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Supporting Family Scaffolding and Collaboration through Digital Interactive Tabletop Exhibits

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Abstract: This paper presents a qualitative analysis of family interaction around digital interactive tabletop exhibits. Parents play a teaching role in museum visits, using strategies from encouragement, to giving directions about using exhibits, to offering explanations that connect an exhibit to children's previous experiences. Touchscreens and touch tables offer different ways of engaging families in museums, raising questions around how these interactive tabletops support family collaboration, specifically their role in fostering scaffolding forms of activity. A multimodal analysis using video data of family interactions around three tabletop exhibits examines the role of digital exhibit design in fostering family collaboration and adult scaffolding behaviour. Findings show that particular design elements in exhibit set up, expert video/audio and touch interaction influenced family formation around the exhibit, adult scaffolding and family engagement with the exhibit activity. The paper draws on these findings to inform the design of interactive tabletop exhibits for family collaboration.

Keywords: family visitors; digital exhibits; family collaboration; adult scaffolding; exhibit design

Introduction

Museums place particular value on family interaction, bringing renewed interest in the concept of 'family learning' (Ellenbogen et al, 2004; Shaffer, 2015; Moussouri & Vomvyla 2015), encouraging museums to design collaborative family experiences. Families are defined as intergenerational groups, with at least one child, and a significant adult (although typically a parent, may be a carer or other relative (Tison Povis, 2016)). This highlights museums' awareness of the important role that adults play in supporting children's interaction and learning and has led to a significant move from designing exhibits with a child-centred approach to one that fosters collaborative activity (Wolf & Wood, 2012).

Digital technologies offer new opportunities for supporting group interactions that family visitors are seeking. Interactive surfaces are appealing due to increased affordability and availability, and their potential to promote collaboration through co-located simultaneous hands on interaction (Hornecker et al., 2008; Pontual Falcao & Price, 2010), and foster learning participation through interaction beyond hands-on activities, actively engaging visitors in meaning making (Dillenbourg & Evans, 2011; Stuedahl, 2014). While digital exhibits offer promising routes for museums to enhance collaborative family experiences, we need to better understand how their design shapes family engagement and collaboration, and the role of bodily and sensory communication in collaboration and scaffolding.

This paper reports a study of family interaction in the Natural History Museum, London to address the following questions: What forms of family collaboration can interactive tabletop exhibits facilitate? How do the design factors shape interaction and scaffolding of learning? This study took a multimodality approach (Jewitt, Bezemer, OHalloran, 2016) to analyzing video data of family interactions around three digital tabletop exhibits to focus on the role of body positioning, bodily action, gaze, gesture and verbal interaction in shaping family engagement, specifically related to collaboration and scaffolding forms of activity. Observations were supplemented by post-visit family interviews. The paper contributes to understanding the role of digital interactive tabletops in supporting learning through family collaboration around exhibits, and how particular design elements support or not parental/adult engagement in scaffolding activity with their children.

Background

Theoretical Framing

This paper aligns with socio-constructive ideas of meaning making, specifically the notion of 'scaffolding' through collaborative family interaction around digital exhibits. The term scaffolding (Wood, Bruner & Ross,1976) builds on Vygostsy's (1978) argument that learning is enhanced through socially mediated interaction whereby a more expert partner assists a novice in reaching better understanding or more independence in the learning process. In this sense, it carries an 'instructional' component, where the parent or technology support meaningful engagement in tasks they could not do unaided (Belland et al., 2014). Puntambeker & Kolonder (2005) identify three main scaffolding relationships: one to one, peer and technology, and a combination providing a distributed form of scaffolding, as in the study presented here.

Much research on scaffolding focuses on dialogic verbal forms of interaction (e.g. Rojas-Drummond et al., 2013) rather than wider communicative acts (non-verbal forms of interaction) that play important roles in 'scaffolding', while little research has examined how parental/adult scaffolding in museums is realized or fostered through interactive digital exhibits. Taking a multimodal approach, this study seeks to address this challenge, by foregrounding analysis on bodily modes of interaction, in conjunction with verbal communication around interactive tabletop exhibits.

Family Learning in Museums

Research shows that family physical and verbal interactions around show indicators of learning and joint meaning making (e.g. Borun et al. 1997, Eardley et al. 2018). Parents have been shown to play a 'teaching' role in museum visits (Diamond 1986; Ellenbogen, 2002) using a range of strategies including pointing to draw attention to

exhibit aspects, questioning, and giving explanations that connect the exhibit to prior experiences (Ash, 2002). Research of family museum learning examines talk, gender differences, splitting of groups, time at exhibits, and performative and multimodal interaction (e.g. Studart, 2000; Meisner et al., 2007; Rowe & Kisiel, 2012; Tison-Povis & Crowley, 2015; Christidou and Diamantopoulou, 2016).

