



**Manchester
Metropolitan
University**

Kelton, ML and Ma, JY and Rawlings, C and Rhodehamel, B and Saraniero, P and Nemirovsky, R (2018) *Family meshworks: children's geographies and collective ambulatory sense-making in an immersive mathematics exhibition*. *Children's Geographies*, 16 (5). pp. 543-557. ISSN 1473-3285

Downloaded from: <http://e-space.mmu.ac.uk/621807/>

DOI: <https://doi.org/10.1080/14733285.2018.1495314>

Please cite the published version

<https://e-space.mmu.ac.uk>

Molly L. Kelton, Jasmine Y. Ma, Cierra Rawlings Bohdan Rhodehamel
Patti Saraniero and Ricardo Nemirovsky

ABSTRACT

We present a video-based study of family visits to Taping Shape, an immersive exhibition that allows visitors to explore the inside of geometric objects. The exhibition was designed to support embodied sense-making, intimacy, and material encounter with mathematical objects. This study builds on research on walking and movement as forms of place- and sense-making. We draw on the notion of a meshwork to examine how children and their families co-produce, develop familiarity with, and assemble meanings for the exhibition space. This case study focuses on 4-year-old Easton and his extended family, exploring how Easton's talk and movements are part of an intergenerational meshwork that weaves together an emergent and distributed sense of place within the built geometries of Taping Shape. Our findings further considerations of embodiment and materiality in children's geographies.

Introduction

Museum mathematics exhibitions constitute an increasingly prominent, worldwide phenomenon (Nemirovsky, Kelton, and Civil 2017), yet are largely under-theorized within the field of children's geographies. As spaces designed to engage children and their families with mathematics in ways that contrast with both schooling and everyday life, mathematics exhibitions hold rich potential for children's geographers to explore new theoretical possibilities for understanding children's experience. Investigating these spaces can advance emerging and interrelated considerations of movement, materiality, embodiment, and agency within children's geographies (Horton and Kraftl 2006), particularly given the emphasis many mathematics exhibitions place on physical, play-based, and immersive experiences with subject matter typically regarded as both abstract and heavily schooled.

We present a video-based study of family visits to Taping Shape, an immersive exhibition that allows visitors to explore the inside of geometric objects. Through a micro-ethnographic case study of four-year-old Easton¹ and the multi-generational family group with whom he visited this exhibition, we explore how a young child's geography of an immersive mathematics exhibition unfolds through embodied exchanges with family members and the material environment. This

work enriches intersections among children's geographies, studies of family sense-making in museums, and informal education.

First, we situate this study within relevant scholarship in children's geographies and museum studies. Then we describe our theoretical orientations, including scholarship on walking and embodied movement as forms of place- and sense-making (Horton et al. 2014; Ingold 2011; Hackett 2016), especially the notion of a meshwork (Lefebvre 1991; Ingold 2011). Drawing on micro-ethnographic techniques to analyze video of a visit to Taping Shape, we interpret how Easton and his family co-produce their experiences through inter-articulated lines of walking, talking, and interacting with one another and the environment. Our analysis focuses on the co-development of a spatial routine – or local tradition (Hackett 2016) – for moving through and bodily engaging with the exhibition. We trace how this repeated walking pattern initially develops and then evolves over multiple laps through the exhibition, emerging as an important product of – and resource for – Easton's lived geography of Taping Shape. Our analysis contests the commonplace reduction of young visitors to mathematics exhibitions to cognitive or individualistic dimensions, showing instead how children's geographies of such spaces emerge through a rich meshwork of movement, sociality, and materiality, all taken up and co-created by young children in agentic, competent, and resourceful ways.

