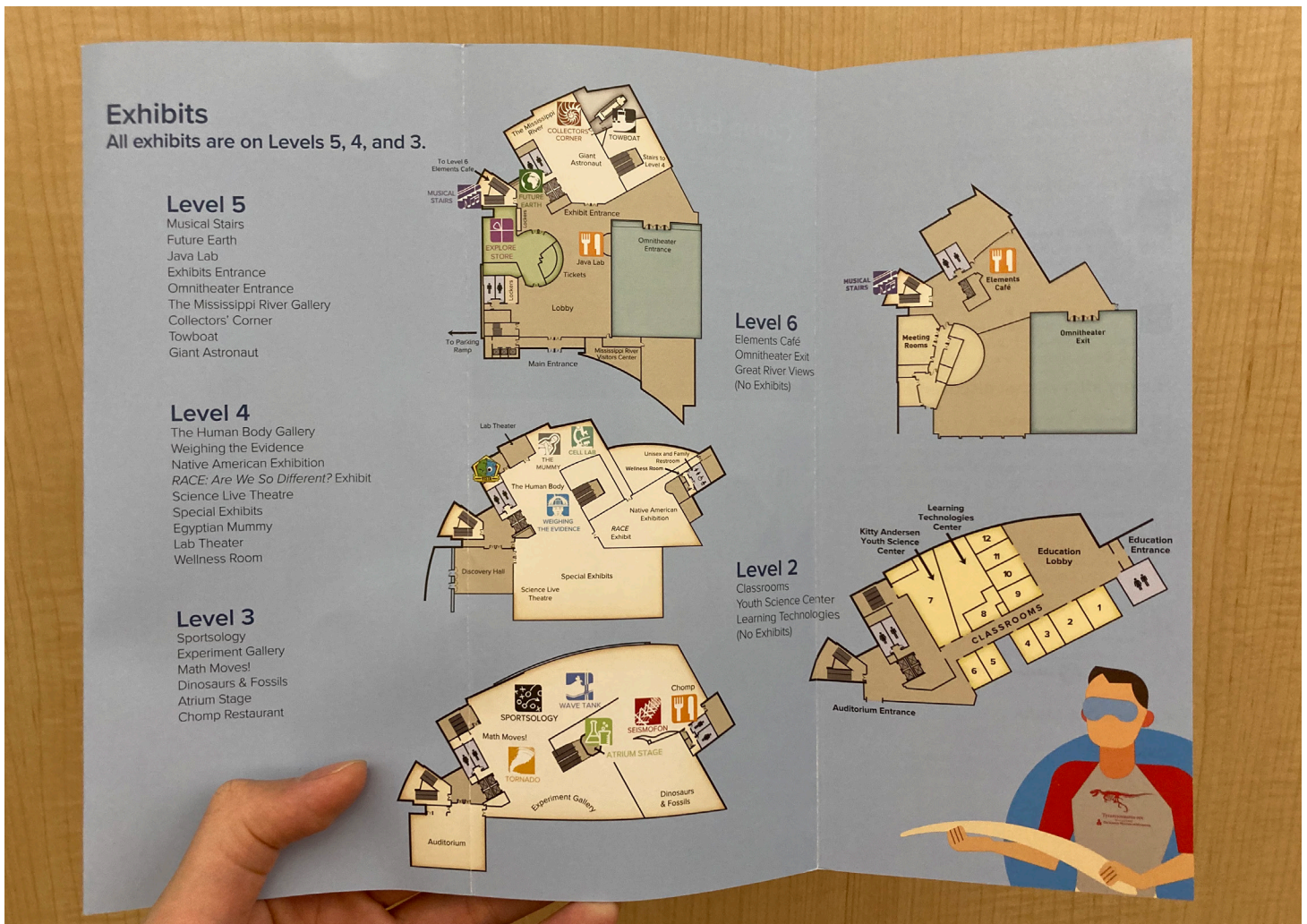


GAME 3

CHALLENGE ROOMS

While Chris is filling out the accident report, and Alex is rebooting the biosecurity system, **you** have to prove your understanding of evolution to Administrator Jobsworth, earn your VISTA license, round up our

fuzzy friends, and save the VISTA research program for another day. And you've got just one hour to do it. No problem, right?



FOUR HIDDEN ROOMS

- V = Variation
- I = Inheritance
- S = Selection
- T = Time
- A = Adaptation (back in the Theater)

But how to find them?

Wayfinding at the Science Museum of Minnesota is a challenge under any circumstances. After experimenting with paper maps, we realized that video hints about where to find the hidden rooms might work better. But how to serve up those videos? Since the Alex character in Game 2 is already obsessed with his/her phone, communicating with visitors via text messages during Game 3 was an obvious possibility.

To send and receive **SMS content**, we employ the automated call and texting service called **Twilio**.

Our application integrates the Twilio API to generate customized text messages for each group based on its current progress within the overall game. For example, we insert a "group name" variable into a templated message so that, when received, the team feels like Alex is personally addressing them. This deepens the sense of immersion in the game world. The same technique allows us to deliver personalized access codes for each room, specifically assigned to groups at the start of each game.

Texting (SMS)

- Audience is already familiar with Alex's phone
- Users are comfortable with the interface
- Use yours, or borrow one of ours
- No app download

it to me and I'll be able to unlock the door! And remember, keep it amazing!