Family learning research in museums has led to a stronger focus on collaborative and participatory activity (Ellenbogen et al., 2004). The role of objects and hands-on displays (mechanical and digital) in facilitating meaning making has been a research focus in museum contexts, yet the most significant finding is the importance of the social interactions between family members in scaffolding meaning making, particularly around interactive exhibits (e.g. Diamond 1986, Stevenson 1991, Moussouri 2007). More recent work suggests the benefits of different perspectives, interactivity and multimodality in promoting family learning conversations (Degotardi et al. 2019).

Work exploring how technology might scaffold visitor interaction has shown that parents using a mobile device take on managerial and educative roles (McClain et al. 2018), and the more formalized (as in structured) the scaffolding, the more engagement and participation is reduced (Yoon et al. 2013). In contrast, Rowe and Kisiel (2012) highlight the role of touch in extending socially mediated interactions, specifically through demonstration and exploration. Museum professionals therefore need to think critically about how to engage the child and adult in learning (Shaffer, 2015). For family-centred exhibits this means designing to incorporate the adult role in a variety of interactive modes (both physcial and verbal) and engage diverse visitor group combinations and ages (including grandparents and other relatives).

Interactive Tabletops: Museum Exhibits

Museums are increasingly using technologies to enhance family visitor experience and support collaborative interaction (van Dijk et al. 2012). Traditional screen and mouse computers (e.g. Explore@Bristol) are shown to increase interactivity but hinder social and collaborative activity (Heath et al, 2005), and do not fit well with the sensory, tactile experiences central to museum interaction (Geller, 2006).

In contrast, interactive tabletops have the capacity to design structure and guidance into activities, and promote collaboration through enabling hands-on co-located simultaneous interaction (Hornecker et al., 2008; Pontual Falcao & Price, 2010), and support learning (Dillenbourg & Evans, 2011). Yet much of the research on interactive tabletop technologies is orientated to interface usability, or 'talk' (e.g. scientific argumentation). Less is known about how bodily modes of interaction support or scaffold children's activity.

Research Design

Participants and Procedure

Participants were 9 intergenerational families recruited on a voluntary basis at the entrance to the Cocoon gallery, in the Natural History Museum, London. Ethical approval was obtained from the university ethics committee, and all procedures agreed with the museum. The researcher explained the purposes of the study, provided an information leaflet, and obtained informed written consent from adults and verbal assent from children, highlighting their right to stop participating at any point. Participant ages ranged from 25-62 for adults and 2-18 years of age for children.The families were encouraged to freely explore the gallery. The researcher discretely followed each family throughout their gallery visit using a roaming video camera to record their interactions

with the selected digital exhibits. As they moved between exhibits the researcher made key observation notes and documented their trail using a tracking sheet (a map of the museum gallery and exhibits). After their visit the researcher conducted a video-recorded 30-45 minute semi-structured interview in a separate room. The interview took a conversation approach and used a topic guide to probe three key areas of the family experience - motivation for visit, reported experience with the exhibits using prompts around sensory forms of interaction and responses to specific technologies, and collaborative experience, rather than content specific information. This approach extends conventional museum-based studies to include data on bodily action, to better evaluate technology-based exhibits (Heath et al., 2005).

Digital Exhibits

The three exhibits discussed in this paper involved touch screen tabletop interaction with different design features and a focus on the process of science rather than the outcome of scientific endeavour. The museum target audience for all exhibits was adults aged 25-29, and learners at formal key stages 3, 4 and 5 (11-18 years old). Despite this, these exhibits are frequented by family groups with members outside this target group.

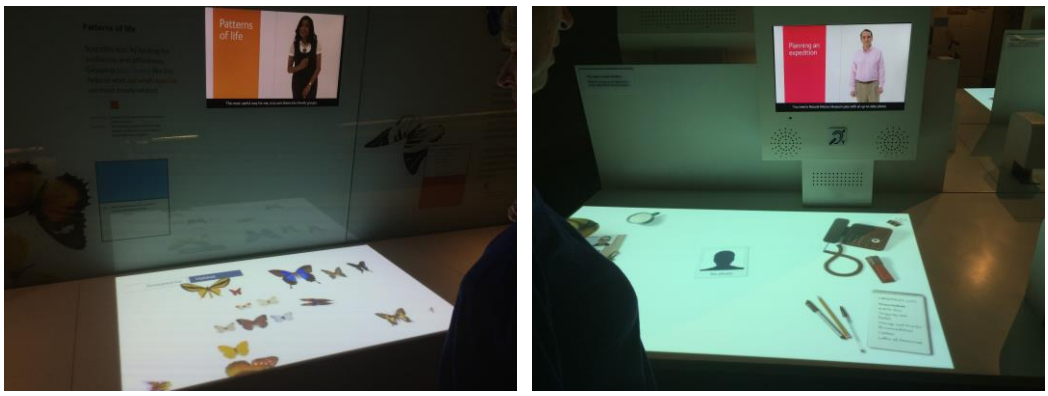

Figure 1: The Patterns of Life display (left) and Planning a Trip display (right)

The *Patterns of Life* exhibit (height approx. 90cms) concerned understanding scientific classification. Visitors play the role of a butterfly curator who is putting new specimens into the museum collection: they have to determine to which existing group each new butterfly belongs. The exhibit comprised a vertical screen on the wall on which a scientist guide appears to assist visitors in their challenge; and a horizontal touch surface, onto which virtual butterflies are projected, and where visitors drag and drop specimens into various classification groups. More information about specific features of the different butterflies is given through the verbal narration of the video and interaction with the touch screen (Figure 1).

