A JOURNAL BY SISSA MEDIALAB

PRACTICE INSIGHTS

Translating research into play: design insights for evidence-based science games in museum settings

Lisa Bailey, Daniel Lawrance, Allan James, Sarah Azad, Kristin Alford and Brooke Ferguson

Abstract

Digital games in museums face the challenge of translating complex scientific concepts into engaging experiences that facilitate both individual learning and peer discussion. This practice insight examines *Symbiosville*, a touchscreen learning game designed using an event → choice → consequence pedagogical model to increase visitor understanding of the human microbiome's role in health.

Through visitor observations and survey data, this case study demonstrates how evidence-based game mechanics can effectively communicate microbiome science, with players successfully understanding relationships between personal choices and microbiome health. However, the study revealed limitations in encouraging peer-to-peer learning in museum environments, where individual screen-based interactions can inhibit social engagement despite networked game features. The analysis identifies key design considerations for science communication practitioners developing digital learning games for informal settings, including the tension between personalised experiences and collaborative learning.

Keywords

Public understanding of science and technology; Science centres and museums; Informal learning

Received: 5th May 2025
Accepted: 18th November 2025
Published: 28th January 2026

1 ▪ Introduction

MOD. is a future-focused museum of discovery at the University of South Australia that creates interactive and immersive experiences at the intersection of art, science and innovation, with a vision of inspiring young people (target age range 15–25) about science and technology.

Symbiosville was a touchscreen game developed for the 2019 exhibition HEDONISM [Bailey & Lawrance, 2019]. The subject of the game is the microbiome, the complex system of microorganisms, environmental conditions, and microbial structural and metabolite elements that exist on and in us [Berg et al., 2020]. The objective is to give people a better understanding of the ways in which their personal choices might affect gut microbiome health. These microbes play all sorts of roles in human health, ranging from bowel disease to cancer and depression. While scientists are still unravelling the complex relationships between us and our microbes, it does appear that increased microbiome diversity is associated with increased resilience and wellbeing [Dogra et al., 2020].

The game was loosely inspired by *The Sims*, where the player controls a human character who navigates a town (*Symbiosville*). The character is always hungry or bored, and so you are constantly required to make choices for the character in regard to choice of food or activity. These choices affect the diversity of the character's microbiome, where the aim of the game is to develop the most diverse, and therefore resilient and robust, microbiome. Failure to do so may lead to the need for a faecal transplant! A browser-based version of the game is still available to play at https://mod.org.au/up-close/inside-us/symbiosville.

1.1 ▪ *Game based learning in museums*

Museums are complex sites of learning, with visitors interacting with various exhibits and artworks, either physical or digital, and also with each other and gallery staff. In most instances, visitors have no prior knowledge of what to expect when they enter the space. MOD.'s design principles are aligned with a constructivist approach of open-ended exploration, with the gallery experience designed to allow visitors to move freely, at their own pace, through an offering of rich, multisensory experiences. It also occurs in a social context, which can encourage group discussion and sharing.

Game-based learning for museums has been shown to be effective across many settings and topic areas [Chen et al., 2021] and is the pedagogy underpinning the design of this experience, utilising the motivation and engagement of gameplay to communicate concepts relating to the human microbiome.

A 2020 review of educational digital storytelling games found that most examples in the literature are on humanities and social science topics, with STEM topics much less frequently covered. Within STEM, biology is very poorly covered [Wu & Chen, 2020], despite the effectiveness of digital game based learning compared to other STEM learning activities [Gui et al., 2023]. So *Symbiosville* occupies a unique niche in relation to educational content on the microbiome. This is important because people's understanding of biology concepts influences their ethical attitudes and life choices in regards to diet and health [Christopoulos et al., 2023].

The learning outcomes for this game were for players to:

- Understand that personal choices in relation to activity and diet can impact the microbiome
- Understand some of the roles of the microbiome in human health
- Engage in subject specific discussions with peers

This case study presents an overview of the game design process with a focus on the importance of aligning game mechanics and intended learning outcomes, results of visitor gameplay, and concludes with key insights from the design and exhibition of *Symbiosville* that can support others in designing games for informal learning environments such as museums.

2 ▪ Design process

The challenge for the design of this game was to create a mechanic that was engaging, simple, and based on evidence. When selecting a game mechanic, it should align to the skill or concept in the learning outcome. For example, using resource management mechanics for teaching about economic principles, puzzles for problem solving, or simulations for skill development and practice [Martin & Shen, 2014]. The selected mechanic should actively change how learners interact with the content, prompting them to think, decide, explore, and take action in a way that mirrors the desired learning objective.