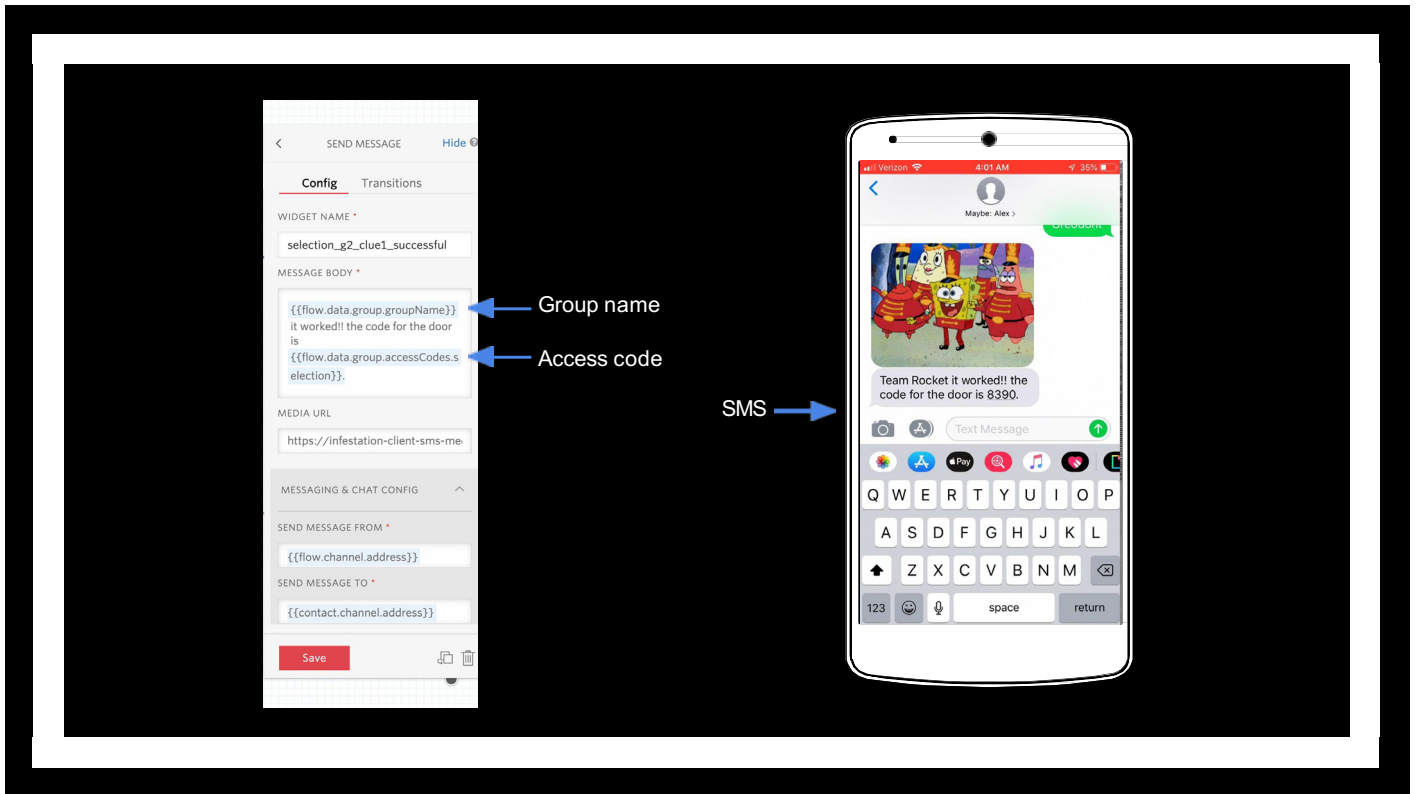
The code is: W 3 Q 8 9 X

That worked! Your team is A-MMAAAZZIZNNG!!! :D The door should be unlocked now.

Yo! I see you're having trouble finding Dr. Looshun's lab :(No sweat, I recorded a quick video to help you.

<https://youtu.be/xk7vezL36IU>

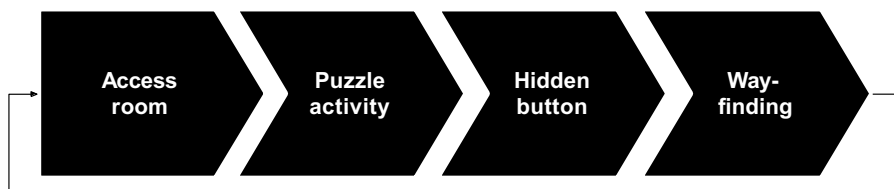
Thanks Alex! We're in



To create and organize all the SMS content that is delivered throughout the game, we used **Twilio Studio**—a fairly recent dialog-tree tool. With Twilio Studio, we can create self-contained logic, branching dialog, call-and-response interactions, and calls to custom functions. During a live game, the “Flow” JSON files exported from Twilio Studio are parsed and dispatched by our custom flow parser and wayfinding application.

