PRISM

# Move2Learn

# Practitioners and Researchers Investigating Sensorimotor Movement (PRISM) Toolkit

Did you ever notice in a crowded and noisy exhibit that young children and their parents sometimes seem to have a private language, using hand movements (gestures) to communicate with each other?

We all use gestures to some extent when we talk, often to emphasize an idea and young children/early language learners frequently use gestures to communicate an idea or a concept they don't totally understand or just don't yet have the vocabulary to communicate. Research has shown that these gestures aren't random or meaningless – they are actually a very important part of how all people interact and think.

What if we as museum educators, facilitators and exhibit designers could somehow learn from these messages and incorporate what we learn into the design and context of our exhibits, our signage, and our facilitation strategies? Would that help children explore with more meaning-making, help them to remember the experience, or to communicate with their parents what they gained (learned) from the visit?

Could it help us look at our exhibits and programs for preschoolers differently? Address the concern sometimes expressed that young children don't really "learn" anything in museums? Could we encourage parents to be more aware of how their use of gestures and speech might help their child benefit even more from their museum visit? Do the children gesture themselves when recalling a museum experience? Can we use gestures to scaffold comprehension of early science concepts by grounding somewhat abstract ideas in a body-based form? Overall, how can gestures be used for directing attention, emphasizing, and shaping concepts?

The Move2Learn project (M2L), a collaboration of science and children museum practitioners and education researchers in the UK and US, joined forces to investigate these questions. As practitioners we discovered a whole world of gesture research that we knew little about but sensed was important. For example, different types of gestures have long been categorized by researchers (McNeill, 1985) to convey different intent. In particular, *beat* gestures are hand movements that do not convey meaning but match the rhythm of speech, and are often used for emphasis and communicative flow; *deictic* gestures, such as pointing, could be used by an adult to direct a child's attention to part of an exhibit to talk about, express feelings towards, or to provide encouragement; while *iconic* gestures are embodied representations that are more easily interpreted and provide a more concrete picture of an object, movement or science concept and reveal something about one's thinking.

With a little bit of practice, you can use these research-based approaches to investigate how your visitors engage nonverbally with your exhibits. Below are some examples of gestures/movements in museum settings and their categorization.

This material is based upon work supported under a collaboration between the National Science Foundation (NSF), the Wellcome Trust, and the Economic and Social Research Council (ESRC) via a grant from the NSF (NSF grant no. 1646940) and a grant from the Wellcome Trust with ESRC (Wellcome Trust grant no. 206205/Z/17/Z) Disclaimer Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of NSF, the Wellcome Trust, or ESRC.

## What kind of gesture is this?


Representational: Mom opens hands like alligator jaw


Representational: size of an opening


Deictic: Dad pointing to something on the wall


Representational: Figure 8 movement from Bug Sweeping


Representational: Balance with hands out front


Representational: Boy showing size of the fish

Using this approach, alongside other project-based assessments, our research evolved over time, and ultimately focused on investigating four primary questions:

1. What types of gestures/ movements were elicited by the exhibits we studied? Were they aligned with the key messages the exhibit intended?
2. Did children use gestures and movements to communicate their experience post visit?
3. In what ways did parents/ adult caregivers use gestures/ actions to scaffold their child's understanding of exhibit features, and science ideas as well as to encourage exploration?
4. Did parent attitude about science learning/ and their own science confidence impact how they interacted with their child during a museum visit?

The PRISM Toolkit that follows includes assessment and training tools that we used during our research and are offered here for your use or adaptation to explore similar questions. The Move2Learn Video Animation, lessons learned, related resources and findings to date can be found at http://move2learn.net

**Tools include:**

- Embodied Interaction Scaffolding Observation Tool (EISOT) Training Guide (PowerPoint)
- Embodied Interaction Scaffolding Observation Tool (EISOT) Template
- Guide for Designing Exhibits that Promote Embodiment (Article and Trainer Notes)
- Parental Attitudes about Learning and Science Survey (PALS)

# Move2Learn

## Embodied Interaction Scaffolding Observation Tool (EISOT)

# What is Move2Learn?

Move2Learn (M2L) is an international practitioner–researcher collaborative project. We are investigating how gestures and physical actions in museum exhibits can support children (ages 3-6 years) to effectively explore, communicate and develop their scientific thinking.

# What is embodied cognition?

The use of gestures and physical actions to explore, communicate, and develop their scientific thinking is referred to as embodied cognition.

Recent research suggests that we do this because the way we think is inseparably linked to the ways in which our bodies have experienced the world.

Our mind is integrated into the body's sensorimotor system.

# What is embodied interaction?

M2L is exploring what museums can learn from research in the field of embodied cognition that might enhance the learning experience of families.

We are using the term *embodied interaction* to promote the design of experiences that incorporate whole body movement/ actions to support and reinforce learning.

# Common Aspiration

We affirm and support family interactions at our children's and science museums that can impact learning opportunities – for **all** children!

Move2Learn

# What is the EISOT?

The Embodied Interaction Scaffolding Observation Tool (EISOT) was developed for use by museum practitioners and researchers to capture how adults use action and gesture to support children's learning during exhibit interactions.

- Designed to gather detail to examine the differences in how adults scaffold children's learning.
- Paper-and-pencil and/or tablet tool for use with real time observations, or later with video recordings of interactions.

# How can it help you?

Provides data that:

- has the potential to inform practitioners about the nature of interaction at certain exhibits, how exhibits can be designed or redesigned to enhance interaction.
- may inform practitioners about how to use gesture to scaffold children's conceptualization of science ideas.
- gives practitioners a tool to think about and develop their own interaction with children.

# How can it help you?

- Helps to assess the range of exhibit experiences in your museum.
- Highlights features of the exhibit that are iconic or troublesome.
- Can help inform design of signage that fosters relevant movement in relation to science ideas.

# Move2Learn — Embodied Interaction Scaffolding Observation Tool (EISOT)

**EISOT is an observation tool to capture how adults support children's learning during exhibit interaction.
Please complete for each observation.**

| Participant ID | Coder Name | Estimated adult age | M F | Probable relationship to child: |
|---|---|---|---|---|
| Exhibit Name | Site | Estimated child age | M F | Duration of observation:<br>Start time: End time: |

**Exhibit Type:**
Single User ☐ Multiple Users ☐ Open-ended ☐ Digital Prescribed ☐ Collaborative ☐ Whole Body Immersive ☐ Partial Immersive ☐

| Reason for Leaving: | Observation Notes | |
|---|---|---|
| Adult led ☐ Injury ☐ | More than one adult? Y N | Can you hear adult? Yes Somewhat No |
| Child led ☐ Safety ☐ | More than one child? Y N | Can you hear child? Yes Somewhat No |
| Overcrowding ☐ | Visitor density: High Med Low | Fire alarms/disturbances: Y N |
| Other (describe): | | Other (describe): |

**Other observation context notes:**

**If using video, provide video file name/identifier:**

| | | Gesture/Speech | Action/Speech | Speech (ONLY) | Gesture (ONLY) | Action (ONLY) |
|---|---|---|---|---|---|---|
| Scaffolding | Science Ideas | | | | | |
| | Exhibit Features | | | | | |
| | Encouragement | | | | | |
| | Behavior Management | | | | | |

# Definitions: Interaction Behaviors

*Speech only:* adult may introduce important words, ask questions, and/or direct child's attention relevant to the exhibit.