The design process, outlined below, drew together expertise from museum designers, science communicators, microbiologists and game developers.

2.1 ▪ *Identify themes*

The explosion of microbiome research in the last decade has shown that it has implications across almost all areas of human health and wellbeing [Ma et al., 2018]. There is however, hype around how broad-scale findings can be implemented at individual levels, and there have been a number of dubious claims made by commercial products in regards to microbiome benefits [Ma et al., 2018], showing it was an important topic for providing some evidence-base to public understanding.

2.2 ▪ *Play testing existing games*

We took inspiration from social simulation videogames such as *The Sims*, *Theme Park* and *Rollercoaster Tycoon*. We also identified a couple of table top card games about the microbiome, *Gut Check*, developed by researchers at the Genome Center, University of California, Davis [Coil et al., 2017]; and *Gutsy*, developed by the American Museum of Natural History [AMNH, 2015]. We also played a variety of other games to look at different scoring mechanics. A game developed independently by the Graz Institute for Technology for a Massive online open course, *Tiny Biome Tales* [Schweitzer et al., 2024], was recently published but was not available at the time of development of *Symbiosville*, and also uses a similar choice-based model for game design.

2.3 ▪ *Interviews with local researchers in the field*

Part of the remit of MOD. is to showcase South Australian research, and so identifying local researchers who are exploring the field of the microbiome identified several groups working across a range of microbiome fields. Interviews were carried out with four researchers from a range of institutions covering fields that included health, environment and antimicrobial resistance. This expert input guided selection of environmental choices included in the game such as the role of outdoor interactions or additional local context such as the impact of antimicrobial resistance in Australia. The contribution of these researchers is acknowledged with a photo and short biography included in the game information screen.

2.4 ▪ *Literature review*

A literature review was carried out to investigate the interactions of the human microbiome in relation to diet, environment and activity. All of the game interactions discovered in the literature review and researcher interviews were documented in an interaction table to inform game mechanics, and are supported by existing published research (examples demonstrated in Table 1).

Table 1. Example choices presented to players of *Symbiosville*.

Interaction	*Microbiome effect*	*Scholar message*	*Reference*
Eat salad	Increase diversity	Eating plant proteins makes for a happy environment to allow bugs with anti-inflammatory effects.	[Singh et al., 2017]
Eat artificial sweeteners	Decrease diversity	Artificial sweeteners cause changes in the microbiome that affect the way we metabolise real sugars, counteracting the reason they're used in the first place!	[Valdes et al., 2018]
Eat red meat	Composition change	While a bit of red meat is ok, eating too much can throw out the balance of your gut microbiome, meaning more bugs associated with increased risk of inflammatory bowel disease and colorectal cancer.	[Singh et al., 2017]
Visit farm	Increase diversity	Living and working on a farm is a sure fire way to boost your microbial diversity. Kids raised on farms and exposed to things like cows and straw, have much more diverse microbiomes than their city friends, and are much less likely to suffer from diseases like asthma. This is sometimes known as the 'Farm Effect'.	[Wlasiuk & Vercelli, 2012]
Exercise	Composition change	Exercise changes our microbiome — favouring bugs that can produce inflammation fighting short-chain fatty acids.	[Allen et al., 2018]
Watch TV	Composition change	We are all guilty of binge watching a TV season or two. A couple of nights of poor sleep is enough to cause changes to your microbiome. Researchers have seen changes to the ratio of bacteria such as *Firmicutes* and *Bacteroidetes*, bacteria which have a role in how our bodies metabolise sugar.	[Benedict et al., 2016]

2.5 ▪ *Game design workshop*

To develop the game, MOD. collaborated with the Visualisation and Interactive Solutions for Engagement and Research team from Queensland University of Technology (QUT VISER). The workshop explored the game's look, feel, interface, mechanics, play end states and goals, resulting in a completed scope of work, as well as identifying further areas for research to complete the interaction table informing game mechanics.

The mechanics of the game follows an event → choice → consequence model in the 'world' of *Symbiosville*. This mechanic was selected to mirror the desired learning outcomes for the game: to understand the consequences of choices relating to diet and activity on the microbiome. Providing choices with consequences for players increases sense of player agency and improves learning [Joshi et al., 2025].