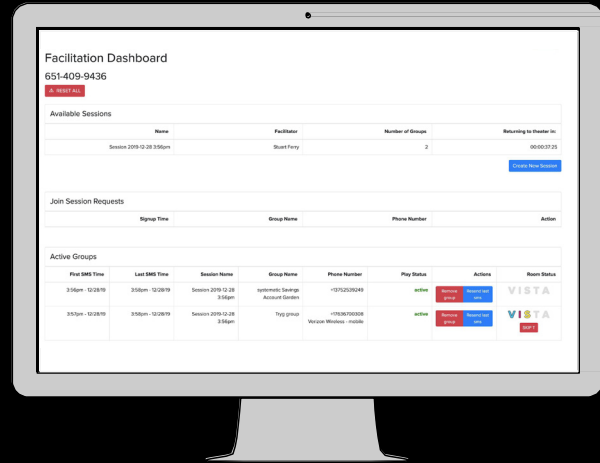
The wayfinding is designed to feel organic during the game, but our flows are strictly structured so each of the five rooms have exactly two associated with them: one that gets a team to the room, and one that tells the team where to look for the hidden “VISTA Vac” button inside that room.

PER-ROOM CYCLE



Dashboard

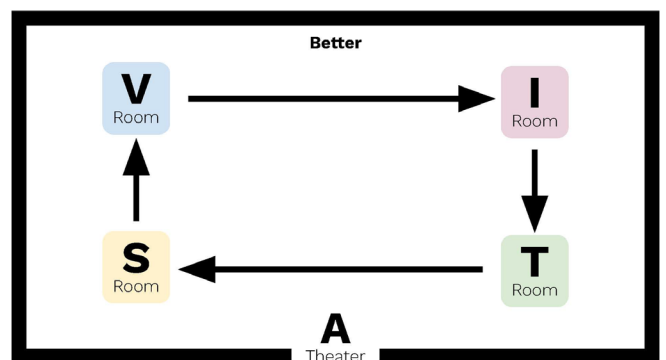
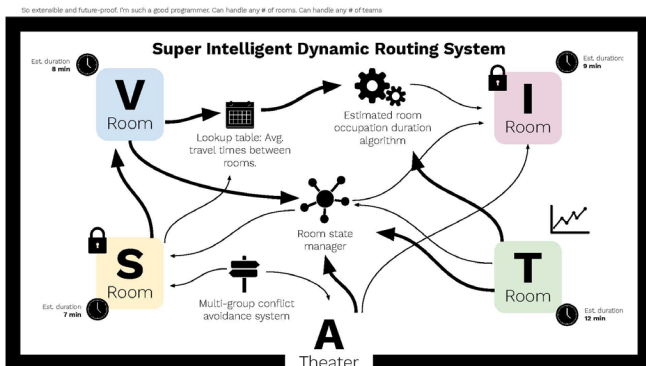
Actors create and monitor game sessions.



Alex uses a laptop **facilitator dashboard** at the start of Game 3 to create a new game session and accept/reject teams into that session as they text in appropriate group names.

With four teams simultaneously navigating to four hidden rooms in the museum, we faced the challenge of routing each team to each room without causing traffic jams and pile-ups, especially when some teams move