*Gesture only:* adult has made a physical movement in space that does not cause an 'effect' (change) in the environment.

*Action only:* adult has physically interacted with the exhibit or with the child that causes an 'effect' (change) in the environment.

*Gesture/Speech*: adult makes a physical movement in space without physically affecting the exhibit or child, and also uses speech to accompany the gesture.

*Action/Speech*: adult physically interacts with exhibit or child while also speaking.

# Closer look at scaffolding behaviors

# Scaffolding: Science Ideas

- Adult provides some type of verbal explanation of relevant science ideas.
- Uses gestures and/or actions as part of their explanation.
- Asks science-relevant questions, i.e. “what if...,” to encourage child to predict and investigate an idea.
- Models/demonstrates a scientific phenomena/ relationships with action or gesture.

# Closer Look: Science Ideas

# Scaffolding: Exhibit Features

- Adult demonstrates how to use features of the exhibit, often involves pointing or labelling.
- Speech is focused on exhibit operation or manipulation.
- Instructs child on what to do in an exhibit or provides them with other support to complete a task.
- Interactions may encourage child-led explorations of exhibit features.

# Closer Look: Exhibit Features

# Scaffolding: Encouragement

- Encourages child to keep on going verbally, as well as with facial gestures nods, raises eyebrows.
- Moves physically closer to child to let them know they are there.
- May be hard to identify actions for encouragement on their own, so look at context for clues.

# Closer Look: Encouragement

# Scaffolding: Behavior Management

Adult's actions that relate to child safety, cleaning the environment, managing the movement of the child within the space (to avoid other children) or resolving conflicts between children.

# Closer Look: Behavior Management

Move2Learn

# Embodied Interaction Scaffolding Observation Tool (EISOT)

**EISOT is an observation tool to capture how adults support children's learning during exhibit interaction.**
**Please complete for each observation.**

| Participant ID | Coder Name | Estimated adult age | M F | Probable relationship to child: |
|---|---|---|---|---|
| Exhibit Name | Site | Estimated child age | M F | Duration of observation:<br>Start time: End time: |

**Exhibit Type:**
Single User ☐ Multiple Users ☐ Open-ended ☐ Digital Prescribed ☐ Collaborative ☐ Whole Body Immersive ☐ Partial Immersive ☐

| Reason for Leaving: | Observation Notes | |
|---|---|---|
| Adult led ☐ Injury ☐ | More than one adult? Y N | Can you hear adult? Yes Somewhat No |
| Child led ☐ Safety ☐ | More than one child? Y N | Can you hear child? Yes Somewhat No |
| Overcrowding ☐ | Visitor density: High Med Low | Fire alarms/disturbances: Y N |
| Other (describe): | | Other (describe): |

**Other observation context notes:**

**If using video, provide video file name/identifier:**

| | | Gesture/Speech | Action/Speech | Speech (ONLY) | Gesture (ONLY) | Action (ONLY) |
|---|---|---|---|---|---|---|
| Scaffolding | Science Ideas | I I | I | | I I | |
| | Exhibit Features | I I | | | | |
| | Encouragement | | | I | | |
| | Behavior Management | | | I | | |

# EISOT Observation Form

- Complete the section at the top of the page before/after the observation.
- Code each incident based on the scaffolding category AND behavior.
- All codes should be mutually exclusive to each interaction – one code per interaction. For example, if an adult lifts a block and speaks, this must be coded under speech + action, NOT one in speech another in action.

# Putting it All Together: Observation Video Practice

Work with a partner to practice coding for the EISOT categories:

- Science Ideas
- Exhibit Features
- Encouragement
- Behavior Management

# Observe/code video clip

With your partner:

- Complete the top section of the EISOT form
- View the video clip. Pause/rewind as needed.
- Record the start and end time of the clip.
- As the adult gestures, acts, speaks, make a mark in the appropriate box.
- Compare your observations with your partner's. If needed, review any segments where you are not in close agreement.

Move2Learn

# Reflection Questions

- What scaffolding behaviors did you observe?
  Did you and your partner agree?
- Describe your experience coding the interaction behaviors.
- Did sharing the different perspectives between you and your partner improve the quality of your coding? Increase your understanding?

Move2Learn

# Why does this work matter?

- Provides a new window into how we think about children's acquisition of science ideas, and the important role of adults and their use of gesture/action.
- Helps recognize the diverse ways that children communicate their understanding.
- Can inform the design or redesign of early learning exhibits to encourage relevant gestures and physical actions.
- Raises implications for exhibit facilitation and/or signage that encourages adult participation.

move2learn.net

This material is based upon work supported under a collaboration between the National Science Foundation (NSF), the Wellcome Trust, and the Economic and Social Research Council (ESRC) via a grant from the NSF (NSF grant no. 1646940) and a grant from the Wellcome Trust with ESRC (Wellcome Trust grant no. 206205/Z/17/Z) Disclaimer Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of NSF, the Wellcome Trust, or ESRC.

# Move2Learn

## Embodied Interaction Scaffolding Observation Tool (EISOT)

**EISOT is an observation tool to capture how adults support children's learning during exhibit interaction. Please complete for each observation.**

| | | | | |
|---|---|---|---|---|
| **Participant ID** | **Coder Name** | **Estimated adult age** | M F | **Probable relationship to child:** |
| **Exhibit Name** | **Site** | **Estimated child age** | M F | **Duration of observation:**<br>Start time: End time: |

**Exhibit Type:**
Single User ☐ Multiple Users ☐ Open-ended ☐ Digital Prescribed ☐ Collaborative ☐ Whole Body Immersive ☐ Partial Immersive ☐

| | | |
|---|---|---|
| **Reason for Leaving:**<br>Adult led ☐ Injury ☐<br>Child led ☐ Safety ☐<br>Overcrowding ☐<br>Other (describe): | **Observation Notes**<br>More than one adult? Y N<br>More than one child? Y N<br>Visitor density: High Med Low | **Can you hear adult?** Yes Somewhat No<br>**Can you hear child?** Yes Somewhat No<br>**Fire alarms/disturbances:** Y N<br>**Other (describe):** |

**Other observation context notes:**

**If using video, provide video file name/identifier:**

| | | Gesture/Speech | Action/Speech | Speech (ONLY) | Gesture (ONLY) | Action (ONLY) |
|---|---|---|---|---|---|---|
| Scaffolding | Science Ideas | | | | | |
| | Exhibit Features | | | | | |
| | Encouragement | | | | | |
| | Behavior Management | | | | | |

# Move2Learn

## A Guide to Designing Exhibits that Promote Embodiment

**Activity 1. Read article about practitioner/researcher collaboration at Glasgow Science Centre**

Menzies, Ghazali-Mohammed, Macnab, Meikleham, Rose, Manches (2020). *Embodied Learning in Museums: exhibit design for preschool scientists.* Education in Museums Journal No 40 25.