The *Planning a Trip* exhibit (height approx. 80cms) was designed to engage visitors in playing the role of a scientist to gather paperwork and equipment to go on a fieldtrip. A scientist guide appears on a vertically positioned screen. He/she starts by explaining that planning fieldtrips carefully is crucial and introduces the challenge. Visitors have to find and pack the items they need (e.g. collecting permit, anti-venom, pruner) by dragging and dropping their selected items into a virtual bag located on the interactive surface (Figure 1).

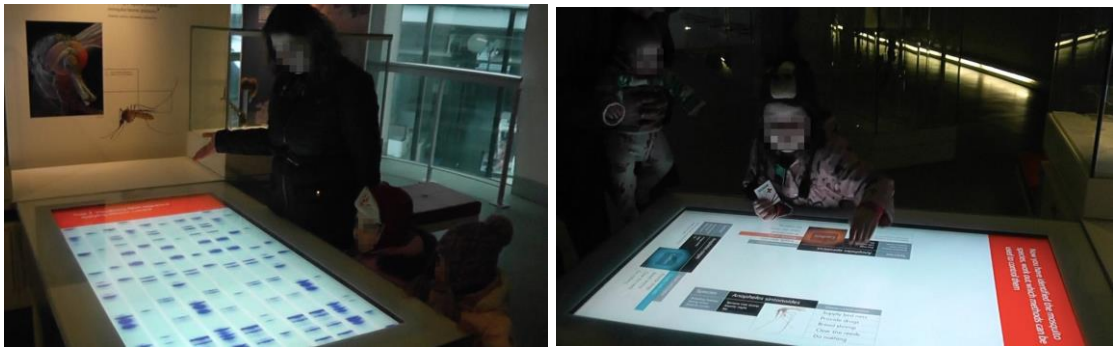

Figure 2: The Challenge Exhibit

The Challenge exhibit (height approx. 70cms) comprised a multi-user horizontal interactive tabletop projection. This exhibit challenges the visitor to stop the spread of malaria involving a problem solving activity: mosquito species can look very similar

but need different strategies to keep them under control. Scientists use the mosquitoes' DNA as a barcode to identify different species. Visitors could work co-operatively to identify which mosquito species was spreading the disease and try to control the disease spread by using different methods (Figure 2).

Analytical Approach

A total of 5 hours of video data of family interactions with the interactive tabletop exhibits (table 2) and post interview data were collected. The video data provided a rich unstructured data set, thus a thematic analytical approach was taken with a focus on family collaboration and parental/adult scaffolding. A multimodal approach (Jewitt et al., 2016) was used to generate and investigate these themes. Multimodality provides a fine-grained account of interaction-in-context looking beyond what people say to study *all* communicative modes (e.g. image, gaze, touch, gesture, body posture). The modal and semiotic choices that visitors made sought to understand the implications of their choices for meaning and learning (Jewitt et al., 2016; Jewitt & Price, 2019). Specifically, we analyzed the different design features of the digital exhibit environments, their affordances and constraints, in terms of how these shaped body positioning, family grouping, touch practices and experiences, as well as the principles that visitors used to organize their interactions. This enabled us to investigate how the digital exhibits were used and interpreted by family groups differently and the consequences for a collaborative meaning making experience. This approach reduced research dependence on talk in order to interrogate digital interaction. The analysis was complemented by data from transcripts of post interviews.

Analytical themes were developed and refined through repeated collaborative viewing of the video data. This involved a process of noticings (Erickson, 2011) towards the development of sensitizing themes. These themes were discussed in

dialogue between the data and two researchers. The themes were applied to the data independently to iteratively refine them. Table 1 outlines interaction aspects identified as relevant for gaining insight into how these digital exhibits supported (or not) family collaborative interaction and scaffolding strategies.

Coding category	**Code description**
Family members/group split	Family members interacting with specific exhibit
Bodily Positioning	Position around tabletop surface /in relation to one another
Touch action	Forms of touch interaction, making the interface work Touch forms of scaffolding
Gesture	Pointing, drawing attention to interface aspects/ activity aspects /learning concepts
Verbal	Scaffolding interaction/the activity/ learning concepts

Table 1: Coding themes

All coded instances were analyzed with specific attention to joint action, collaborative interaction and adult scaffolding behavior, attending to and identifying adult strategies beyond talk that aided children's engagement, interaction and meaning making. This extends previous research foci on talk (e.g. Ash, 2002; Tison-Povis & Crowley, 2015) to embrace observed physical strategies, such as touch, used to foster collaboration and scaffolding strategies.