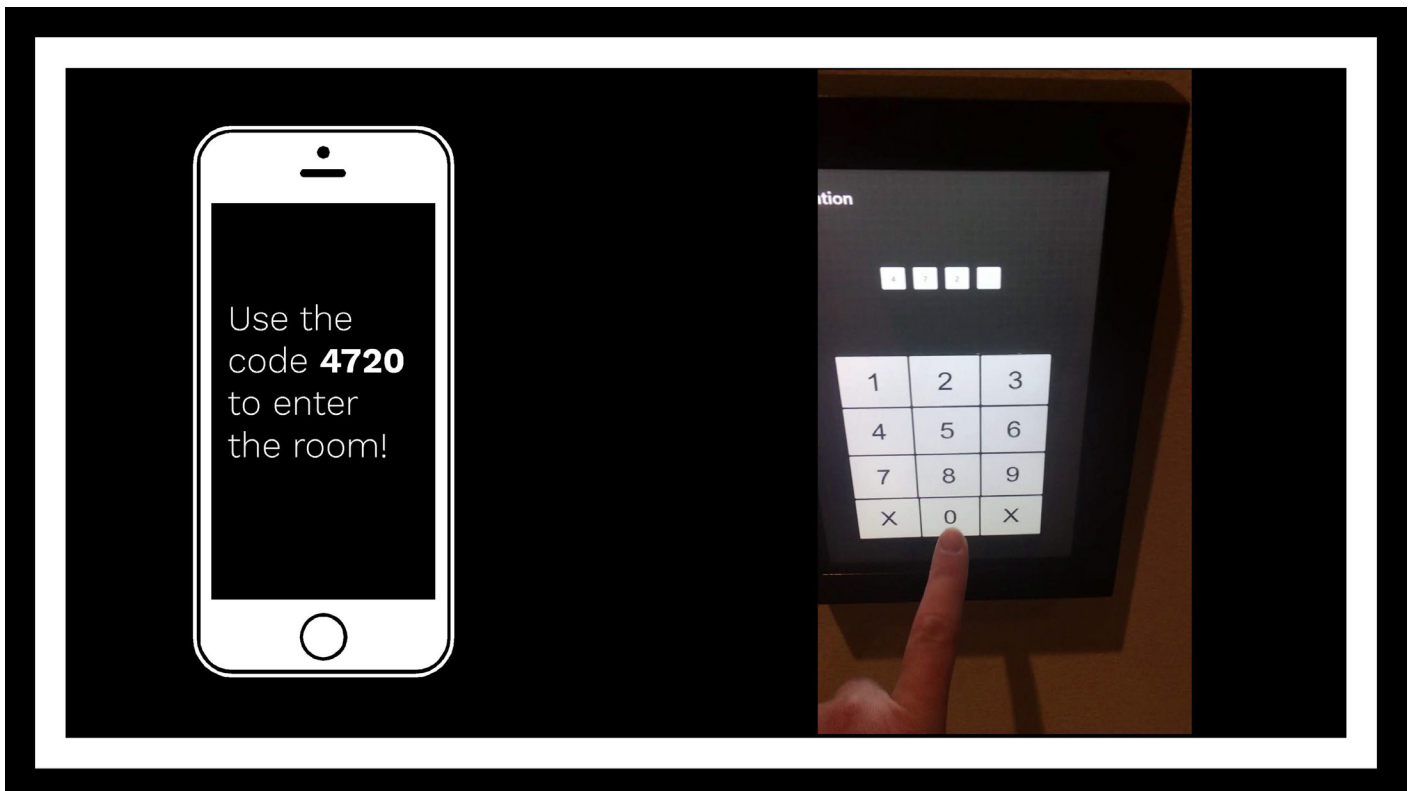
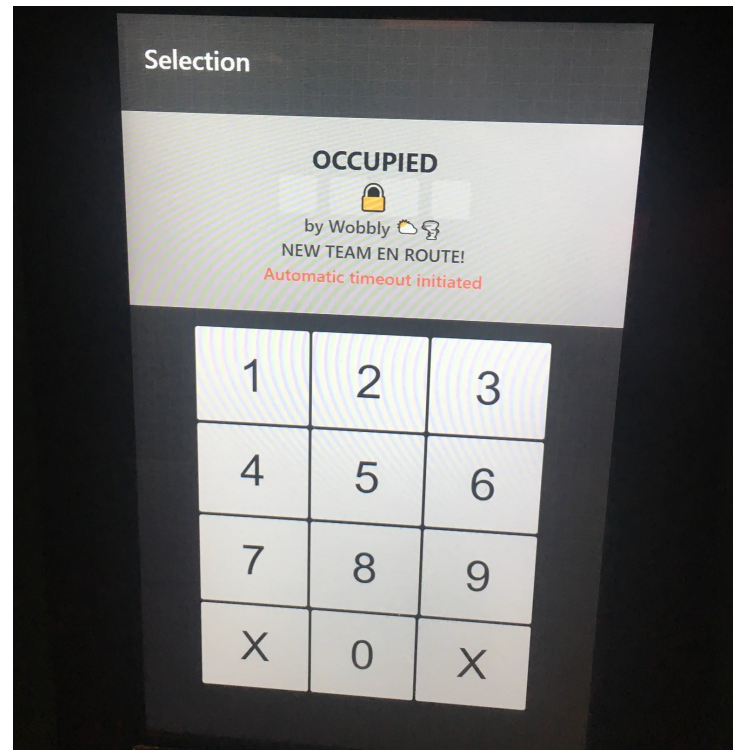
much faster than others. After experimenting with some overly complex algorithms and dynamic wayfinding techniques, we found the best method was simpler: we start each team in a different room, then rotate them from room to room in a predictable order. The actors monitor progress via the dashboard, and have the ability to manually "skip" groups past rooms when they fall behind.



To avoid confusing non-playing museum visitors, the rooms are tucked into discreet corners of the galleries and can't be accessed without entering codes into **touchscreen access panels** located outside each room. A code for each room is delivered through SMS wayfinding and is unique to each group and each game session.

The access panels and the puzzles inside each room are in constant communication with our **central game server**, which tracks the progress of each group during a game session.

The dashboard updates each time a group enters a room, completes an activity, or presses the hidden "VISTA Vac" button before leaving to find the next room. The whole-game networking provides useful information for the wayfinding system to react to.



SO... DOES IT WORK?

More than 18,000 visitors have already experienced one or more of the games.

In early tests, all of the respondents (n=30) used at least one of the VISTA concepts when asked to share one or two ideas about how the VISTAs changed. Many also found the show so engaging that they attended multiple times, and 92% of people surveyed indicated that the show was “fun” or “very fun” on a four-point scale. Early game testers shared that the challenge room experiences were fun, with half saying they’d recommend even the early prototypes to others. Formal evaluation is just beginning to see if *INFESTATION: The Evolution Begins* succeeds in shifting visitors’ conceptions about evolution and whether dosage (just Game 1, for example, vs. Games 2 and 3) affects this desired outcome.

OBSERVER: THE KIDS ALL HUGGED EACH OTHER AT THE END. THEY WERE STRANGERS.

“I don’t want to go back to school! I want to stay and help Chris and Alex!”

“This is our favorite show. We’ve seen it three times.”

“What a terrific way to learn about evolution! I teach biology, and would love to bring my students here.”

“This is awesome. This is by far the best thing at the museum. And we’re members, so we come here a lot. This was our first time doing Infestation. So fun!”

NO KIDDING: A YOUNG VISITOR (WHO WAS NOT PLAYING THE GAME) PULLED OUT A TWENTY-DOLLAR BILL AND BEGGED A PLAYER FOR THE CODE TO HARRY TENSE’S SECURITY OFFICE.