**Design Principle 1:**

**The exhibit should encourage actions that are meaningful and congruent to the ideas at hand.**

*In the ELM article what movements were aligned with the key science concepts and takeaway messages of the exhibit?*

Thinking about your exhibit:

Identify potential concepts/ideas that could be represented by embodied representations such as gestures/ movements. Briefly describe below:

**Design Principle 2:**

**Provide relatable and age-appropriate context to guide activities.**

*How was this addressed in the ELM article?*

Thinking about your exhibit:

What would attract young children to want to visit your exhibit? Does the look-and-feel encourage playful movement? What features could they be used to direct attention, emphasizing and shaping embedded concepts.

## Design Principle 3:
**The use of space can help or hinder embodied and social interaction.**

*How did the exhibit described in ELM article address this principle?*

Thinking about your design:
Does the space encourage movement? Can it accommodate two or more people?
Is it designed for multiple players to use without interfering with each other?
Can the exhibit be used from multiple sides? Share your initial thoughts below.

## Design Principle 4:
**Recognize the multi-modal ways children communicate their thinking.**

*What are examples of actions children made at the Balance exhibit that communicated their understanding?*

Thinking about the science concepts and ideas you want the exhibit to convey:
Consider whether the exhibit will need adult facilitation/support. Would an exhibit title suggesting what to do at the exhibit and/ or signage recommending actions be helpful? Perhaps adding text that offers a challenge to try would encourage?

Try writing a label below that asks at least one open-ended question to elicit a representational gesture or action:

# Embodied Learning in Museums: exhibit design for preschool scientists

**Jamie Menzies, Dr Zayba Ghazali-Mohammed, Dr Sharon Macnab, Susan Meikleham, Graham Rose and Dr Andrew Manches**

## Introduction

Museums and science centres are recognised for their value in supporting young children's learning through an active, play-based approach. This is particularly valuable for science learning which benefits from the multimodal aspects (be it verbal, actions or gestures) of physically interactive science exhibits (Allen, 2004). These create a sense of discovery and lay important foundations for understanding complex concepts. However, to date there is limited research on how science communicators or facilitators can use these various modes of communication to explain science ideas.

Within the sector, the importance of physical interactivity is evident in terms including "hands-on" or "kinesthetic" learning, however, it remains unclear how this more general physicality supports children's ability to understand and communicate different ideas. Whilst science centres and museums are under continual pressure to deliver meaningful learning experiences, there is a lack of research knowledge in what types of experiences are most valuable to learning, and how these can be best designed to enable participants to transfer their experiences beyond the science centre setting.

These challenges are central to Move2Learn, an international collaborative project investigating how museum exhibits can be designed and facilitated to allow preschoolers (identified here as 3-6 years old) to meaningfully express, communicate and develop their scientific thinking. In this paper, we draw upon lessons learnt from this project to discuss the potential and challenges of using an *Embodied Learning* approach to achieve these aims. We suggest ways that science centres and museums can apply this research for exhibit and experience design, and demonstrate the benefits of researcher-practitioner collaboration in the co-creation of a physical-digital science exhibit.

## Embodied Learning

Embodied Learning refers to how we can create more meaningful learning by providing particular embodied (sensory and movement) experiences (Kontra et al., 2012; Linden and Johnson-Glenberg, 2013). Moreover, we know that gestures can reveal how we draw upon previous sensory and movement experiences when we think about science ideas. In other words, our thinking (cognition) is *embodied*. Research demonstrates the benefits of Embodied Learning for children – for example by encouraging particular actions or gestures when exploring new ideas. A key challenge is identifying *which* actions or gestures are most valuable for learning. One approach is to explore the types of gestures we create when communicating our understanding. For example, we can see the similarities in an adult's (Figure 1a) and children's (Figure 1b) gestural description of the concept of balance, all involving flat hands moving up and down (Ghazali-Mohammed et al., in prep).

By providing a means to understand which types of sensory and movement experiences support children's thinking and learning, an Embodied Learning approach has significant implications for exhibit design and facilitation. Where children and adults might consider speech to be the pervasive means to communicate ideas, Embodied Learning emphasises the value of other means, notably the use of actions and gestures. There may be benefits in encouraging purposeful uses of gesture to communicate ideas at science centres and beyond (Goldin-Meadow and Alibali, 2013). This can be particularly valuable to children who experience difficulties or lack confidence in communicating what they know verbally. We propose that Embodied Learning has potential to contribute to informal science learning design, facilitation, and multimodal communication in particular by:

1. Providing a framework for noticing, understanding, and evidencing the *value* of exhibit interactions;
2. Informing meaningful exhibit designs;
3. Informing more meaningful facilitation;
4. Capturing diverse ways that children communicate science thinking.

## Overview of the project

The project reported in this paper is a partnership award to increase the impact of the broader Move2Learn project. Over a year, education practitioners and exhibit designers from Glasgow Science Centre (GSC) worked with Learning Sciences researchers from the University of Edinburgh (UoE) to evaluate some design implications of Move2Learn by co-designing an Embodied Learning exhibit for preschoolers. We set out to explore the key facets of exhibit design that best promote embodied interactions, as well as develop a best-practice approach to researcher and practitioner partnerships (RPPs). This offered a rare opportunity for the two groups to consider and extend their ways of partnership working. Significantly, UoE and GSC were equal partners – neither was simply advising or consulting. This involved frequent meetings, shared office spaces and collaborative outputs, with each partner acting as a 'critical friend' to the other, bringing different experiences and expertise.

**Figure 1. Balance gestures during science learning (a) by parents as children interact and (b) by children after interacting.**

During the design process, we discussed and documented how the contributions of each institution, educational theory (UoE) and exhibit requirements (GSC), affected our decision making and the project outcomes. Our final aim was to translate Embodied Learning theory into an exhibit prototype to be tested on the GSC floor.

## Introduction to Glasgow Science Centre (GSC)

GSC is a 5-star visitor experience dedicated to raising awareness throughout Scotland of the importance of science to our well-being, economy and society in the 21st century. We engage with over 400,000 visitors annually, including community and education groups from across Scotland. Our vision is of a Scotland where all people value science and technology to inform decision making, empower individuals and enrich lives. We inspire people of all ages to explore and understand the world around them, to discover and enjoy science and understand its relevance to their own lives.

Within GSC, we carefully consider how to engage all of our different audiences. We are very much led by the user. Who is our main audience for that activity or experience? What life experience might they bring? What restrictions might they have and how can we both engage them at their own level? By asking ourselves these questions, we intend to create an experience that fosters ownership among our visitors over their learning journeys and extends their experience to support the development of their science narrative.

## Design-based research

Throughout the project it was important to bring together educational theory and our existing exhibit research with the requirements of an exhibit to be used in the everyday context of GSC. Here, designs need to withstand hundreds or thousands of interactions per week, be aesthetically appealing and age appropriate to attract users to test the exhibit for themselves. Consequently, Move2Learn adopted a design-based research (DBR) approach (Figure 2) as a means to iteratively draw upon and inform theory and practice.