Expanding children's geographies through museum mathematics

Science centers are part of an international movement integrating mathematics into museum offerings (e.g. Nemirovsky, Kelton, and Civil 2017), leading to development of exhibitions on topics like algebra, geometry, and calculus. Recent research has explored how visitors make sense of these spaces (e.g. Dancstep, Gutwill, and Sindorf 2015; Nemirovsky, Kelton, and Civil 2017). Yet, although young children are key visitors for many science centers, little research has explored their experiences in mathematics exhibitions (but see Guberman et al. 1999). Moreover, research on mathematics exhibitions has focused on design conditions that promote targeted cognitive gains (e.g. Dancstep, Gutwill, and Sindorf 2015), treating unexpected results as shortcomings. The result is a relatively adultist, schooled account of these spaces. However, young children can engage with exhibits in surprising ways, forging new meanings within and across exhibits (Guberman et al. 1999). More work is needed at the intersection of children's geographies and museum studies that attends to and respects the emergent meanings and unanticipated interactions young children have with these under-examined – yet increasingly prominent – environments.

Krafl (2014) argues for the value of understanding the geographies of alternative spaces of education as important not only in their own right, but also because they can 'throw into sharp relief most of our assumptions about education and childhood' (p. 136). In particular, mathematics exhibitions, one form of alternative education space, may be particularly rich sites for responding to calls by children's geographers to consider embodied, material aspects of children's lives and mobilities (Horton and Krafl 2006; Middleton 2010). Museums can facilitate 'material encounters with mathematics' (de Freitas and Bentley 2012) through multi-sensory (Nemirovsky, Kelton, and Rhodehamel 2013) and immersive (Dancstep, Gutwill, and Sindorf 2015) designs around topics typically regarded as disembodied, abstract, and immaterial. As such, mathematics exhibitions can help us understand environments that provisionally unsettle schooled configurations of children and subject matter. For children's geographers, a focus on embodied sense-making in mathematics exhibitions can make children's everyday sense-making visible, unearth negotiations around children's physical and conceptual agency, and reveal children's ineluctable resourcefulness in constructing and navigating their worlds.

Here, we foreground embodiment and materiality in children's geographies while relating these qualities to sociality. In particular, we are informed by a commitment to intergenerational exchanges as key loci of children's educational geographies (e.g. Valentine 2000) and sense-making in museums (Ellenbogen, Luke, and Dierking 2004). However, we critically depart from the many studies that

examine parents' verbal facilitation of children's cognitive learning. Those studies emphasize adult talk and agency, and privilege the cognitive or conceptual over the concrete, sensual, and affective aspects of children's museum experiences (e.g. Eloff, Maree, and Miller 2006; Tscholl and Lindgren 2016; Vandermaas-Peeler, Massey, and Kendall 2016). We also complicate arguments focusing on how families and family relationships shape children's geographies or vice versa (Holloway 2014) by centering the experiences, actions, and agency of a young child in interaction with older family members while viewing verbal expression as part of a holistic communicative and spatial ecology that includes physical movements like walking, touching, and gesturing (e.g. Hackett 2014, 2016; MacRae et al. 2018).

Taping Shape: designing for immersive material encounters with mathematics

Taping Shape was installed at a US science museum and developed by a partnership of museums and educational researchers. Taping Shape is a large, immersive installation containing corridors, twists, and bends through which visitors can walk, crawl, and slide. Made entirely of packing tape and structural scaffolding, it immerses visitors in unusual geometries while engaging them with the aesthetics and material science of design. Taping Shape is inspired by several geometric objects: (a) the torus, (b) a shape called a Schwarz-P surface, and (c) a 'pair of pants,' a surface that can be used to construct a surprising variety of more complex surfaces (Figure 1).