“It’s nice to have some humor for the adults, too, and it made me think. I now see how evolution works.”

Learn from others as you go!

Playing games feels universal, but audiences are drawn to different elements of game play.

>> Use our list of game elements and accompanying survey to explore how your audiences are drawn to different aspects of gaming.



Some theatre-goers thrive on direct interaction with live actors and fellow audience members, while others may prefer to observe performances.

>> Use our theatre-goer profile document and accompanying survey to understand how your audiences prefer to engage with immersive theatre.

Need to understand how visitors think about tricky concepts? Review some lessons we learned about approachable surveys.



When you're able to create a story that builds on emotional connections, immersive environments, and the right level of gaming challenges to support learning, people want to come again and again. After one gaming experience, staff overheard a mother talking to her children: "We've seen Infestation three times. Are you sure you want to do it again?" "We want to go again," they replied.

HOW CAN YOU LEARN FROM VISITORS ALONG THE WAY?

We've identified some best practices for research in learning that support the creation and production of theatrical games in informal learning institutions such as the Science Museum of Minnesota.

EVERYTHING AT ONCE

You may be tempted to prototype individual components first, but that would be a mistake.

Traditional models of experience development usually follow a process of building—and testing—from the ground up. This approach, however, isn't really suited to developing a theatrical game. During our literature review and our work with advisors, it became clear that the most important element in a theatrical game is the narrative and how the components work together to support it. We found it almost impossible to develop a narrative without also imagining the types of experiences players might experience throughout the game. To address this, we moved forward in fits and starts, working to develop and refine the narrative as we created components that drew on that storyline. All of this had implications for how we worked with visitors to get feedback on early versions of our story and interactives.

INVITE PLAYERS IN

We focused on hearing from groups of invited guests as they tried out early, rickety experiences that featured both a narrative arc and several challenge components.

Inviting groups to play-test experiences helped

us in many ways. Several groups of players generously gave us hours of their time and feedback, providing in-depth information about the ways that the story and elements were engaging or off-putting. Our focused recruitment, aided by community partners, allowed us to sample from teens, adults, and family groups, representing multiple ethnicities, income levels, and gender identities. Also, play-testers' existing relationships from outside the museum supported them in interacting more naturally with our prototype experiences and being more forthcoming about issues and challenges they faced in different versions of the theatrical game. We provided a meal, admission to the museum, gift cards, free parking, and special badges from the theatrical gaming experience as a thank you for their time and effort.

Experience is a master teacher, even when it's not our own.

—Gina Greenlee

REMEMBER YOUR MANNERS: FEED YOUR GUESTS AND SHOW THEM A GOOD TIME

We used observation, group discussions, and interactive evaluation methods to collect feedback and input during development.

Evaluators got to know participants over a light catered meal, then joined groups as they split up to try the theatrical gaming experience. Careful observation revealed where and when players

had stronger reactions, made connections to their personal lives, ran into issues, or shared insights. Immediately following the experience, participants had dessert before responding to a short survey to garner their initial reactions. Then the whole group—game developers, evaluators, and players—engaged in discussion about particular aspects of the theatrical game, trading insights, reactions, understandings, and suggestions for areas that could be improved.

In one meeting, evaluators hung pictures representing different elements of the prototype experience. Each play-tester received ribbons to “award” those elements in categories such as “most likely to make me LOL,” “best at helping me understand something new,” and “most unique experience,” among others. Then participants discussed why they’d chosen different components to receive the ribbons. Feedback from this activity helped the team identify what resonated with players and what might be improved. In another meeting, the development team was particularly curious about how players understood the data visualizations and animations used in the theatre show. During the discussion period, we replayed animation and data visualization sequences and asked participants to describe what these might be trying to show, what may have been confusing, and what was helpful about them. As we talked, participants also had printouts of the visualizations in front of them, so they could circle confusing parts and draw squares around helpful parts. We collected these at the end of our discussion, and this data helped the team identify and remove complicating features of the data visualizations.

KEEP ASKING QUESTIONS

Once each theatrical game could be run on the floor of the museum, we gained feedback from visitors in addition to invited groups.

We continued to get feedback as early iterations of the theatrical game were run on the floor of the museum. Invited groups were still part of this phase of collecting feedback, but we also recruited general visitors who had chosen to experience the game to fill out post surveys. The results were encouraging, and offered additional feedback for improvement. For example, since the average visit at our institution is about two hours in length, the team worried that the theatrical game time commitment might be too long for visitors. The survey results (and highly attended experiences) showed that this concern wasn’t warranted. Survey results also reinforced the team’s guess that the narrative arc was engaging, that people cared about the main human characters, and that the VISTA creatures were highly popular and engaging. Finally, data about player’s understanding of evolution’s key concepts after the experience helped the team make adjustments to the game that reinforce content messaging.

OUR INSTRUMENTS AND PROFILES MIGHT HELP YOU DO THIS, TOO

Early research on gaming and theatre profiles, as well as the development of instruments more adept at measuring thinking around evolution in our context, could be helpful for your next project.

No need to start from scratch! If you want to explore how visitors are approaching gaming, theatre, or the topic of evolution in your space, please use our frameworks, surveys, and interviews. The rest of the report shares these tools for learning from visitors, and provides a little more information on how they were developed and what they are trying to measure. Please modify and adapt these tools for your space and context for the best results.