Key to this DBR process is researchers and practitioners working closely together. In this context, researchers were able to critically comment on the exhibit design in terms of how it could best tap into Embodied Learning mechanisms and scaffold learning experiences with or without adult support, as

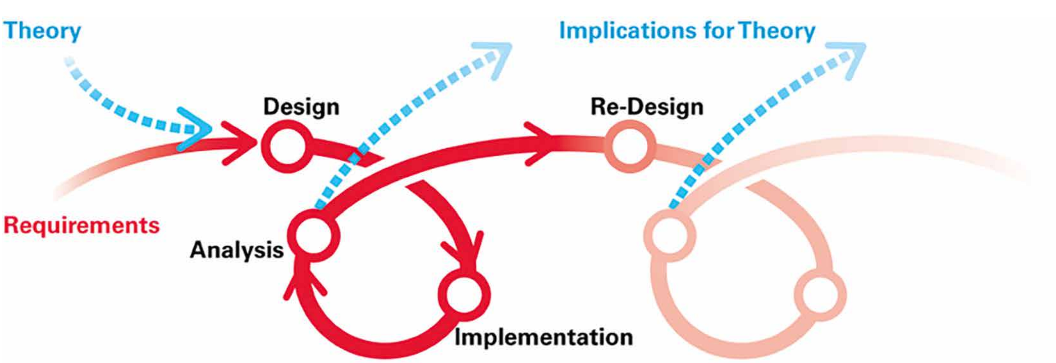


**Figure 2. Process of DBR used in the project (Fraefel, 2014). The main Move2Learn project provided theoretical input, which was combined with the requirements of GSC to create the initial prototype design. This exhibit prototype was then implemented in context and analysed to inform future re-designs.**

well as ways to evaluate the exhibit as a form of research tool. The exhibit designers and practitioners were able to draw upon their wealth of experience of exhibit interaction to refine the desired research outcomes into a physical exhibit structure that could be realised in context. Through collaboration, the team articulated clear design guidelines that were communicated over several meetings with external consultants for fabrication and software development.

## Learning about balance

Our exhibit focuses on the scientific concept of balance. Balancing is a common experience for preschoolers (think see-saws and riding a bike) but the developmental steps to understanding balance concepts (such as forces) are challenging. Prior work has shown how children's gestures can reveal more understanding than speech alone (Pine et al., 2004) and this is supported by our studies which asked children to explain balance concepts before and after interacting with an existing balance board exhibit at GSC. This exhibit (Figure 1a) was investigated and our interviews showed that it led to some confusion for children, evident in difficulties children demonstrated during interaction and in their post interaction explanations. Issues identified included accessibility (height was not appropriate for children), number of variables (making the relationships difficult to understand) and the fact that children could only place blocks on one side at a time. Significantly, some children also needed explicit prompting of the aim to balance the board.

To help us gain more insight into how young children are able to explore balance concepts, we observed an existing school workshop at GSC, *Brilliant Balancers*, which is specifically aimed at preschoolers. In the workshop, we observed ways children engaged with concepts of balance, such as 'mirroring' (Figure 3a). We also observed the way that facilitators and nursery practitioners often used gestures that simulated the physical balance designs to communicate with children (Figure 3b). Feedback from the GSC practitioners suggested that when delivering the workshop to family groups, adults were more likely to draw upon personal examples

**Figure 3a. Children were given planks of wood balanced on a central wooden block and asked to balance wooden bricks on the board to keep it balanced. As is often the case with wooden blocks, many of the children tried stacking blocks on top of each other. Children were also interested in making mirror images and repeating patterns on both sides. The idea that having the same pattern on both sides leading to balance was well understood.**

**Figure 3b. At the beginning of the workshop there was an introduction to balancing by the GSC facilitator who used movements and actions, such as holding out one bent arm and moving their forearm up and down, when explaining the concepts. It is worth noticing that the facilitator was not prompted to use movements, they were created naturally to communicate ideas.**

like a see-saw. These observations informed our design goal to help children link their interaction with a physical balance exhibit with other real world contexts that involve balance.

## Exhibit design and build

Based on our observations and the aims of the project, we planned to design an exhibit that provided clear action experiences which closely aligned to the dominant gesture used to communicate balance. This alignment is also referred to as 'congruency' (Lindgren and Johnson-Glenberg, 2013). We then designed the physical exhibit to closely map to digital representations and activities that could help children link their experiences to other contexts, as well as provide structured activities to progressively explore key concepts of balance. Reflecting other balance designs, our balance beam centered on a pivot upon which the user can place weights at predetermined increments in order to make the beam 'balance'.

Our evaluations of the existing balance board exhibit clarified the problem of the circular board that required multiple weights to be placed at multiple points, considering angular distances. Hence our first design solution was to constrain variables by creating a single dimension (like a see-saw), with fixed distances to place weights from the pivot (central point). From our evaluations, we agreed upon two different weights and two distance points from the centre on each side. Our evaluations of existing balance apparatus also revealed a significant challenge of many balance designs (e.g. Figure 4a) – that they are too sensitive to changing weights, making it difficult for children to compare and reflect upon the influence of varying weights and distances, as well as having several safety issues in terms of the speed the balancing arms dropped. After consultations with balance manufacturers and scientists, we found that a high fulcrum (central vertical piece) made for easier and quicker settling. To address this challenge, we evaluated the benefits of springs (Figure 4b) and a lower pivot point (Figure 4c). Figure 4d illustrates the digital augmentation – a screen based version of the balance beam that mirrored the movements of the physical design.

Safety was considered throughout the design process. This included ensuring the exhibit was sized appropriately for the youngest in our age group (3 years) and had safety features like beveled edges and no finger traps (e.g. between stacked weights).

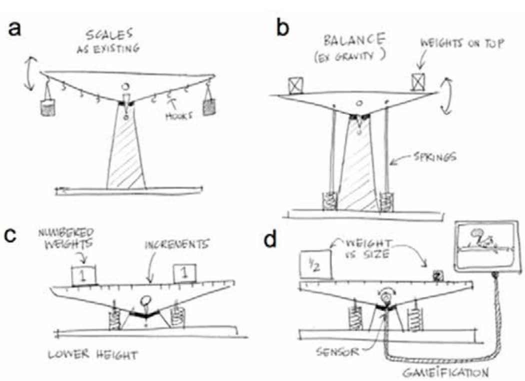


**Figure 4. The four iterations of the physical exhibit design, with the fourth iteration integrating the digital component.**

**Figure 5. Initial physical prototype design.**

Dampening and maximum heights of the movement also minimized any chance of children being struck by ends lifting (Figure 5).

## Digital augmentation

The potential of digital technology is well recognised in Embodied Learning research (e.g. Abrahamson, 2014) as it provides a way to link a user's physical interaction with more symbolic representations of the learning domain. We adopted this principle to map children's physical balance exhibit experiences to a virtual screen-based representation. One challenge was the design of the digital representation. Echoing educational research literature (Uttal et al., 2009), our initial aim was to offer children a simple abstract representation that they could explore in an open-ended way. From our fieldwork we also identified a need to draw children's attention to when the balance board was balanced. Hence we proposed a simple balance representation, using both colour and sound to emphasise when the board was and was not balanced (Figure 6a). Figure 6b shows an early version of the prototype linking physical exhibit to the digital representation.