Characters travel randomly to various locations (e.g. restaurants, gardens, gym), where players are prompted to choose one of four different options, from performing some activity (e.g. exercise, gardening, watching TV) or eating and drinking (e.g. fast food, red meat or vegetables — see Table 1). Each option is categorised broadly as beneficial, neutral or detrimental to microbiome diversity.

Player choices impact the diversity of their microbiome, which also represents the score for game progress. Other events that can impact character health are chance encounters, which can happen during food and activity tasks, and interruptions, encounters while travelling to a location (Table 2).

Table 2. Sample of chance encounters for characters in *Symbiosville*.

Interruption/ chance event	*Microbiome effect*	*Scholar message*	*Reference*
Drink Kombucha	Increase diversity	Fermented foods can change the make up of the microbiome — for example lowering the proportion of *E.coli*, a bug that can cause diarrhoea	[Singh et al., 2017]
See Crime Scene	No impact	While we are genetically all very similar to each other, our microbiomes are uniquely personal. To the point that it could be used in forensic analysis.	[Fierer et al., 2010]
Run into parent and baby in pram	No impact	Newborn babies quickly pick up their microbiome from a wide range of sources including from their mum's vagina, breastmilk, mouth and skin during pregnancy and birth, and from their environment. By a baby's first birthday, 10 to power 13 or 10 to power 14 bacteria will have made home in their gut.	[Tasnim et al., 2017]
Run into Sickly Scott (child character)	Gain pathogen	Hope you don't get sick! If you do, a few days rest might be the best medicine. Antibiotics have saved millions of lives since their discovery. But we need good stewardship of them to prevent antibiotic resistance spreading. Australians are some of the highest consumers of antibiotics in the world.	[Turnidge, 2017]

After each decision, players were presented with the consequence of their choice via a 'scholar message' which provided contextual information based on the available evidence for each decision. For example, after making a decision to spend time in nature, players are presented with the scholar message shown below in Figure 1. Scholar messages were not direct quotes from researchers, but included as a game design element to provide feedback on player choices, supported by scientific evidence.

Figure 1. Scholar message presented after making a choice for their character.

2.6 ▪ *Design and technical approach*

Visitors were encouraged to explore different kinds of foods and activities to learn which options might be more beneficial for their microbiome (Figure 2).

Symbiosville was designed with the gallery space in mind, where it needed to be a short experience providing visitors with key messaging around the effects of daily life decisions in a memorable way.

Above the individual play screens the projection space hosted a full isometric map view of the *Symbiosville* town. All of the unique player avatars from the running games are shown together on the projected town map. In addition to making the virtual town and the gallery

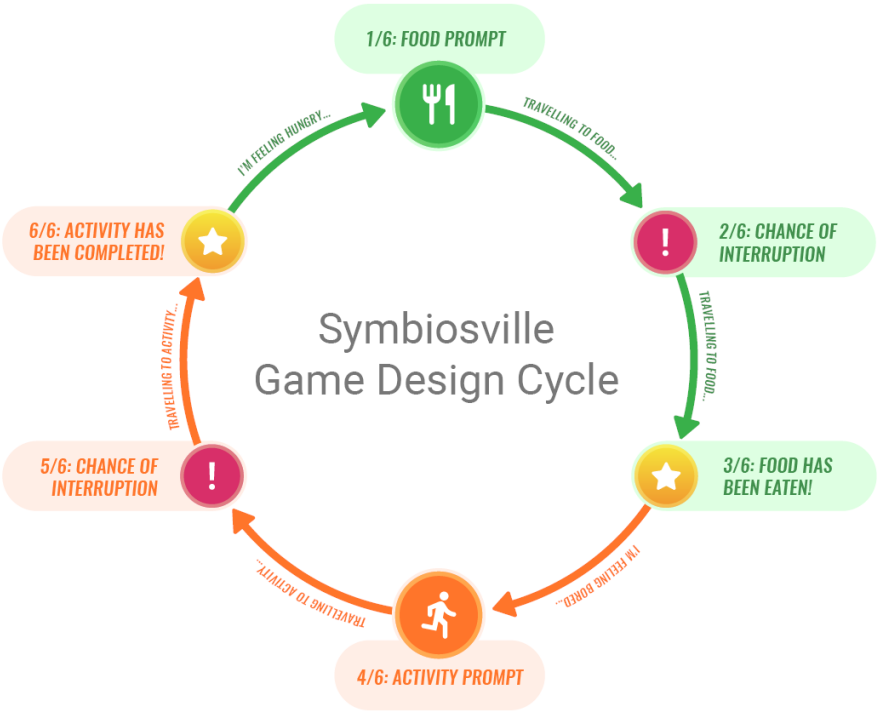

Figure 2. *Symbiosville* Game Design Cycle.