DEVELOPING A GAMING PROFILE FOR INFORMAL LEARNING EXPERIENCES

Researchers can explore creating a handful of likely gaming profiles that make sense for their context by combining different elements of game play with other factors, such as how often a person is motivated to play games in his or her everyday life.

In our work, we identified several elements of game play likely to show up in informal learning environments like the *INFESTATION* experience.

Table 1. Elements of Game Play

ELEMENTS OF GAME PLAY	SUB-ELEMENTS	QUESTIONS THAT HELP DEFINE GAME PLAY ELEMENTS
Overcoming	Overcoming	Are you defeating or overcoming villains?
Social vs. Solitary	Social	Are you playing with or against other people?
	Solitary	Are you playing alone?
Novelty & Narrative vs. Conventional	Novelty	Does this feel new every time you play?
	Narrative	Is there a narrative or no storyline at all? How immersive is the story? Do you take part in an existing story or create your own?
	Conventional	Is this game mostly the same experience every time you play?
Physical vs. Stationary	Physical	Do you actively play this part with your whole body? Are you moving around physically, in real life, during game play?
	Stationary	Do you stay in one place (physically, in the real world) the whole time?
Challenge vs. Pastime	Cerebral	Are you engaged in deep thought? Do you need to think deeply to win? Are you trying to learn something new about the real world?
	Pastime	Can you do this in a pretty mindless way? Can you play without thinking deeply?

Our group then developed a survey for use with adults or youth (ages 10 and up) to help identify which gaming elements were the biggest motivators for our particular audiences. Below is the key we used to align survey responses from the instrument (also part of this packet) with the elements of game play that seemed most or least appealing for visitors.

Table 2. Analysis Key for Survey Responses and Game Play Elements*

ELEMENTS OF GAME PLAY	SUB-ELEMENTS	QUESTIONS THAT HELP DEFINE GAME PLAY ELEMENTS
Overcoming	Overcoming	Q2 l
Social vs. Solitary	Social	Q1 a, b
	Solitary	Q1 c
Novelty & Narrative vs. Conventional	Novelty	Q3 m
	Narrative	Q3 o, p, q
	Conventional	Q3 n
Physical vs. Stationary	Physical	Q1 d
	Stationary	Q1 d
Challenge vs. Pastime	Cerebral	Q1 e, g
	Pastime	Q1 f

*We identified additional elements of gameplay and used questions on the adult and youth survey to align with them, but removed them from this analysis key as they were less relevant to the end product we developed. We are happy to provide more information to anyone interested in seeing the additional survey items or elements we identified through our literature review and work with the project team.

GAMING PROFILE SURVEY

For this survey, when we talk about games we mean anything that has rules for play and a goal.

Please take a moment to think about the different kinds of games that you've played recently and in the past before you respond.

1) How much do you enjoy games where you...

Please circle how much you enjoy this.

a)...compete against others?	Not at all	A little	Some	A lot	I'm not sure.
b)...work with others?	Not at all	A little	Some	A lot	I'm not sure.
c)...play alone?	Not at all	A little	Some	A lot	I'm not sure.
d)...are physically active?	Not at all	A little	Some	A lot	I'm not sure.
e)...need to think deeply to win?	Not at all	A little	Some	A lot	I'm not sure.
f)...can win without thinking deeply?	Not at all	A little	Some	A lot	I'm not sure.
g)...are trying to learn something new about the real world?	Not at all	A little	Some	A lot	I'm not sure.

2) How much do you enjoy games where you...

Please circle how much you enjoy this.

h)...solve a puzzle?	Not at all	A little	Some	A lot	I'm not sure.
i)...collect or upgrade resources?	Not at all	A little	Some	A lot	I'm not sure.
j)... level-up or improve a character?	Not at all	A little	Some	A lot	I'm not sure.
k) ...try to find something hidden?	Not at all	A little	Some	A lot	I'm not sure.
l)...defeat villains?	Not at all	A little	Some	A lot	I'm not sure.

3) How much do you enjoy games that...

Please circle how much you enjoy this.

m)...feel new every time you play?	Not at all	A little	Some	A lot	I'm not sure.
n)...are mostly the same every time you play?	Not at all	A little	Some	A lot	I'm not sure.
o)...you can take part in a story?	Not at all	A little	Some	A lot	I'm not sure.
p)...you can create your own story?	Not at all	A little	Some	A lot	I'm not sure.
q)...have no story?	Not at all	A little	Some	A lot	I'm not sure.

4) How often do you play games of any kind?

- A couple of times a year or less.
- A couple of times a month.

- A couple of times a week.
- Almost every day

DEVELOPING A THEATRE-GOER PROFILE FOR UNDERSTANDING EXPERIENCE PREFERNECES

By better understanding audiences' theatrical profiles, or preferences for engagement in theatre experiences, we can design experiences better and later measure the effectiveness of theatrical elements in facilitating learning.

Based on motivation theory, we have identified four categories of motivational stances that a participant can take in engaging with a theatrical experience. Use the Theatre Profile Survey to identify the characteristics that your audience members prefer. If you'd like to design for a specific type of audience, you can also ask demographic questions that may help you generally understand that audience's possible preferences.