As well as provide a simple abstract representation, we wished to address the challenges children had in mapping one experience to another balance context. Hence we designed a 'real world context' version that embellished the digital representation with an engaging narrative. After discussion and feedback from children, we decided to create a more fantastical context of a very light animal (caterpillar) trying to cross a bridge to reach some food. To help the caterpillar, the user needs to place rocks (mapped to discs on the physical design) to balance a bridge to obtain the food on the other side. We then used this context to present challenges of increasing levels of difficulty.

Based on exploratory work with test groups, other adults and our initial designs, the team mapped out a series of scenarios across three challenges relating to three key concepts for balance, defined below. Each stage became a challenge within our exhibit gameplay.

*1. Equal weights = balance*

When balancing an object around a central point or pivot, if the same weight is on both sides, the object will be level; therefore, the object is balanced. Children were instructed

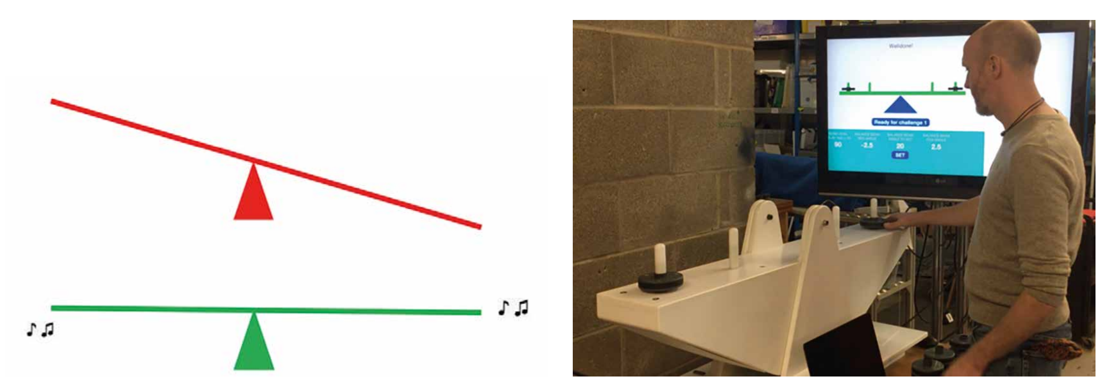

**Figure 6. Early image of prototype being tested. Note, in final versions, the physical and digital apparatus were parallel to each other and onscreen text significantly reduced.**

to put a weight on one side of the balance board and to choose a single weight that would balance the other side.

*2. Equivalent weights = balance*
If there is an equivalent weight on both sides, the object is balanced. For example, a one-kilogram weight will balance with two half kilogram weights. Children were asked to select **two** weights that would balance a single large weight.

*3. Weight and distance*
If the distance from the central point or pivot is increased on one side, the weight must be decreased to maintain balance. For example, a one-kilogram weight at five centimetres from the pivot will balance with a half kilogram weight at ten centimetres from the pivot. Children were asked to choose a weight to place at a specific point that is double the distance from a primed weight on one side.

## Current work, reflections, and next steps

As part of the DBR process we are finalising the digital scaffolding for iterative evaluation and re-design work. However, much has been learnt through the process reported in this paper of how the RPP drew together Embodied Learning theoretical work with practical requirements of museum exhibit interaction. From this process, as well as fieldwork with the existing balance exhibit and our evaluations, we have identified more general guidelines for designing embodied learning experiences in this setting, as well as reflections on the process of collaboration.

## How can museums support Embodied Learning at exhibits?

### 1. Design exhibits and experiences with congruence between actions and scientific phenomena.

The exhibit should encourage actions that are meaningful and congruent to the ideas at hand. One way to consider this is to ask whether simulating these actions (e.g. with gestures) helps communicate the ideas. For example, the dominant gesture we observed for balance (flat palms, upwards, arms moving up and down), correlates with the moving arms of the balance beam or the settling of a pan balance. This action-concept relationship may often seem obvious; however, it is often unclear in exhibits.

### 2. Accessibility matters. Use height-variable prompts and size-appropriate equipment.

It is often tempting to design exhibits that span age groups; however, young children have particular accessibility needs. We deliberately designed the sides of our balance beam to be at arm height for an average four-year-old, so children could map the movements of the exhibit to their bodies.

### 3. Provide relatable contexts that are age-appropriate to guide activities.

Our design focused on limiting the features of the physical exhibit to help children focus attention on key concepts, whilst providing a more engaging animated digital context that could extend children's experience. We used a caterpillar as a fun and inviting way to provide context to our balance game. This digital component is influenced by the user's physical actions on the balance board. Contexts are important to encourage further discussions between children and adults and to 'map' the physical exhibit into the digital space.

### 4. Encourage embodied communication at exhibits by careful design of the space, raising staff awareness and providing gesture prompts at exhibits.

Our work demonstrated the valuable role of adults in scaffolding children's Embodied Learning including the use of gestures. There is therefore much potential to support and encourage this, for example through facilitator training, or more simply through information and resources at the exhibit itself.

*5. When evaluating experiences and learning, be aware of the multimodal ways children communicate their thinking.*

Although simpler, measures such as dwell time consider engagement rather than what children learn at an exhibit. Measuring learning is problematic, particularly for young children, where common methods often focus on speech. Embodied Learning work emphasizes the importance of considering more diverse modes of communication from the actions children make at the exhibit to how they abstract and communicate particular experiences through gestures. For example, children's gestures may indicate they are aware of the importance of distance from the pivot before they can communicate this verbally.

## Closing remarks and reflections

### Dr Zayba Ghazali-Mohammed, Post-doctoral Research Associate, UoE

It is quite rare for an academic to see the fruits of their labour being applied in society. Often, despite years of research, the outcomes of our studies can be lost in academic texts. Working on this project has allowed researchers like myself to investigate and design real change as a result of the collaborative work we have done with practitioners. The value of RPPs lies when practitioner settings are not simply used as research sites, but when active collaboration, knowledge and skills exchange is encouraged. This is what inevitably counted towards the success we have had in our research and exhibit design process. As a researcher, it was hugely beneficial to understand the unique challenges science centres faced. This included understanding the typical process of exhibit design, outsourcing, intellectual property and ownership requirements to name but a few. This helped to provide context to our research and allowed exploration of ways that the RPP could address some of these key issues. One way we did this was to provide background resources to exhibit designers to understand why we made certain decisions as a project, for example, providing images/video clips of our preliminary research and short summaries about what we learned. This sharing of information allowed for more 'buy-in' from collaborators. Similarly, asking the designers to document their working process allowed us to understand the key practical challenges of our work and how they related to our research outcomes.