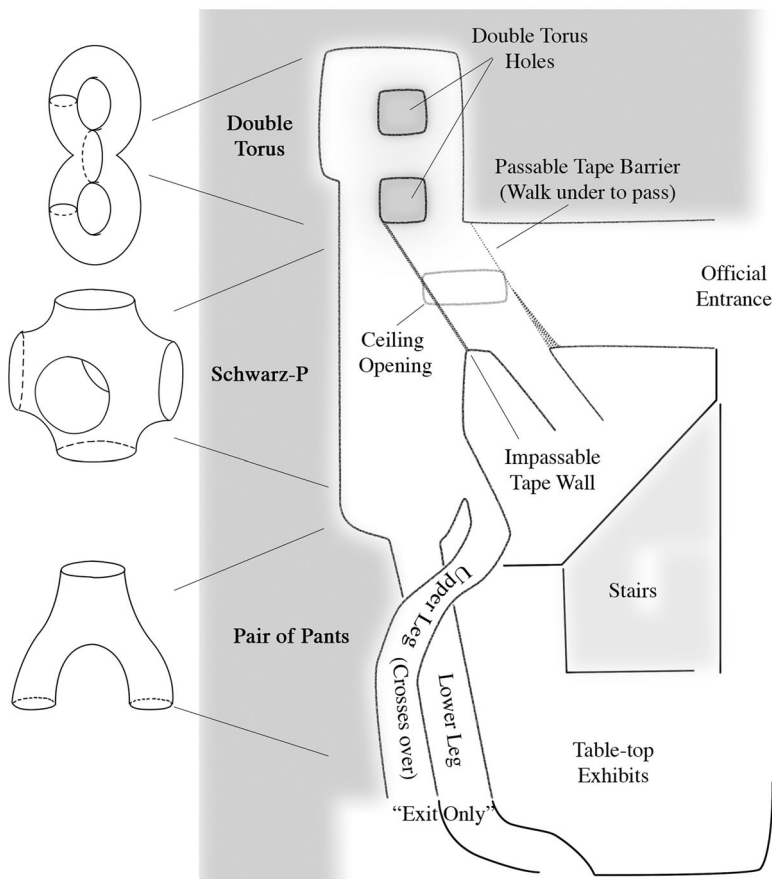


Figure 1. Top-down map of Taping Shape.

From a design perspective, visitors have the unusual opportunity to, say, slide through a twisted 3-holed sphere (a pair of crossed pant legs) or walk inside a double torus (two donuts ‘glued’ together). In this sense, the exhibition provisionally engenders intimate, physical contact, material encounter (de Freitas and Bentley 2012), and affective exchange with mathematical objects typically regarded as (literally and figuratively) out of reach.

Theoretical framing

Our theoretical orientation aligns with efforts to re-imagine relationships between space and social process (e.g. Lefebvre 1991; Massey 2005) and think beyond metaphors of educational environments as static ‘containers’ for learning (Leander, Phillips, and Taylor 2010). We focus on how learning and development are ineluctably emplaced, yet still shape and produce the very spaces in which they unfold – geographies of educational space (Holloway et al. 2010). We also consider the sensual, material qualities of museum experiences and the embodied, multimodal nature of mathematical sense-making (e.g. de Freitas and Bentley 2012; Nemirovsky, Kelton, and Rhodehamel 2013; Ma 2017; Kelton and Ma 2018). Our focus on embodiment foregrounds walking as a kind of place- and sense-making (e.g. Lee and Ingold 2006; Hackett 2014, 2016).

Walking as place-making

We conceptualize space as continually under production in social activity, subject to histories of participation within and across places, and differentially experienced by individuals and groups over time (Lefebvre 1991; Massey 2005). Ingold (2007) lamented that ‘place has been reconfigured in modernity as a nexus within which all life, growth and activity are contained’ (p. 96). Alternatively, places can be conceptualized as inhabited, experienced, and in-the-making. Consequently, walking in and across spaces comprises a kind of place-making. Following Middleton’s (2010) call to illuminate the practices of walking, we avoid glossing over or instrumentalizing children’s museum pathways. Walking is not simply the functional movement between locations; it is a practice of meaning- and place-making. As visitors walk exhibitions, they make personal sense of the designed environment. Repeated walks produce ‘thick lines’ (Lee and Ingold 2006, 77) that call on past experiences and support the development of new meanings (Hackett 2016).

Moreover, place-making is not simply about moving through space, but the sensorial engagements involved in balancing, crawling, and slipping – feeling one’s way through space. The material environment, including ground, architecture, and light, shapes participants’ meaning-making and is shaped in their activity (Ingold 2004, 2011; Hall 2009; Fors, Bäckström, and Pink 2013; Ma and Munter 2014). Therefore, our analysis of walking as a place- and meaning-making activity considers routes through the exhibition and the sensorial engagements that constitute wayfaring.