MOTIVATION	CHARACTERISTICS	WHAT ARE WE LOOKING FOR?
Theatrical Immersion	Physical Integration of Narrative	To what degree did participants experience immersivity into the set/scene? Do participants enjoy immersivity?
Affective (Emotional) Motivation	Interaction (Actors/staff/texts)	Do interactions with actors/staff engage participants emotionally in the experience?
	Narrative Structure	Did the dramatic questioning and/or engagement in the story's conflict motivate audience members to participate in the narrative action?
Social Motivation	Experiencing With	How much value do participants place on experiencing the theatrical event with family/friends? Do they enjoy watching friends/family/other audience members interact with the characters?
Intellectual Motivation	"Edutainment"	How did theatrical elements/facilitation (e.g. character, narrative arc, etc.) support learning? Did participants report both entertainment and learning?
	Transformative Learning	Did participants apply information to solve problems? Did participants report expanded perception/understanding?

In order to evaluate the success of a designed theatrical experience, we recommend identifying specific elements or moments of the theatrical experience that correspond to each of these motivational categories. To observe/test these elements, develop a survey or observational tool to help you collect data.

THEATER PROFILE SURVEY

What do you like about museum theatre shows?

What do you like about live actor-performed theatre shows at places like museums, fairs, or festivals? There are many different kinds of live-actor theatre shows: plays, musicals, improv comedy shows, etc., think about any type of show with a live actor as you answer the questions. If you haven't been to the type of live actor theatre show described, try to imagine whether you would enjoy that show. Otherwise, you can choose: "I'm not sure." Thanks for your time!

How much would you enjoy shows where...	Please circle how much you would enjoy this.			
a)...you watch the show from a distance, for example: you are in an audience and the show happens on a stage?	Not at all	A little	A lot	I'm not sure.
b)...you feel like you are actually in the time and place that the show is about?	Not at all	A little	A lot	I'm not sure.
c)...you believe that the actors are from the time and place that the show is about?	Not at all	A little	A lot	I'm not sure.
d)...you get to move around and see the show in different parts of the building/place where the show happens?	Not at all	A little	A lot	I'm not sure.

How much would you enjoy shows where...	Please circle how much you would enjoy this.			
e)...you get to change the story by interacting with the actors?	Not at all	A little	A lot	I'm not sure.
f)...the story does not change based on who is in the audience?	Not at all	A little	A lot	I'm not sure.
g)...you are emotionally affected by the story or characters?	Not at all	A little	A lot	I'm not sure.
h)...your friends or family members are invited onstage?	Not at all	A little	A lot	I'm not sure.
i)...you are invited onstage?	Not at all	A little	A lot	I'm not sure.

How much would you enjoy shows where...	Please circle how much you would enjoy this.			
j)...you learn something new?	Not at all	A little	A lot	I'm not sure..
k)...the show is entertaining?	Not at all	A little	A lot	I'm not sure.
l)...there is suspense and you guess at what's coming next?	Not at all	A little	A lot	I'm not sure.



EXPLORING UNDERSTANDING OF TRICKY CONCEPTS WITH VISITORS

During the *INFESTATION* project, our research team reviewed formal education paper-based activities designed to support children's learning about evolution, as well as instruments designed for use after seeing evolution exhibits in informal learning environments.

TO EXPLORE THE TRICKY CONCEPT OF EVOLUTION, WE DEvised A THOUGHT ACTIVITY FOR STUDY PARTICIPANTS.

Our goal, given the informal learning setting, was to develop a survey that could help quantify understanding across audiences, that would feel comfortable for both children (ages 10 and up) and adults to respond to, and that felt more like an activity and less like a test.

WE SELECTED A NEW, IMAGINARY ANIMAL AS THE FOCUS.

INFESTATION highlights the made-up VISTAs' evolution, but also features other examples, such as experimental foxes or domesticated animals.

Choosing an animal, instead of asking about how evolution might work in insects, plants, or viruses, parallels the theatrical presentation and helped focus our instrument on ideas that should have been explored and supported through the informal experience.

But early tests of our activity, using real animals (chimpanzees, foxes, and squirrels) as examples, were plagued with difficulty. Although prior knowledge was never assumed, many respondents were uncomfortable not knowing much about these animals. We discovered a very real temptation for participants to "out-think" the activity, drawing on varied pockets of in-depth knowledge to try to figure out different aspects of an evolution story.

We needed to give our respondents "permission" to think about the questions more broadly. To help them apply their thinking around evolution in a new setting, without bogging down in the details about a real animal or circumstance, we instead posed questions about an imaginary animal—one that no one already knew anything about. This allowed visitors to engage at the right level of depth: instead of thinking too much about all the strategies that a particular species might employ in order to survive or pass on its genes, they focused more on the five evolutionary concepts (variation, inheritance, selection, time, and adaptation) explored in *INFESTATION*.

WHAT WILL YOU LEARN?

We've included our survey, and the key for its analysis, here to illustrate how we explored visitor understanding of evolution before and after experiencing *INFESTATION*. We hope other theatrical game designers can build on our approach, using this concrete example to support the development of new instruments specific to other content and audiences.

Understanding Evolution Survey

Please read the story and answer the questions below.