Findings and Discussion

This section describes overarching findings, followed by a presentation and discussion of four themes that emerged around the relationship between digital design and adult scaffolding: set-up and body positioning; touch interaction; video mediated scaffolding; and taking the lead. Implications for exhibit design are discussed in the final section.

Table 2 details the family interaction: which families visited each exhibit, which family members took part, and dwell time. The average dwell time indicates that the three exhibits engaged families longer than the typical 1.1 minutes of museum exhibits

(e.g. Horn et al., 2012): Patterns of Life averages 6.1 minutes; The Challenge averages 4.6 minutes; Planning a Trip averages 5.6 minutes. However, the distribution of time spent differs significantly across families.

Family grouping (Adult/**C**hild**)**	**Exhibit**	**Family group split**	**Dwell time**	**Note on interaction**
1 (3A; 3C)	Patterns of Life	DNE	DNE	Moved on as other family already at exhibit
	Planning a trip	2 girls, joined by A, joined by all	30s	Short dwell time: left, as table not responding to touch
	The Challenge	All (6)	2m 10s	Left when technology stopped responding
2 (2A; 2C)	Patterns of Life	2A; 2C	1m 30s	Parent/child have different activity focus during time at exhibit
	Planning a trip	DNE	DNE	Walk past exhibit
	The Challenge	DNE	DNE	Moved on as other family already at exhibit
3 (2A; 1C)	Patterns of Life	DNE	DNE	Video not running, and walk past
	Planning a trip	Dad + girl (mum observes)	8 min	Completed the full activity
	The Challenge	DNE	DNE	Moved on as other family already at exhibit
4 (2A; 2C)	Patterns of Life	DNE	DNE	Walk past exhibit
	Planning a trip	All	1.5 min	Discussion around expedition, but did not interact with exhibit
	The Challenge	All (dad + boy leave briefly & return)	7 m	Almost completed full activity
5 (2A; 2C)	Patterns of Life	DNE	DNE	Moved on as other family already at exhibit
	Planning a trip	DNE	DNE	Walk past exhibit
	The Challenge	DNE	DNE	Moved on as other family already at exhibit
6 (2A; 2C)	Patterns of Life	DNE	DNE	Walk past exhibit
	Planning a trip	Mum + boy (dad + boy watch)	10 min	Complete full activity
	The Challenge	All	1m 9s	Catch mosquitos, then move on
7 (2A; 3C)	Patterns of Life	All (mum + girl, others watch)	6m 30s	Complete a number of buttefly selections & additional information
	Planning a trip	Dad/ girl/ baby; joined by mum	8 min	Complete full activity
	The Challenge	All then mum + girl	9 m	Interacted for 2 cycles of the exhibit
8 (1A; 3C)	Patterns of Life	Mum + girl; 2 boys watching	4m	Complete a number of buttefly selections
	Planning a trip	Mum + girl	3.5 min	Complete majority of activity
	The Challenge	All	3m 10s	Complete one cycle of exhibit
9 (1A; 3C)	Patterns of Life	A + 2C, then A +1C	12m 30s	Complete a number of buttefly selections & additional information
	Planning a trip	DNE	DNE	Passed by: child needed bathroom
	The Challenge	All	5m 23s	Complete one cycle of exhibit + mosquitos twice

Table 2: Family group make-up and interaction at each exhibit. DNE: did not engage

Setup and Body Positioning

Analysis showed that the setup of the exhibits afforded different family groupings, accessibility and perspectives. *Patterns of Life* and *Planning a Trip* enabled up to 5 people to gather around, with adults or older siblings standing behind smaller children. However, the characteristic tendency of the observed families was for them to interact in pairs (adult and child), while other family members moved on. Groupings around Patterns of Life were generally larger but worked most effectively when one adult and child engaged together. In contrast, family groups tended to stay together in The Challenge where positioning around three sides of the table enabled multiple interaction points.

The differing tabletop heights across the exhibits, shaped attention and joint activity. Patterns of Life was less accessible to younger children, yet the linked video display situated higher on the wall was visible to, and engaged, small children. Planning a Trip was more accessible for children, leading to more joint activity, through facilitating the child touching and adult making suggestions, standing behind or to the side to view both the video expert and the tabletop. The Challenge being lower was accessible to a wider age range, including younger children.

While the physical and social affordances of interactive surfaces (typically offering access on four sides) have been shown to foster collaboration (Sharp et al. 2007), the physical set up and presence of the expert presenter video in Patterns of Life and Planning a Trip meant interaction was constrained to one perspective. This contributed to the typical paired family interactions observed, together with the touch interaction opportunities afforded through the interactive surface itself.

Touch Interaction with the Interface

Touch-based interaction was central to interacting with these exhibits. Analysis suggest that touch and hands on activity are highly valued by families: "*it's nice to be able to stop and use your hands rather than just looking at things*" (F3), and this was said to "*trigger an interest among children due to their familiarity with touch screens, consoles, and phones"* (F1). However, the particular touch-based technology was found to influence the level and type of collaborative activity, and frequently disrupted the flow of interaction. Despite this disruption the majority of families worked to overcome digital interaction difficulties. This suggests adults' perceived relevance of the exhibits for younger children. This maintained their engagement with the exhibits, as well as resulting in joint action and instances of parental/adult scaffolding.