Understanding how the newly designed exhibit contributed toward the learning experience of children is something that we wish to explore in time, particularly by relating this to design decisions. This in itself should provide a valuable resource to all those involved in the RPP to allow for future exhibit design based on science centre requirements and values as well as in evidence-based research. As a researcher, this collaboration has highlighted how encouraging active involvement from practitioners at the start of a project can help to ensure the endurance and value of the work you do for years to come. Moving forward I can say this is something I will take with me from the project to apply in any future work.

### Dr Sharon Macnab, Science Partnerships Manager, and Susan Meikleham, Senior Learning Coordinator, GSC

In a bustling science centre environment where we are juggling multiple projects and visitor types, we have never had the time or space to look beyond, to pause and examine the granular detail of an exhibit interaction that an academic study enables. This project, the funding and the perspective of our academic researchers has enabled us to understand the need to record interactions and to reflect upon how speech, gesture and action all work together to scaffold learning. Whilst we had previously taken account of what adults (both parents and carers and us as science communicators) say to young people and what actions we take to support engagement at an exhibit, we had never considered the role of gesture to explicitly support the development of science ideas, or indeed how these all work together. Extensive literature reviews around this topic were not part of our day to day activities. Working with researchers has brought this field to life for us in a real context, and enabled us to begin to think about how we can integrate it into our practice.

We had doubts about how we could record participants in our study to gather data. Could they ever feel comfortable and 'act naturally'? Would they even agree to participate? In fact, our audiences were delighted to engage in a study that looked to develop exhibit ideas and enhance young children's learning experiences. As science communicators, we are aware of the value in building rapport with learners as a foundation for further engagement. We found that through blending this kind of practical skill with the expertise of the academics in building a robust methodology, we were together able to create an assessment tool that highlighted the benefits and drawbacks of an existing exhibit to engage this young audience. As we had co-created the study methodology, we were able to take ownership of our findings and work together to extend our research findings into the design process of an exhibit that should provide a more embodied experience for our youngest learners.

**External links**

www.de.ed.ac.uk/project/co-creation-embodied-learning-technology-early-science

www.move2learn.net

www.glasgowsciencecentre.org

For more information on Learning Sciences:

Sommerhoff D, Szameitat A, Vogel F et al. (2018). What do we teach when we teach the learning sciences? A document analysis of 75 graduate programs. *Journal of the Learning Sciences*, 27(2), pp.319-351.

**Funding acknowledgement**

This material is based upon work supported under a collaboration between the National Science Foundation (NSF), the Wellcome Trust, and the Economic and Social Research Council (ESRC) via a grant from the NSF (NSF grant no. 1646940), a grant from the Wellcome Trust with ESRC (Wellcome Trust grant no. 206205/Z/17/Z) and an Institutional Partnership Award from the Wellcome Trust (Wellcome Trust grant no. 904RDE R45935). Disclaimer: Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of NSF, the Wellcome Trust, or ESRC.

**Acknowledgements**

Thanks to 4C Design Consultancy, Pixel Stag Digital Media and Software Studio and all children and families who have supported this work.

**Authors**

Jamie Menzies | Research Assistant at Moray House School of Education and Sport, University of Edinburgh

Dr Zayba Ghazali-Mohammed | Post-doctoral Research Associate, Moray House School of Education and Sport, University of Edinburgh

Dr Sharon Macnab | Science Partnerships Manager, Glasgow Science Centre

Susan Meikleham | Senior Learning Coordinator, Glasgow Science Centre

Graham Rose | Creative Director, Glasgow Science Centre

Dr Andrew Manches | Director of the Children and Technology group, Moray House School of Education and Sport, University of Edinburgh

**References**

Abrahamson D (2014). "The monster in the machine, or why educational technology needs embodied design." In *Learning technologies and the body: Integration and implementation*: pp.33-50. Routledge.

Allen S (2004). Designs for learning: Studying science museum exhibits that do more than entertain. *Science education*, 88(S1), pp.S17-S33.

Fraefel U (2014). "Professionalization of pre-service teachers through university-school partnerships." Paper presented at the WERA Focal Meeting Conference, Edinburgh, UK.

Ghazali-Mohammed Z, Meikleham S, Macnab S and Manches A. (accepted 2020). "Video-analysis to real-time observation of adult-child interaction: the challenge of translation." American Educational Research Association (AERA), San Fransisco, USA.

Goldin-Meadow S and Alibali MW (2013). Gesture's role in speaking, learning, and creating language. *Annual review of psychology*, 64, pp.257-283.

Kontra C, Goldin-Meadow S and Beilock S L (2012). Embodied Learning across the life span. *Topics in cognitive science*, 4(4), pp.731-739.

Lindgren R and Johnson-Glenberg M (2013). Emboldened by embodiment: Six precepts for research on Embodied Learning and mixed reality. *Educational Researcher*, 42(8), pp.445-452.

Pine KJ, Lufkin N and Messer D (2004). More gestures than answers: Children learning about balance. *Developmental psychology*, 40(6), pp.1059-1067.

Uttal DH, O'Doherty K, Newland R et al. (2009). Dual representation and the linking of concrete and symbolic representations. *Child Development Perspectives*, 3(3), pp.156-159.

# Move2Learn

## A Guide to Designing Exhibits that Promote Embodiment

## Trainer Notes

**As a trainer, in addition to the Move2Learn animation you may need to draw from exhibit examples from the Move2Learn research sites.**

**Exhibit Description:** Bug Sweeping, The Children's Museum of Indianapolis
YOUR EXHIBIT NAME, MUSEUM NAME

Bug Sweeping is a Kinect-driven digital interactive in the ScienceWorks gallery of The Children's Museum of Indianapolis. The primary goal of the exhibit is to help learners understand a process scientists use to assess the potential threats insects pose to food crops, namely "sweeping" a field for insects. The exhibit simulates the steps scientists must go through to assess and maintain healthy levels of productive and counter-productive insects in a field. A secondary goal addressed by the exhibit is to demonstrate evidence-based decision making, which consists of four steps: (1) ask an answerable question, (2) collect relevant data, (3) analyze that data, and (4) decide on a course of action.

### Design Principle 1:

**The exhibit should encourage actions that are meaningful and congruent to the ideas at hand.**

Thinking about your exhibit:
**Identify potential concepts/ideas that could be represented by embodied representations such as gestures/movements. Briefly describe below:**

The exhibit includes the concepts of "sweeping" or capturing insects in a net to collect a sample. To do this in real life, a scientist or farmer walks through a field moving a net in a figure 8 pattern to "sweep" up insects that are on the leaves of the crop. The next stages is examining the insects that have been captured, i.e., categorizing and counting the insects present in the sample. The final stage in the process is controlling the counter-productive insects with options including releasing beneficial insects, use of pesticides, planting pest-resistant crops, or making the field a less-friendly habitat for the pests. The first two stages are the easiest to embody.

## Design Principle 2:
**Provide relatable and age-appropriate context to guide activities.**

Thinking about your exhibit:
What would attract young children to want to visit your exhibit? Does the look-and-feel encourage playful movement? What features could they be used to direct attention, emphasizing and shaping embedded concepts.