The Divos

A small, short-furred, gray animal called a divo lives on one island. This island is the only place on Earth where divos live. The island habitat is warm and provides plenty of the divos' only food – tree ants. Divos sleep in nests that they make in the trees.

1) How likely is it that these divos...	Circle one for each question below.					
...have gotten traits and genes from their parents?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely
...have gotten traits and genes from the tree ants?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely

2) How likely is it that these divos...	Circle one for each question below.					
...are all equally adapted to life on the island?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely
...have all the same traits and genes?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely

Please let the researcher know you're ready for the next part.



Understanding Evolution Survey

Please read this short story and answer the questions below.



which fell on the ground.

A Cold Year on Divos Island

One year, the island had really cold weather.

All the tree ants died during the months of cold.

The trees lost their leaves and seeds,



3) How likely is it that these divos...	Circle one for each question below.					
...each evolved to survive the cold weather?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely
...had different chances of surviving?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely

Please let the researcher know you're ready for the next part.



Understanding Evolution Survey

Please read this short story and answer the questions below.

Seeds



Almost all of the divos starved during the long, cold year. Some tried eating the tree seeds, but they were poisonous! Most of the divos that tried eating the seeds died, but a handful lived and had babies. The next year, the island grew warm again.



Years and Years Later

Many, many generations of divos were born and had babies of their own after that one cold year.

4) How likely is it that divos living years and years later...	Circle one for each question below.					
...have all the same adaptations as earlier divos?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely
...are adapted to eat tree ants and seeds?	Definitely Not	Probably Not	Maybe Not	Maybe	Probably	Definitely

Please let the researcher know you're ready for the next part.



Analysis Key for Understanding Evolution Survey

We used a scale for confidence guessing to support visitor comfort and provide nuance for analysis

The *Infestation* experience was based in five key concepts of evolution (Variation, Inheritance, Selection, Time, and Adaptation), which we explored through the survey questions above. It is almost impossible to talk about one aspect of evolution without referencing other concepts that support it, so in our survey design, we attempted to include relevant vocabulary for the concepts that were mentioned in the show and have at least one item that especially highlighted a concept (but that may also include other concepts).

In order to support visitor comfort, we made each item a guess – not something that was true or false, but that admitted a range of surety. In addition to supporting the feeling of it being more of an exploration of thinking and less like a test, we felt that the gradation of surety around a guess might help us uncover more nuance in visitors’ understanding and confidence around the key concepts. We reversed scoring for items (ie, made the more correct responses appear at either end of the response scale) randomly, in order to avoid eliciting rote responses.

Table 1 shares how each of the concepts aligns with what was asked in the survey above, its justification for inclusion, and how we scored the variety of responses. At the end of the analysis, a person would have a possible score ranging from 0 – 24, with areas of that range suggesting less of an understanding of the five concepts (0-12) and the higher end (13-24) more confidence around understandings that could be explored more through interviews.

Table 1. Analysis Key for Survey Responses and Five Key Evolution Concepts

Survey Question	Evolution Concept	Question Scoring	Reasoning
Q1 a	Inheritance	“Definitely Not” – “Maybe Not” = 0 “Maybe” = 1, “Probably” = 2, “Definitely” = 3	This item draws on vocabulary (genes, traits) and an idea from the show (that individuals inherit traits and genes from their parents).
Q1 b	Inheritance	“Definitely Not” = 3, “Probably Not” = 2, “Maybe Not” = 1 “Maybe” - “Definitely” = 0	Same as above, but reversed likelihood of responses expected.
Q2 a	Adaptation & Variation	“Definitely Not” = 3, “Probably Not” = 2, “Maybe Not” = 1 “Maybe” - “Definitely” = 0	Draws on vocabulary (adapted) and several ideas from the show (there is variation within a population, some are better suited to their environment).

Analysis Key for Understanding Evolution Survey

Survey Question	Evolution Concept	Question Scoring	Reasoning
Q2 b	Variation	“Definitely Not” = 3, “Probably Not” = 2, “Maybe Not” = 1 “Maybe” - “Definitely” = 0	Draws on vocabulary (genes, traits) and idea from the show (there is variation within a population).
Q3a	Time	“Definitely Not” = 3, “Probably Not” = 2, “Maybe Not” = 1 “Maybe” - “Definitely” = 0	Draws on vocabulary (evolved) and ideas from the show (time is needed for populations to change; individuals do not evolve).
Q3 b	Selection & Variation	“Definitely Not” - “Maybe Not” = 0 “Maybe” = 1, “Probably” = 2, “Definitely” = 3	Draws on ideas from the show (selection acts on variation occurring in a population, allowing some individuals with useful variations to survive and pass on genes).
Q4 a	All five concepts	“Definitely Not” = 3, “Probably Not” = 2, “Maybe Not” = 1 “Maybe” - “Definitely” = 0	Draws on vocabulary (adaptations) and ideas from the show (over time, populations become adapted to their surroundings by selection of traits from variation in the population; adaptation will not remain constant, as variation continues to arise and surroundings continue to change).
Q4 b	All five concepts	“Definitely Not” - “Maybe Not” = 0 “Maybe” = 1, “Probably” = 2, “Definitely” = 3	Draws on vocabulary (adapted) and ideas from the show (adaptation will not remain constant, as variation continues to arise and surroundings continue to change; selection for some traits do not preclude the maintaining or changing of other traits).