Touch interaction was not always intuitive, since some features required a tapping movement and others a dragging movement, with no clear instructions as to which to use when. Furthermore, some visualizations looked interactive when in fact they were automated. In the Challenge, for example, the visualization of the DNA sequencing raised ambiguity around touch capacities resulting in all families experiencing some difficulties in discerning the touch requirements: *'it took a while to get to know whether to touch-touch or hold-touch…how much to touch the screen*' [F9].

In Patterns of Life and Planning a Trip camera recognition software was used to realize touch interaction. This relies on a camera recognizing where the hand/arm is, tracking its movement and altering the visualization accordingly. If more than one hand/arm is in the camera field of vision, the software does not always identify which item to track, often resulting in no interface response. For some families this was problematic, being time consuming to understand why it did not work, resulting in repeatedly failed attempts to drag items from one location to another, or caused confusion when more than one family member attempted to interact with the interface

simultaneously. Interference also occurred when a child leant on the surface watching another family member interacting. Two family groups spontaneously realized that multiple touches affected the interaction (*"too many hands confuses it"*, F7) enabling them to more productively support their children's interaction. Three families experiencing these difficulties were observed to leave the exhibit after a short interaction.

A common difficulty was observed with the dragging gesture required to move selected objects from one place to another, e.g. butterflies into their classification group or objects into the expedition bag. This is common where novel interfaces co-exist in a gallery making it difficult for visitors to know what to expect and how to make it work (Moussouri & Fakatseli 2005). Dragging object images worked best with a flat palm, yet commonly visitors began their drag interaction with one or two fingers. Seven families experienced difficulties with this, with most making repeated attempts to move an object, by tapping, slapping, dragging with one or two fingers or dragging with a flat palm, through a trial and error process. However it also prompted adults to demonstrate, through physically mediated action to scaffold children's action (aligning with guided action in Rowe & Kisiel, 2012), or offer verbal encouragement:

> **Demonstration**: F6 [Planning a Trip] adult tells child that he needs to drag an item by using his whole palm, and shows him how to do the movement with the palm- slow, firm, smooth movement… The adult leaves the child to drag the item into the bag. He uses his whole palm firmly and slowly to move the item. The item responds by moving towards the bag and the adult says *'that's it! Keep going! Keep going! Keep going! Keep going!'*. The adult says *'yay'* as the child succeeds.

> **Physically mediated action**: F8 [Patterns of Life] The adult placed their hand over the child's to drag the butterfly together, giving verbal guidance as to how to manipulate the image as the interaction progressed, *"touch, drag and let go".*

However, the example below illustrates what happened when attempts at dragging items continued to be problematic.

> **Verbal encouragement**: F8 [Patterns of Life]: Adult places her hand on the butterfly and drags across the screen, *"you have to put this butterfly here in the group"*. The butterfly moves away as the expert on the video says, "*it is not that family*". The adult slaps the butterfly to try to make it stay and tries to drag the butterfly to the same group again, pressing harder on the surface. The butterfly springs back, the video expert says '*try again'*, and child 2 says *"hey"* in an annoyed tone. She immediately tries to drag it back again to the same group and slaps it to try to make it stay as the expert says *"it is not that family".* Child 2 then drags the butterfly once more, this time more slowly. It catches the edge of a different family grouping, and slides into this family group.

In this latter example the families' initial experience with the touch interaction led to a *perceived* difficulty with the physical interaction rather than their classification choice. Here the family focused on getting the technology to work and were unable to pay attention to the expert guidance. Nevertheless, such interaction led to serendipitous touching, leading to an 'additional information' section on butterfly features resulting in more reflective and attentive engagement, e.g. exploring the butterfly tail, claws, shape of wings and length of body.

The Challenge, being a multi-touch surface, did not have the same touch related difficulties. The exhibit involved two episodes where the system responded to touch interaction: catching mosquitoes, which required tapping on the mosquitoes as they rapidly moved around the screen; and making selections of strategies to reduce the spread of malaria from mosquitoes. (During the remaining time the exhibit showed visualizations of scientific processes and effects.) At these points touch interaction moved the activity forwards, and fostered playful forms of sensory interaction (Perry, 2012). Several family members simultaneously tapped the screen to catch mosquitoes in

a rapid and excited manner, and 3 families made strategy selections in collaborative ways: each member chose different strategies in each of the three selection boxes (F7); a child made a selection and the adult helped with touch interaction (F8); the adult prompted children to think about their choices by asking what and why they were choosing, rather than leaving them to randomly select from the options (F9). However, since more than one group could touch the exhibit simultaneously it was unclear who made it work or whether action on the screen was not controlled by visitors.