A picket fence surrounds the exhibit making it feel "exclusive" or set apart from the nearby exhibits. Children like to open the gate and step inside the enclosure. The exhibit has a large monitor (70 in) that is attractive to children and as they approach, they can see themselves on the monitor, adding to its attractiveness. The content is conveyed via the monitor, so its size and seeing yourself on screen are advantages in holding attention.

## Design Principle 3:
**The use of space can help or hinder embodied and social interaction.**

Thinking about your design:
Does the space encourage movement? Can it accommodate two or more people? Is it designed for multiple users to interact without interfering with each other? Can the exhibit be used from multiple sides? Share your initial thoughts below.

The exhibit is intended for one user at a time and more than one user creates a poor experience because the system does not know which individual to lock on to. It being a single-user experience is indicated by a single pair of footprints in the center of the enclosure. The enclosure created by the fence is large enough for movement; it meets ADA requirements for wheelchair accessibility.
The fence prevents other visitors from approaching the user and interfering with the Kinect, but it also creates a barrier that separates social groups. Children who may need the support of an adult are therefore separated physically by the fence; if the adult chooses to enter the enclosure, the system may not work properly. This may present difficulties especially for families with young children or groups where multiple children want to participate together.

## Design Principle 4:
**Recognize the multi-modal ways children communicate their thinking.**

Thinking about the science concepts and ideas you want the exhibit to convey:

Consider whether the exhibit will need adult facilitation/support. Would an exhibit title suggesting what to do at the exhibit and/ or signage recommending actions be helpful? Perhaps adding text that offers a challenge to try would encourage?

Try writing a label below that asks at least one open-ended question to elicit a representational gesture or action:

Scientists and farmers catch insects to learn what kinds are in a field. How would you catch an insect? What tool would you use?

# Move2Learn

## A Guide to Designing Exhibits that Promote Embodiment

## Trainer Notes

As a trainer, in addition to the Move2Learn animation you may need to draw from exhibit examples from the Move2Learn research sites.

Exhibit Description: Build a Dam, Sciencenter, Ithaca, NY
YOUR EXHIBIT NAME, MUSEUM NAME

Build a Dam is an open-ended exhibit located at the Sciencenter in Ithaca, NY. Visitors use heavy metal bricks to block the flow of water. Visitors learn about engineering and about water pressure.

**Design Principle 1:**
**The exhibit should encourage actions that are meaningful and congruent to the ideas at hand.**

Thinking about your exhibit:
Identify potential concepts/ideas that could be represented by embodied representations such as gestures/movements. Briefly describe below:

Children build a dam with heavy bricks. They can observe the weight of the bricks and the best ways to place the bricks.

Children can also observe the flow of water and how that flow is altered by the placement of bricks. As the dam gives way, children observe the movement of bricks and of water.

**Design Principle 2:**

**Provide relatable and age-appropriate context to guide activities.**

Thinking about your exhibit:

What would attract young children to want to visit your exhibit? Does the look-and-feel encourage playful movement? What features could they be used to direct attention, emphasizing and shaping embedded concepts.

| |
|---|
| The exhibit is designed to be low to the ground – so the "action" is observable from a distance across the room. Flowing water is attractive for children. Children use their hands and arms as they build a dam. |

**Design Principle 3:**

**The use of space can help or hinder embodied and social interaction.**

Thinking about your design:

Does the space encourage movement? Can it accommodate two or more people? Is it designed for multiple users to interact without interfering with each other? Can the exhibit be used from multiple sides? Share your initial thoughts below.

| |
|---|
| The exhibit is big enough for two or three people to work side-by-side, and is accessible from two sides. Children often work together or with their parents to build a dam. |

**Design Principle 4:**

**Recognize the multi-modal ways children communicate their thinking.**

Thinking about the science concepts and ideas you want the exhibit to convey:

Consider whether the exhibit will need adult facilitation/support. Would an exhibit title suggesting what to do at the exhibit and/ or signage recommending actions be helpful? Perhaps adding text that offers a challenge to try would encourage?

Try writing a label below that asks at least one open-ended question to elicit a representational gesture or action:

| |
|---|
| Can you show me what happens to the water when the dam breaks? Does this remind you of water flowing in other places? |

# Move2Learn

## A Guide to Designing Exhibits that Promote Embodiment

## Trainer Notes

**As a trainer, in addition to the Move2Learn animation you may need to draw from exhibit examples from the Move2Learn research sites.**

**Exhibit Description:** River of Grass, Frost Science, Miami, FL
YOUR EXHIBIT NAME, MUSEUM NAME

River of Grass is an exploratory, open-ended exhibit located at the Phillip and Patricia Frost Museum of Science (Frost Science) in Miami, FL. It supports visitors' learning about the Florida Everglades: the terrain, creatures, plants, and trees that live there, the properties and importance of water, the impact of the day/night cycle, and the impact of human activity.

It allows children to be immersed in an animated, virtual version of the Everglades and to observe and interact with the plants and animals that live there. The exhibit is housed in a rectangular 270-degree immersive space, including projections on the walls and floor, with 7 depth-sensing cameras to track visitors as they move and interact with the simulation.

### Design Principle 1:

**The exhibit should encourage actions that are meaningful and congruent to the ideas at hand.**

Thinking about your exhibit:
**Identify potential concepts/ideas that could be represented by embodied representations such as gestures/ movements. Briefly describe below:**

Children can observe animal behaviors (protecting, creeping, scanning), modes of movement (swim, hop, run, fly), and the time of day they tend to appear.

Daytime animal movements include birds fly/move wings, and fish, otter, turtles, and baby alligators swim, mother alligator opens jaw, frogs hop.
At night, the panther lies down and groom herself, crouches, pounces, prowls; owls open eyes; gar fish jump out of the water.

## Design Principle 2:
**Provide relatable and age-appropriate context to guide activities.**

Thinking about your exhibit:
What would attract young children to want to visit your exhibit? Does the look-and-feel encourage playful movement? What features could they be used to direct attention, emphasizing and shaping embedded concepts.

Using cartoon-style animation, the exhibit portrays common creatures in the Everglades, including alligators, panthers, otters, ducks, anhingas, garfish, and nine others. Animal characters and environment representations are accurate but playful, and many interact/respond to visitors' movements. Props (large foam logs and flashlights) are provided to allow children to notice and interact with specific features of the exhibit.

## Design Principle 3:
**The use of space can help or hinder embodied and social interaction.**

Thinking about your design:
Does the space encourage movement? Can it accommodate two or more people? Is it designed for multiple users to interact without interfering with each other? Can the exhibit be used from multiple sides? Share your initial thoughts below.

The space is large enough for several children and parents to interact with exhibit features and each other.

## Design Principle 4:
**Recognize the multi-modal ways children communicate their thinking.**

Thinking about the science concepts and ideas you want the exhibit to convey:

Consider whether the exhibit will need adult facilitation/support. Would an exhibit title suggesting what to do at the exhibit and/ or signage recommending actions be helpful? Perhaps adding text that offers a challenge to try would encourage?