Family walking in museums as meshworks

We anchor our analysis of family encounters with Taping Shape in the notion of *meshwork*. Lefebvre (1991) posited that ‘mental and social activity impose their own meshwork’ (p. 117) on the physical environment in which they unfold, a process that dynamically transforms the environment and its meanings. Through meshworks, ‘places are marked, noted, named’ (ibid., 118). Moreover, ‘such traces embody the “values” assigned to particular routes: danger, safety, waiting, promise’ (ibid., 118). Meshworks are never finalized but ‘open on all sides’ (ibid., 118). Ingold (2007) further describes meshworks as the interwoven entanglement of multiple inter-related lines of movement, an always-emerging relational web of ‘trails *along* which life is lived’ (p. 81, emphasis in original). Knots in meshworks resemble Massey’s (2005) conceptualization of ‘place as an ever-shifting constellation of trajectories’ (p. 151) that are multiple, heterogeneous, and always becoming.

If places are produced through the coming together of lines of wayfaring, then exhibitions like Taping Shape are not static containers for visitors' activities but, rather, dynamic knots (Ingold 2007) of multiple, entangled lines of movement, perception, and expression. In this study, we trace these lines of movement to feel and follow the textures – or 'archi-textures' (Lefebvre 1991, 118) – of an exhibition as encountered by the young children and their families who visit it. In contrast to a single line of wayfaring, our interpretation of meshwork keeps in frame the relationality of children's ambulatory sense-making, including the sociality of interactions with others' lines of movement as well as the material relationality of exchange with the environment. Within different configurations of walking together – e.g. tandem or side-by-side – participants interact through talk and bodily engagements that include shared vistas and coordinated rhythms of looking, walking, and attending (Lee and Ingold 2006; Marin 2013). Walking together is a kind of socio-material place-making and development of shared meaning, even as individuals independently create place and meaning.

Here, we explore the multiple, inter-articulated movements and expressions of family members visiting Taping Shape to understand how a young child's place- and sense-making in the exhibition intermingles with the 'stories-so-far' (Massey 2005, 130) of cousins, parents, and grandparents, as well as the shifting movements of materials like packing tape. We also consider the backdrop of power relations that are implicated in spatial constructions – in particular, how sociohistorical relations involved in the co-production of space can shape children's experiences (Holloway et al. 2010). The construction of children and childhood depend on control over how spaces can be used, who can be in them, and when they are explored (Massey 1998; Nespor 2000). Two common (and contradictory) Western constructions of the child include children as unsocialized threats to civilized adult life, and children as innocents to be protected from the adult world (Holloway and Valentine 2000). While the tension between these two conceptualizations of children plays out in the design and implementation of museum exhibitions like Taping Shape, we follow Valentine (1997) by taking up an analytic ethos that treats children as competent actors in their place- and meaning-making. Thus, we aim to 'account for childhood as a structural feature of society in the moment of its impinging upon children's experiences in daily life and the reshaping of the institution of childhood by children through their day to day activities' (Prout and James, 1995, 81; cited in Holloway and Valentine 2000, 6).

Methodology

We draw on video-based studies of museums (vom Lehn, Heath, and Hindmarsh 2002), collecting and analyzing naturalistic records of visits to Taping Shape. Video cameras were mounted inside the exhibition, and participants wore small video cameras strapped to foreheads or chests. Visitors were recruited at the exhibition entrance and included seven family groups. Following the visit, families participated in a debriefing interview with a researcher. We focus on the case of Easton (age 4) and his family members Margo (Easton's mother), Angie (Easton's aunt, Margo's sister), Chloe (age 11, Easton's cousin, Angie's daughter), and Granny (Easton's and Chloe's grandmother, Margo's and Angie's mother). We selected this group because they presented a rich matrix of intergenerational, multi-age relationships for investigating a young child's sense-making in Taping Shape. Easton also displayed little reactivity to the recording equipment, giving the data greater ecological validity.