During interviews 8 out of 9 families (except F4) reported that difficulties with touch interface disrupted their experience, and in some cases created feelings of frustration. Despite this 8 out of 9 families (except F2) also reported the positive impact of the touch interactive elements. Most adults considered that interactivity and the idea of using one's hands to do an activity encourages deeper and longer engagement, for example:

> F9 [Patterns of Life] I really liked that you could touch the four circles down the side and zoom in on the claws and zoom in….. I mean a lot of museums have drawers that you can pull out but they don't necessarily make a connection, whereas this was actually giving them information.

Others commented that "*being interactive means all the information is not coming at once, so having to mediate it through action makes you engage*" (F8).

Video Mediated Scaffolding

Interaction with the exhibit activity and domain concepts were centrally mediated by the expert videos, visualisations and texts linked to the exhibits. These were used by all families and shaped scaffolding forms of interaction in two key ways: *(i)* joint exploratory performance which involved adults in guiding the activity and guiding learning, and *(ii)* joint attention.

Joint Exploration: Guiding Activity

Adults used the expert knowledge from the videos in Patterns of Life and Planning a Trip to mediate their children's interaction with the activity. Typically the adult watched and listened to the expert instructions or read the text (the Challenge) and relayed these to the child, similar to behavior adults display when encountering interpretive text and repahrase it for the children (Diamond 1986; Zimmerman et al, 2008; Tare et al 2011). However, adults used the video narratives to support their *own guidance* of their child's activity, enabling them to progress activity tasks through the exhibit narrative. This behaviour was most prominent in Patterns of Life where children tended to focus on the touch activity rather than the video; and in The Challenge, where the visualization drew attention away from instruction-text displayed at the end of the tabletop.

> F2 [Patterns of Life] Boy repeatedly touches a small butterfly on the surface, which elicits a description of this family group from the expert on the video. Mum moves his hand away, "*Don't. Don't keep touching that because she keeps telling about the same thing".*

Here the feedback from the video helps mum to understand how the interaction is working and to guide the interaction so that the activity can progress.

Adults used the video and visualisations to inform how they guided the activity, to provide encouragement (e.g. *'go on get them, come on')*; direct action (e.g. '*put the object in the bag*'); make suggestions (e.g. pointing out new objects); prompt reflection through questions (e.g. '*so what do you want to take with you?*'); or draw attention to important events taking place.

Joint Exploration: Guiding Learning

Adults used the video expert knowledge and visualizations to mediate and support their children's learning. For example:

> F7 [Patterns of Life] The father listens to the expert explaining how to find out about the characteristics of butterflies used to classify them, while his daughter attends to the touch screen activity of moving butterflies from one location to another. Another butterfly appears on the tabletop display. The girl reaches to drag it, and dad says 'look at these details' pointing to the features down the side of the butterfly. He asks 'Has it got brushed foot? No. Has it got funny footlinks? No. He's a….

Adults in these families drew on the video scientific information to guide the child's attention to appropriate details, scaffold engagement with scientific concepts (e.g. elimination of characteristics to help select a classification group) and introduce the process and concepts underpinning scientific-related practice.

Adults used the text on The Challenge and animated visualisations to describe and explain events, as props to pass on information, and translated these to make the information more accessible to children, explaining what is happening, reiterating ideas or as a basis for asking questions to help the child think about choices e.g. in thinking about mosquito-nets as a preventative measure *"so if it bites at night, where would people be?"* and build understanding.

These examples illustrate how the video expert information or visualisations supported parents/adults in promoting science learning-based engagement, and to do so in a non-directive way, scaffolding the interaction as a facilitator or guide to the reflective process that underpins learning.

Joint Attention

Joint attention is a socio-cognitive experience, involving both shared attention and shared cognitive engagement with the object or activity (e.g. Tomasello, 1995; Tison-Povis & Crowley, 2015). Adults play a central role in bringing about joint attention, which in turn plays a key role in parent-child learning and fosters engagement and dwell

time (Tison-Povis & Crowley, 2015). Analysis of the video data showed instances where adult and child jointly attended to the video expert.

> F3 [Planning a Trip] The scientist guide calls them to touch the item appearing on the touch table. The father leans down to the girl's height, while the girl simultaneously responds to the guide's guidelines by touching the item appearing on the touch table.

For three families (F3, F6, F8) at Planning a Trip this joint attention was apparent from the beginning of their interaction. For four other families (F1, F4, F5, F7) this joint attention emerged as their interaction progressed. As the video in Planning a Trip was situated lower than for Patterns of Life it was more easily viewed by a child. The activity also contained more sequential steps, with an iterative rhythm of the expert providing guidance, followed by activity on the tabletop. Together these design features better supported more consistent child engagement with the expert video than Patterns of Life. In The Challenge joint attention primarily took place when families watched the animations together (e.g. DNA sequencing).

Overall the expert video played a central role in supporting family interaction, as did the sequencing of the visualizations and activities. These features of the exhibits facilitated *flow* of interaction specifically through guiding the activity, and supporting parental scaffolding and mutual engagement in the activity.