Figure 3. Overall gallery space experience (projection and touch screen areas, Science on a Sphere®).

space more alive and interesting for passive viewers, the networking feature also proves fun for players to see their personally customised characters on the large projection, alongside the other playable characters, all traveling around the town to the different activities and food locations (Figure 3).

Figure 4. Touch screen interfaces (character customiser, gameplay, scholar messages).

To create a visually enticing experience, a colourful low-poly aesthetic was used (Figure 4). Character animations were exaggerated to give a fun and playful effect alongside the use of the vibrant colour schemes. Ambient audio and music for the space was played on a loop, which set the tone to the *Symbiosville* world. A secondary, passive, quieter audio track fades in to replace the active main track when in the idle state. This is necessary in a gallery environment to reduce unnecessary sound being played on a loop for long periods, which could be bothersome for those within hearing distance of the installation.

Customisable character choices allowed players to choose hair and wardrobe options which were not limited to gender as is often the case in similar games, providing additional player agency. Players could also customise mobility for their character by choosing to use a wheelchair.

As the aim of the game was to increase your microbial diversity, visually representing microbes on screen was an important factor to communicate how well players were doing in the game (Figure 5). The initial idea was to show this through a petri dish that sat on screen at all times, although this felt quite subdued and did not visually communicate the importance on such a large touch screen. The decision was made that the whole screen would then become your microbial petri dish, with increased diversity filling out the screen if you were making all the correct informed decisions. If you were making poor decisions for your character, it would become sparse and the count would reduce and slow down drastically.

This design decision would help the visitor quickly grasp the aim of the game and correlate how the foods, activities and interruptions they were coming across in *Symbiosville* had consequences to their character along with diversity and pathogen bars that would fill and reduce based on the gameplay (Figures 6 and 7).

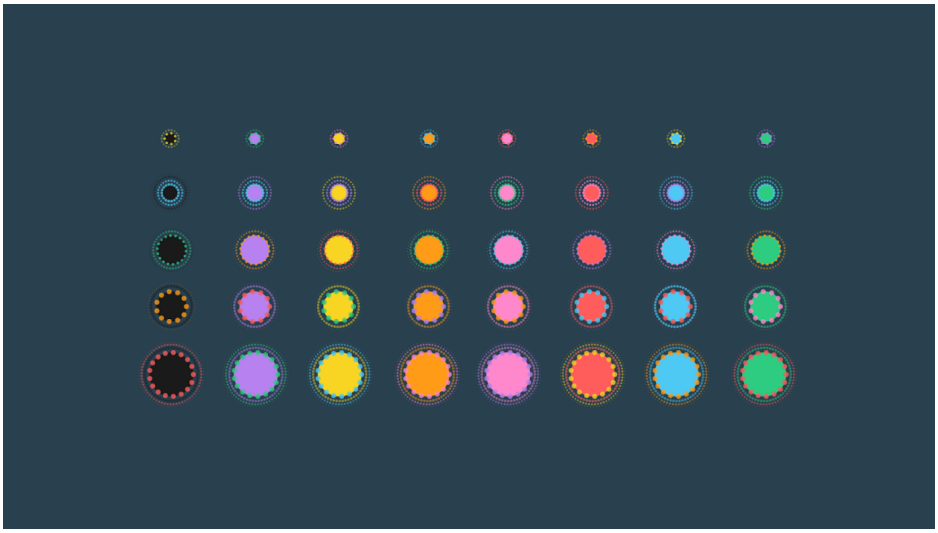

Figure 5. Microbe design variations to represent a range of diversity.

Figure 6. Static *Symbiosville* designs (start results).