Try writing a label below that asks at least one open-ended question to elicit a representational gesture or action:

Can you show me how your favorite Everglades animal moves? How does the mother alligator call her babies? How do the frogs move? What does the panther do?

# Move2Learn

## Parental Attitudes about Learning and Science (PALS) Survey

PALS was developed collaboratively by the US-UK teams of Move2Learn to meet the needs and interests of all institutions. The instrument includes demographic and psychographic items to be used to describe the sample and as independent variables for analysis. The instrument also includes 4 multi-item summated scales on the topics of: 1) engagement in science-related leisure activities with their child (6 point frequency response scale), 2) recognition of the usage of gestures in communication with their child (5 point agreement response scale), 3) personal attitudes towards and comfort with science (5 point agreement response scale), and 4) attitudes related to how young children learn or engage with science (5 point agreement response scale).

The survey is self-report, designed to be answered by the parent of a preschool-aged child. During the Move2Learn research study, PALS was typically facilitated using an online survey platform, SurveyMonkey in the US and REDCap in the UK. Occasionally, it was facilitated as a paper-and-pencil survey which is provided here. When facilitated online, the items within the three agreement response scales were randomized. In the paper version, the scale items are mixed to simulate randomization. The individual items which comprise the 4 summated scales are:

1) Engagement in science-related leisure activities with their child (6 point frequency response scale): Question 15.
2) Recognition of the usage of gestures in communication with their child (5 point agreement response scale): Questions 16, 21, 23, 26, 28, and 33.
3) Personal attitudes towards and comfort with science (5 point agreement response scale): Questions 18, 19, 20, 24, 25, 30, and 32.
4) Attitudes related to how young children learn or engage with science (5 point agreement response scale): Questions 17, 22, 27, 29, 31, and 34.

NSF wellcome E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL

This material is based upon work supported under a collaboration between the National Science Foundation (NSF), the Wellcome Trust, and the Economic and Social Research Council (ESRC) via a grant from the NSF (NSF grant no. 1646940) and a grant from the Wellcome Trust with ESRC (Wellcome Trust grant no. 206205/Z/17/Z) Disclaimer Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of NSF, the Wellcome Trust, or ESRC.

Date (dd/mm/yy)____________ Time (hh:mm) ________
Data Collector____________ ID________________

Thanks for your interest in completing this survey! This survey is about parent's attitudes about science and what the science activities they do with their children. It also includes questions about you and your preschool-aged child. It should take about 5-8 minutes to complete. All responses are anonymous. We will not ask for your name, your child's name or any contact information. All responses are also confidential.

1. When was your child who is participating in the study born?

   Month:____________________ Year: ____________________

2. What is your child's gender?
   ☐ Female
   ☐ Male
   ☐ Another Gender Identity
   ☐ Prefer not to say

3. Has your child visited this museum before today?
   ☐ Yes
   ☐ No
   ☐ Don't know

4. How often have you visited this museum with your child in the last year (excluding today)?
   ☐ Never
   ☐ Only once
   ☐ 2–3 visits
   ☐ 4–5 visits
   ☐ 6–9 visits
   ☐ 10 or more visits
   ☐ Don't know

5. Are you a primary caregiver for this child?
   ☐ Yes
   ☐ No
   ☐ Don't know

6. What gender do you identify with?
   ☐ Female
   ☐ Male
   ☐ Another Gender Identity
   ☐ Prefer not to say

7. Please select your age group.
   ☐ 18–30
   ☐ 31–50
   ☐ 51–65
   ☐ 66+

8. What state do you live in? ______________________________

9. Please select the category YOU identify with: (check all that apply)

☐ African American
☐ Afro Caribbean
☐ Hispanic, White
☐ Hispanic, Non-White
☐ Asian American
☐ Pacific Islander
☐ Native American
☐ White, Non-Hispanic
☐ Multiracial
☐ Other
☐ Prefer not to say

10. Does your family primarily speak English at home?
☐ Yes, only English.
☐ Yes, and we also speak... (Please fill in the language here) ____________
☐ No, we speak... (Please fill in the language here) ____________

11. Do you work in a job using science, technology, computer science, engineering, math, or medicine?
☐ Yes
☐ No

12. Do you have any friends or family who work in a job using science, technology, computer science, math, or medicine? (check all that apply)
☐ Yes, a family member living with me
☐ Yes, a family member/relative not living with me
☐ Yes, friends or colleagues
☐ None of the above
☐ I don't know

13. Please select the highest level of education you have completed:
☐ Less than High School
☐ High School/GED
☐ Vocational/Technical certification
☐ Two-year associated degree
☐ Bachelor's degree or equivalent level
☐ Master's degree or equivalent level
☐ Doctoral degree or equivalent level
☐ Prefer not to say

14. Please select your estimated combined annual household income.
- ☐ Less than $25,000
- ☐ Between $25,000 and $49,999
- ☐ Between $50,000 and $99,999
- ☐ Over $100,000
- ☐ Prefer not to say

15. How often do you do the following WITH your children?

| | **Never** | **At least once, more than a year ago** | **Once a year** | **A few times a year** | **Once a month** | **Weekly or more often** |
|---|---|---|---|---|---|---|
| Go to a science center, museum, or planetarium | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Go to a zoo, aquarium or farm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Do an outdoor activity (e.g., gardening, nature walk, visit park or playground) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Fix, build, or make things (e.g., LEGO®, train sets, cooking, baking) | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Read books about science, scientists, engineering, natural world | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Watch TV/ listen to radio about science, scientists, engineering, natural world | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

Science means a lot of different things to different people, but for this survey "science" or "science activities" mean "exploring the world around you by observing and interacting with your surroundings."

Some of the following questions also use the word "gestures." A gesture is a movement of a body part, often the hands, to communicate an idea.

When a question mentions "children," please think of a child between 3 and 6 years old.

To what extent do you agree with the following statements:

16. When I'm explaining something to my child, I find myself using gestures.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

17. Children can't learn science until they are able to read.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

18. I worry that my child might ask a question about science that I can't answer.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

19. I feel "at home" in places where science is discussed (e.g. in laboratories, in science centers, at the doctors, at a hospital, in industrial setting).
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

20. I see myself as a "science person."
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

21. My child uses gestures to explain what they are thinking.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

22. Children's understanding of science should be left up to their teachers.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

23. My child uses gestures to communicate with other children.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

24. I generally feel confident discussing news stories with other people.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

25. I am interested in science.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

26. My child will use gestures I've used to explain things.
a. Strongly disagree
b. Disagree
c. Neither agree nor disagree
d. Agree
e. Strongly agree

27. Children are able to learn basic science concepts at a young age.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

28. My child moves their body to help them think.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

29. Children tend to learn science better using hands-on materials and objects.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

30. I like to be up to date with scientific news and developments.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

31. Science is too hard for children to understand.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

32. In daily life, I often use my knowledge of science or scientific thinking.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

33. I use gestures to explain ideas to my child to help them understand what I'm saying.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree

34. Parents or caregivers have a responsibility to help children learn science at home.
    a. Strongly disagree
    b. Disagree
    c. Neither agree nor disagree
    d. Agree
    e. Strongly agree