Taking the Lead

Across the families there was an equal balance of instances where adult and child took the lead, with leadership often shifting between the two, differently influencing collaborative activity and adult scaffolding strategies. Within Vygsotky's (1978) ZPD (Zone of Proximal Development) framework the notion of moving from being guided (in this instance by the adult) to taking the lead (the child) is implicit in a novice

becoming more expert in the task. A child leading also better reveals their (gaps in) understanding "allowing educators to diagnose more precisely where to scaffold" (Ash et al., 2012, p. 41).

Adults took the lead in an attempt to initiate or maintain their child's engagement rather than do the activity themselves. Typically, adults drew on the expert video or text to initiate guiding or prompt child engagement:

> F7 [Patterns of Life] Dad appears to listen to the video expert explaining the different features of butterfly classes. When the next butterfly arrives and the girl starts dragging it to a group Dad says 'look at it, look at it'. Mum and Dad point out specific features as activity progresses (e.g. look at its legs).

In addition, the following example, shows how parental active engagement in the activity draws in the child:

> F8 [Planning a Trip] After failing to get the child's interest or attention on the video expert, the mother's touch on the interface reveals the document and triggers the daughter's interest about the activity. The daughter gets up and places herself in the middle of the touch table clearly indicating that she wants to take over.

Adult touch was also used to model interaction for children. In The Challenge, three adults began by demonstrating an action, which children mimicked e.g. catching the mosquitoes.

In child led instances, children typically took control of the interface, leading through physical interaction while the adult gave verbal and gestural guidance on a 'needs be' basis. For example, in Patterns of Life the girl [F7] did all selecting and touching, while both parents made suggestions (e.g. *'where are going to put it?' 'Look at its legs').* The following excerpt illustrates this further.

> F7 [Planning a Trip - father (holding baby) and daughter]: The image of one cutting tool appears on the touch table, while the expert is talking. G1 touches the

> cutting tool with her index finger. Then two additional cutting tools appear. The father says '*Wait! Wait! Wait!*' while the second and the third cutting tool appear. The girl waits. Both look at the cutting tools on the table and listen to the guide's selection. The girl points with her index finger down to one cutting tool, but then chooses another, the machete.

These examples show how the adult's verbal guidance helps to pace the activity in ways that enable more reflective engagement beyond purely touch-selecting or dragging objects. Adults took an instrumental role in shaping activity through engaging conceptually with the exhibit idea (F4, F6, F7), and explaining what was happening, using the video narrative to support explanations and guidance of activity (F4, F6, F7).

Discussion summary

The findings show that adult scaffolding was pivotal in supporting children's sustained engagement with the digital exhibits. Despite interface interaction difficulties collaborative activity was observed across the majority of family interactions through joint explorative activity, where parents adapted their scaffolding practices to individual and developmental differences within their family and/or to paricular design elements. At the same time, children's explorations at the exhibit interface was equally important in shaping this joint activity. Adult scaffolding strategies had three primary functions: to support interaction with the interface; to maintain engagement with the activity; and to facilitate learning. In the context of digital hands-on activity, pattern of roles (but not attention) leading to joint activity emerged: the adult focusing on the expert video and media elements of the activity, the child doing the activities primarily through touch interaction, and the adult employing various strategies to scaffold their children's engagement in the activity and foster exploration.

Design Implications for Adult Scaffolding

The findings suggest that digital exhibits have the potential to be valued by family visitors, and were shown to support adults' scaffolding of children's learning. This section identifies key design implications in terms of adult family scaffolding.

Activity Design

The overall activity designs shaped joint action, scaffolding strategies and focus of attention in particular ways. Planning a Trip and Patterns of Life comprised activities that involved choosing objects or features and moving these by dragging them into specific places on the interface. On the one hand these activities enabled a trial and error approach to activity interaction, reducing attention to the underlying scientific ideas. The design of the video expert feedback also contributed to this. In Patterns of Life the automated response to attempts to put the butterfly in the wrong family group was 'try another family' or 'that is the wrong family group'. Alternative content in the feedback could encourage visitors to look more closely at the features of the butterfly and examine why certain answers were 'incorrect' and explore the relationship between characteristics and classification. In Planning a Trip visitors were given an overview of their collected items and whether or not they were suitable for the expedition at the end of the activity. For some this was problematic, as they did not reach this point in the activity before leaving the exhibit or could no longer recall the options they had been given earlier. Ongoing feedback around the implications of choices may better support deeper and more reflective engagement with scientific planning processes.

On the other hand, this design feature (of making choices) gave the user a high degree of control (an intrinsic motivation feature: Perry, 2012), not only through 'choosing', but also over the pace and progression of the activity. This was critical in making the exhibits accessible to a range of age groups (important for family visitors),

and for adults to appropriately pace and support the activity to individual and developmental differences. Choice and control was mentioned as a positive 'drive' by two families during the post-visit interviews.