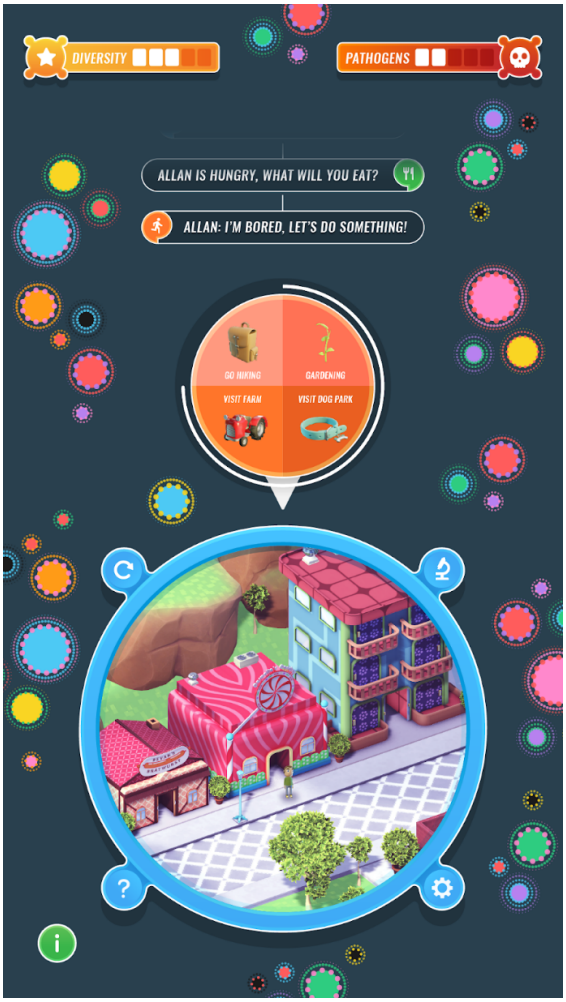

Figure 7. Static *Symbiosville* designs (end results).

3 ▪ Outcomes and analysis

50 visitors completed a short survey after spending time in the gallery. Time spent in the gallery was analysed through direct observation of 118 visitor interactions.

3.1 ▪ *Duration of interaction*

Visitors spent on average 8.5 minutes in the gallery. Many visitors spent quite a lot of time initially customising their character, which is a non-essential option available to players to personalise their experience. The ability to customise an avatar has been shown to have a positive effect on players' engagement and ability to remember events from games [Ng & Lindgren, 2013]. For 10% of visitors character customisation was their favourite element of the exhibit (see Table 3).

Table 3. Visitor preferences for parts of the *Symbiosville* exhibit for enjoyment and learning.

	Creating a character	*Exploring Symbiosville*	*Facts about the microbiome*	*Science on a sphere*
Which part of the exhibit did you find the most useful for understanding the microbiome? (n = 50)	10%	20%	56%	14%
Which part of the exhibit was your favourite? (n = 48)	23%	17%	13%	48%

3.2 ▪ *Impact on visitor learning*

Overall, players enjoyed the experience of the game, with 88% of respondents agreeing that they would recommend the experience to a friend (Table 4).

Table 4. Visitor perspectives after playing *Symbiosville*. Visitors indicated their agreement with the following statements from strongly disagree to strongly agree.

	Strongly disagree	*Moderately disagree*	*Neither agree nor disagree*	*Moderately agree*	*Strongly agree*
I learned something new (n = 50)	4%	6%	12%	44%	34%
This was a good way to learn about the microbiome (n = 50)	2%	4%	12%	46%	36%
I would recommend this experience to others (n = 50)	2%	4%	6%	38%	50%
This experience has changed the way I think about well-being (n = 50)	8%	14%	40%	28%	10%

Visitor comments included:

> "It was engaging and I learnt something new whilst it was still easy to use and understand."

> "The game helps display information about microbes and bacteria through everyday tasks and experiences, in an easy-to-follow and interactive way."

> "I thought the animation was nice and the information was succinct and related to the game well."
>
> "It was funny and had some interesting plot twists, like the crime scene at the family picnic."

82% of visitors surveyed agreed that this was a good way to learn about the microbiome, and 78% said they had learned something new from the experience.

To determine which key concepts visitors had engaged with in the game, the survey included an open-ended question asking "How would you explain to a friend what you learned about from this game today?" (Table 5). Inductive thematic analysis identified themes relating to the experience of playing the game, the effectiveness of the game format for learning, and two learning outcome themes: the role of the microbiome in health, and the impact of choices on the microbiome.