The micro-analysis presented here illuminates nuances of one particular form of walking: a young child engaging in an immersive museum exhibition with his family. The case focuses on the details of meaning-making rather than the construction of universal categories, to contribute to characterizations of the multiplicity of walking as social practice (Middleton 2010), and how walking practices matter for sense-making and learning (Horton et al. 2014). Key analytic themes were also informed by a larger video corpus including seven multi-generational family groups. Aligned with case-study methodology, we primarily follow an *analytic* approach to generalization (Yin 2009), putting case findings into dialogue with extant discourses and literatures.

We follow multimodal microanalysis methods (e.g. Jordan and Henderson 1995; Erickson 2006; Goodwin 2007), treating meaning-making as interactional accomplishment and grounding analysis in video records. We approach interaction as both embodiment and talk, with added emphasis on embodiment as coordinated movement (Goodwin 2007). Therefore, our transcription and interpretation were shaped by how participants moved through the exhibit, as well as their dynamic embodied configurations as they moved (Marin 2013). We crafted a spatial transcription method that coordinates representations of verbal and nonverbal communication with maps of Easton's and relevant family members' pathways over time through the exhibition. Transcription methods were informed by other studies of children's ambulatory sense-making in museums (Hackett 2014) and learning-sciences scholarship on learning 'on the move' (Hall and Stevens 2016). However, we tailored our methods to the exhibition space and our theoretical focus on collective mobility. An example of one of the transcripts we developed is included in the analysis. We suggest that such multimodal, micro-analytic approaches can further efforts in children's geographies to attend to embodiment and materiality by refining our ability to notice – and honor the sensibility of – the details of children's situated talk and movement.

An interpretive account of an emergent spatial routine

We present a sequence of episodes from Easton's family's visit to Taping Shape, assembled to highlight central interpretive themes. We focus on Easton's sense- and place-making through walking, running, sliding, and talking, all through interaction with his cousin Chloe and his adult family members. We present episodes chronologically, weaving an interpretive account of how Easton participates in the creation, practice, and improvisational elaboration (or traditionalisation, Hackett 2016) of a *spatial routine* for moving through and building meaning for Taping Shape. By spatial routine, we mean a loosely repeated pattern of walking and re-walking the exhibition, along with an emergent orientation toward that repeated pattern as a distinct practice. In the approximately half-hour visit, Easton walked through the exhibition at least eight times, sometimes with family members and sometimes alone. Each lap included an overall similar walking pattern (Figure 2).

Over the course of the visit, the establishment and repetition of this embodied spatial routine formed the heart of the significance of the visit for Easton and his family. This routine also emerged as something over which Easton and his cousin, Chloe, held a distinct ownership. In Chloe's words to Angie toward the visit's end, 'Mom, we have laps that we do.'

In the following analysis, we examine portions of Easton's first and fourth 'lap' through Taping Shape. We show how this spatial routine emerged through Easton's ambulatory coordination with social others and (agentically complex) participation in, appropriation of, and resistance to institutional rules and family participation structures.

First steps: contesting meanings of new places through walking

When children and families encounter new spaces together, first steps can illuminate relations between emerging relevancies and relatively more familiar places and practices. We join Easton and family as they first enter the tape installation. The family members cluster closely together, moving forward in a tightly-knit arrangement. Unlike everyday walking surfaces and the rest of the museum's floor, Taping Shape's surfaces bend and reverberate under visitors' movements. The family's talk and movements upon first entry immediately belie and make salient the physical unsteadiness of walking on the tape floor. Angie and Chloe utter, 'Whoa,' as they step in, extending arms for balance. Margo, too, steps gingerly through the entry, arms extended in a cautious gesture. Here, Margo, Angie, and Chloe co-assemble the space as one that destabilizes everyday practices of walking and walking together.