In contrast, The Challenge had a less rhythmic structure in the activity process, comprising a mixture of touch activity engagement and listening or watching visualizations as forms of engagement. This fostered moments of 'stepping in and stepping out', or moments of interaction and moments of reflection, a productive pattern of interaction for learning (Ackermann, 1996). This design also introduced some level of ambiguity about the process of the exhibit making the content less transparent, yet elicited more domain related questions and interest from adults and children, with adults being more involved in learning from the exhibit as well as the children, and thus fostered curiosity (Perry, 2012). In the other two exhibits adults primarily took the role of facilitator rather than engager in learning themselves.

Moments of joint action in The Challenge were more varied than those observed in Patterns of Life and Planning a Trip, in the latter cases participation overwhelmingly comprised of children physically interacting with the interface and adults providing support through verbal and gestural forms of communication. As the findings show the focus of this scaffolding activity was on the task of the exhibit rather than the scientific ideas. This suggests that variety in forms of activity across the exhibit is beneficial, for example, to include distinct moments for touch interaction, moments of observation and moments for reflection in the design.

Embedded Expert Knowledge

Overall the expert video was instrumental in scaffolding family interaction with the activity, but more importantly it enabled parents to scaffold their children's learning in valuable ways. Specifically the video was instrumental in enabling the parent to support

the child's engagement in a knowledgeable and confident way about topics they as parents (not scientists) were unfamiliar with. Families used the video or text (The Challenge) as a foundation for their explanations and to talk about scientific ideas. The findings indicate the value of the 'expert video' in framing the activity (Tison-Povis, 2016), fostering an understanding of the activity, practically, functionally and in extending visitor understanding of scientific ideas and practices.

A key feature of this is the ease with which one can listen to expert instructions or information at the same time as looking at or interacting with the horizontal interface. Adults could hear information or instructions and convey key aspects to their child. This was evident across three families (F2, F4, F5), and sits in contrast to text-based media where there is necessarily a delay of reading and understanding the text before relaying information to the (by then, bored) child. Furthermore, pronunciation of complex scientific names was supported through the audio narrative, and information was given bit by bit once each step was completed, supporting structure in the interaction.

Overall the video expert design was shown to foster curiosity and intrigue, confidence and communication (2012). Given the target audience of the exhibit gallery the parental role was instrumental in tailoring the expert video information and digital media to a wide age range of children, well below the target age group, and illustrates how these exhibits can dynamically be made accessible to most age groups.

Interface Design

While touch and hands on activity are highly valued by families, the choice of technology for hands-on interaction shaped parental intervention, influencing collaborative activity. The findings indicate that technology that consistently elicits successful touch interaction could improve learning opportunities in informal leanring settings.

Patterns of Life and Planning a Trip required individual interaction with the interface to work successfully. This impacted family interaction in three primary ways: flow of interaction, scaffolding interface interaction, and collaborative activity. The flow of interaction was erratic, the interactive features disrupting a smooth flow. Most commonly this occurred with multiple people interacting on camera recognition tabletops, glitches in technology, and siblings interfering with others' actions. This finding sits in contrast to Geller's (2006) evaluation that suggests that overhead projection was not problematic in museum interaction. While this design might not obscure the interactor's visual field, it was problematic in interfering with touch interaction where multiple people gestured over, leant on or attempted to touch the interface.

The multiple visual focal points in Patterns of Life were less clearly linked to action on the tabletop, which at times resulted in family members having different aims in their interaction activity. Aims that could not be easily co-ordinated through a single user touch interface. According to Heath et al., (2005) such single user interfaces minimize the opportunities of others to engage beyond watching or looking over. While this was also true for Patterns of Life and Planning a Trip, in terms of body positioning and 'immersion' in the exhibit, the tabletop offered more potential for joint interaction than desktop computers, and provided better opportunities for more than one person to contribute to the activity verbally, gesturally, tactilely and conceptually. Commonly, this individual nature of touch interaction resulted in a particular pattern of joint interaction with the adult providing verbal and gestural guidance, and the child doing touch related activities. This links to parental beliefs reported in interview that link the notion of '*interactive*' with '*making you think*', and '*making you want to spend more time doing something'*.

Conclusion

This study of family interaction in a museum gallery space focused on interaction with digital tabletop exhibits and their role in supporting collaborative family engagement. A multimodal analytical approach was taken to examine both bodily modes of interaction, which are central to engagement and interaction with these exhibits. The findings show ways in which the specific design elements of digital exhibits shaped family participation engagement, and collaboration, and their potential for supporting adults in scaffolding children's learning: engagement, activity and meaning making. Extending Rowe and Kisiel's (2012) findings interactive tabletops were found to foster scaffolding activity through touch, gesture, bodily posture as well as verbal interaction. However, particular design elements influenced collaborative interaction: the exhibit set up design was found to influence body positioning and access, and shape the ways that families grouped or split around exhibits; the design of the video/audio expert as part of the exhibit was found to play an important part in supporting adults in providing scaffolding forms of interaction with their children; and the touch interaction design was shown to be instrumental in the degree to which engagement with the activity rather than interaction with the interface per se was enabled. Collectively these findings highlight the value of digital interactive exhibits for families, and inform the design of exhibits to improve interface interaction and support family mediated museum learning experiences.

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