Table 5. Qualitative analysis of responses to the question "How would you explain to a friend what you learned about from this game today?" Respondents were provided an open response text box with no character limit, and responses could be categorised under more than one code. (n = 50)

Theme identified	*Visitor responses*	*Example comment*
Experience of playing *Symbiosville*	18%	"Interactive + fun!"
Game based learning effectiveness	14%	"Informative and user friendly"
The importance of the microbiome in human health	22%	"Eating and taking care of yourself is important"
The effect of different decisions on the microbiome	20%	"Different things in your life can impact your gut flora"

Learning outcome 1: understand that personal choices in relation to activity and diet can impact the microbiome
In relation to this outcome, players demonstrated through survey feedback that they had understood the relationship between personal choices and microbiome impacts:

> "By choosing different day-to-day activities, I was able to learn the impact of different foods and activities on the human body."
>
> "Different things in your life can impact your gut flora."
>
> "I learnt that fermented food is good for your gut, and seaweed needs to be broken down differently to other foods."

Learning outcome 2: understand some of the roles of the microbiome in human health
Similarly, visitor comments indicated they had understood some of the connections between the microbiome and human health:

> "Eating and taking care of yourself is important."
>
> "I was also interested to learn the mechanisms behind the effects of poor sleep and the benefits of fermented foods."

42% of visitor responses identified these key concepts relating to learning outcomes 1 and 2 in the qualitative analysis summarised in Table 4.

For both these content related outcomes, the game element that was most useful for understanding were the facts provided throughout gameplay. Facts about the microbiome provided in the 'scholar messages' were rated most useful for understanding the microbiome by 56% of visitors, although only 12% of people rated it their favourite part of the experience.

The finding that the game design element of the scholar feedback message designed for content learning was found to be most useful by players for understanding the consequence of their choices is consistent with the findings of Gui et al. showing that design elements included for content learning have a greater effect on learning outcomes [Gui et al., 2023].

Learning outcome 3: engage in subject specific discussions with peers
As each instance of the game was presented on a single screen, players were able to play individually. The projection layer above the individual screens was networked to show all players in the gallery interacting in the *Symbiosville* environment.

Interaction between players was not consistently observed, with many players solely focused on their touchscreen interaction (Figure 8). While visitors may attend museums with friends

Figure 8. Observing work experience students play *Symbiosville* in July 2022. Each student focused on their own screen.

or family they are more likely to converse with, most visitors don't know each other. How do you encourage discussion among museum visitors?

Nina Simon proposed a model of visitor interaction in *The Participatory Museum* that spans five stages, from individuals consuming content up to individuals engaging with each other socially [Simon, 2010]. Mapping *Symbiosville* to this framework reveals that the underlying design of the game does not span past the third stage — multiple visitors inputs to combine to a shared and networked output displayed as the feature projection in the space — a virtual town where each player's personalised avatar can be seen. However, this has no subsequent effect on player experience (Figure 9). Players often remained focused solely on the touchscreens rather than making the connection with what was happening in the projection space above the screens.

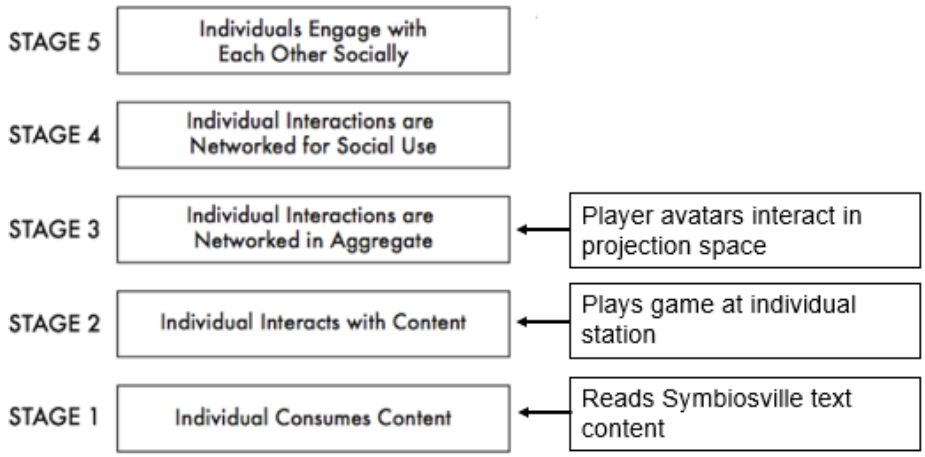

Figure 9. Mapping *Symbiosville* to the Participatory Model for visitor interaction proposed by Nina Simon in *The Participatory Museum* [2010].

The theory of Computer Supported Collaborative Learning emphasises collaboration as its core method of learning [Miyake, 2007]. The ability for learners to reflect on their process and compare their performance to that of others, can contribute to metacognitive and reflective practice of learners. Whilst players can see their own and other players' avatars in the game space displayed in the projection, it was observed in this instance to not be highly engaged with by the participants, and there is no real way for individuals to compare their gameplay with other players nearby. The game does not take advantage of the social cooperation and competition that occurs when many players are in the same environment, as the current game mechanics design does not allow for this. Improving social interaction has been identified as a area that is underexplored in museum based learning games [Zhang et al., 2024] and this could be an area to develop for future game design at MOD.

4 ▪ Discussion

4.1 ▪ *Four key insights for educational game development in museums*

4.1.1 ▪ *Evidence-based design requires systematic research translation*

The Insight: to create scientifically accurate games that are both educational and scientifically rigorous, develop a structured process combining literature review of the current

state of knowledge with expert interviews to create an "interaction table" that maps each game choice to research-backed consequences. This ensures accuracy while also presenting an opportunity to highlight the work of local researchers and links to local context.

Practical Application: before designing game mechanics, create a comprehensive database of research-supported interactions, complete with scholarly references and expert validation. This prevents oversimplification while maintaining scientific credibility.

4.1.2 ▪ *Gameplay mechanics should be analogous to the content and learning outcomes*

Insight: align gameplay mechanics to intended learning outcomes to enhance learning. The idea that 'the mechanics are the message' was first popularised by Brenda Romero's pioneering work in games exploring difficult ethical topics [Brathwaite & Sharp, 2010]. For *Symbiosville*, aligning the game mechanic of event choice consequence to the idea that choices about food and activity impact the microbiome, and by extension human health, reinforced the learning.

Practical Application: at MOD. we have applied this learning to replicate the event, choice, consequence mechanic to examining ecological interactions in *Octopus Estate*, which was adapted for the app store and is still available online at https://mod.org.au/exhibits/play-octopus-estate/; or different mechanics like team-based puzzle solving to support learning outcomes around collaboration.

4.1.3 ▪ *Individual touchscreen interfaces can limit social learning*

Insight: single-screen gameplay, even with shared projection elements, tends to focus attention downward on individual interfaces rather than encouraging peer discussion and collaborative learning. Players become absorbed in their personal experience despite being in a social environment.

Practical Application: design explicit mechanisms for cross-player interaction beyond passive observation. Consider game design elements like turn-taking systems, shared decision points, or competitive elements that require players to engage with each other's choices and outcomes.

4.1.4 ▪ *Contextual information delivery requires careful balance*

Insight: providing the educational content as a call out or pop up can interrupt game flow. "Scholar messages" were rated most useful for learning but least favourite as an experience element. Visitors could identify the usefulness of the information but may see it as interrupting their gameplay enjoyment.

Practical Application: where possible integrate educational content more seamlessly into gameplay rather than presenting it as separate information boxes. Consider progressive disclosure, where deeper information becomes available for interested players without blocking game progression for others [Avila & Schaffer, 2025].

4.2 ▪ *Areas for future study*

By the nature of in-gallery experiences, visitors will on average only spend a short amount of time playing any one game presented in an exhibition. This can be extended by putting the game online, which MOD. did with *Symbiosville* in the 2021 exhibition UP CLOSE. Providing an online browser-based version of the game allows for longer play sessions. Other digital games designed for museum experiences have found increased success online such as Wolf Quest, developed by the Minnesota Zoo, designed to take several hours to complete [Schaller, 2011].

One area of improvement would be to incorporate Multimodal Learning Analytics (MMLA) into the game design. MMLA offers various data points that can be integrated to provide information about visitor engagement and learning such as how often and where attention is directed on the screen via gaze tracking, or how long visitors spend in different states of the game, for example customising an avatar or reading scholar messages via software analytics [Emerson et al., 2020; Cukurova et al., 2020].

A recent review of game-based learning pedagogy found that the overwhelming majority (87%) of educators engage students in some sort of 'pre-game instructional activities' to prepare them for the game [Bado, 2022]. This can't be done in a museum environment in the traditional way that might occur in a formal education setting. At MOD., the use of large provocation questions is often used to frame gallery experiences for visitors. However, this was not done in for *Symbiosville* due to physical restrictions of the space. In future, consideration of inclusion of a provocation (e.g., on the floor) might better frame the experience for visitors.

Additionally, there is no 'post-game debriefing' session done as part of a museum based game experience in a self-guided exploration. Studies have suggested that the debriefing stage is one of the most important for achieving learning outcomes [Bado, 2022]. Currently, MOD. provides a teacher resource to accompany exhibitions that contains useful prompts for educators to use in a debriefing session. In-gallery this is done through the role of Moderators (gallery staff), but in future the importance of these debriefing conversations could be emphasised to educators, and efforts made to make interactive content available online even once the gallery exhibition has finished.

5 ▪ Conclusion

In conclusion, this case-study demonstrates a design process that enabled translation of microbiome research through a literature review and researcher interviews into an event $\rightarrow$ choice $\rightarrow$ consequence game mechanic. These choices were able to meaningfully impact players understanding of the impact of various foods and activities on microbiome diversity, and the link between microbiome diversity and human health and wellbeing, demonstrating the effectiveness of learning through play in a museum setting.

This work contributes to global science communication practice by providing a replicable framework for translating emerging scientific research into relevant game mechanics while highlighting the need for design strategies to overcome the inherent limitations of the individual nature of digital interfaces in social learning spaces. The findings offer practical insights for museums, science centers, and educational game developers seeking to balance

scientific accuracy, visitor engagement, and collaborative learning in digital exhibits addressing public understanding of complex biological systems.

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About the authors

Dr. Lisa Bailey is Director of MOD., Australia's award-winning future-focused museum at Adelaide University. Her career includes managing science engagement programs at cultural institutions including the Royal Institution of Great Britain and The Royal Institution of Australia. She served as President of Australian Science Communicators from 2018–2021 and has lectured in Science Communication at Flinders University. At MOD., Lisa leads innovative approaches to science communication and futures thinking, creating experiences that help audiences explore possibilities for shaping better futures.

lisa.bailey@unisa.edu.au

Daniel Lawrance is the Production Manager at MOD. responsible for the visitor experience including detailed design, build, installation and operation of interactive exhibitions. Daniel manages MOD.'s AV and IT systems, galleries, studios, cafe and casual staff pool of outstanding Moderators. His areas of expertise include video production and audio-visual content creation.

daniel.lawrance@unisa.edu.au

Allan James is a Senior Software Developer at Queensland University of Technology's VISER team, specializing in XR, visualization, and data interaction. With extensive experience, Allan

excels in developing innovative software solutions for 2D/3D data visualization, VR/AR, and interactive systems. His expertise includes scientific data visualization, game engines, and spatial data applications. James has a strong record of developing software for researchers and clients across various industries, along with publications in the field.

ar.james@qut.edu.au

Sarah Azad is a User Experience Designer for the VISER team at the Queensland University of Technology, specialising in interactive technologies and immersive spaces. With a strong belief in collaboration and iterative design, they lead a multidisciplinary team to prototype and launch immersive applications — from spatial data visualisation tools to educational gamified apps. Sarah designs digital experiences that meld creativity and technology, ranging from large scale interactive surfaces to responsive web-based environments. Their approach blends storytelling and experimentation to focus on usability, functionality, and innovation. They are passionate about shaping inclusive, engaging futures through design that challenges convention and invites participation.

s.quijano@qut.edu.au

Dr. Kristin Alford is a futurist and cultural leader passionate about creating spaces for people to imagine and build more just and sustainable futures. She is the Co-Executive Director of The Ubuntu Lab, Adjunct Industry Professor at Adelaide University and was the inaugural Director of MOD. She founded Bridge8, consulting in sustainability and emerging technology futures. She holds a Masters of Strategic Foresight from Swinburne University and a Ph.D. in engineering from the University of Queensland.

kristin.alford@unisa.edu.au

Brooke Ferguson is the Futures Officer at MOD. where she researches and coordinates projects at the intersection of futures theories and museum practices. She looks after MOD.'s Visiting Futurists program and the South Australian Foresight Community of Practice. Brooke also moderates the museum floor, engaging visitors in conversations about exhibitions themes and possible futures. Additionally, Brooke is the Youth Futures Co-Lead and Faciltiator at SA Futures Agency.

brooke.ferguson@unisa.edu.au

How to cite

Bailey, L., Lawrance, D., James, A., Azad, S., Alford, K. and Ferguson, B. (2026). 'Translating research into play: design insights for evidence-based science games in museum settings'. *JCOM* 25(01), N01. https://doi.org/10.22323/159020251118055139.

ISSN 1824-2049. Published by SISSA Medialab. jcom.sissa.it