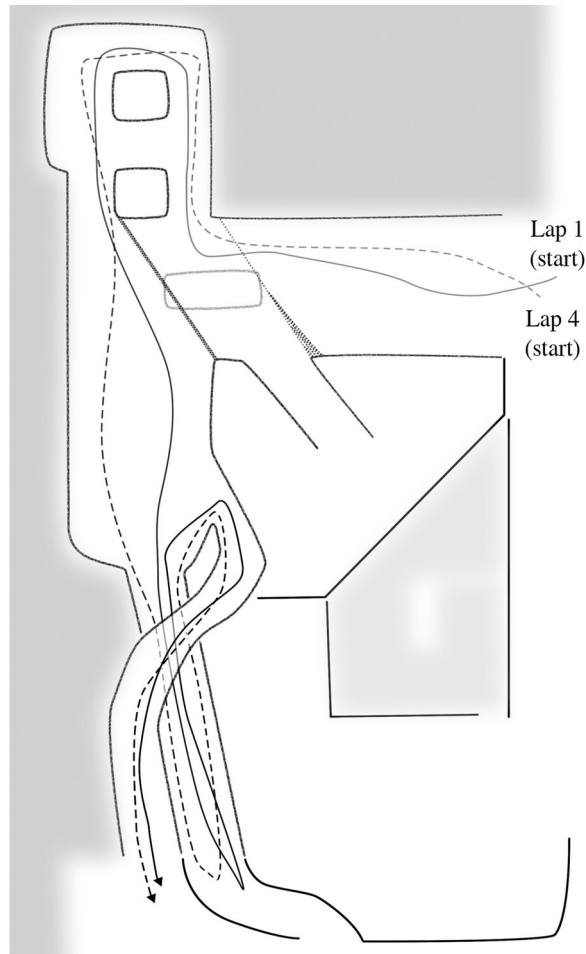


Figure 2. Easton's first and fourth laps through the exhibition.

Easton, in contrast, does *not* similarly enact instability and caution. His gait is less altered, and the conversation he elicits focuses on the exhibition's material composition rather than on potential threats to his balance:

- E What are all of it?
- M Honey it's made of tape ... and Saran wrap
- [A No she said the whole thing is packing tape ((E stumbles))
- [M Oh I thought I read that online-

Yet Easton does stumble twice. Both falls are brief, Easton stands back up quickly, and he doesn't verbally comment on falling. The first stumble goes largely unremarked; the second is more noticeable, with Easton slipping and falling:

- [E Uh how d- it- ((stumbles again))
- [M Woa it's slippery

Easton's talk is interrupted by his fall, which occurs near Chloe. Chloe chuckles and reaches to touch Easton's head in a gesture of aid. Meanwhile, Margo re-emphasizes material instability, saying 'it's slippery.' While Chloe's gesture and Margo's talk mark the event of the fall, Easton himself does not comment on falling, but rather orients to the moment as unremarkable by continuing the

question he began before falling. Standing back up, Easton looks around and asks, referring to the exhibition's shifting colored lighting:

E How- How does it change colors?

Throughout these first steps, the exhibition's unusual materiality arises as salient for Easton and family. For the adults and Chloe, that materiality impinges on the stability of their movements. Yet, while Easton's stumbles also belie the challenges of this new terrain, he recovers from those slips with what we see as a pointed unmarkedness. Instead, Easton communicates through talk and gaze an emerging interest in the material make-up and shifting hues of the exhibition, rather than its potential physical safety threats. Our analysis here shows how inter-elaborated lines of talking, walking, and even falling together when exploring new terrain are not just a matter of instrumental pragmatics, but, rather, an essential part of how children and their families make unfamiliar places meaningful. The multi-modal details of how young children participate in this co-ambulatory meaning making (e.g. recovering from a fall without commentary) can be a key resource for negotiating meaning.

Meshwork bifurcations: charging ahead, negotiating the lead, and subverting institutional directives

A bifurcation next emerges across the family's walking, through a differentiation of the pacing and ordering of collective movements (Figure 3). Chloe and Easton charge forward more rapidly, staying near one another. The adults move more slowly, pausing to read labels and touch walls. Together, Easton and Chloe forge a trajectory around the double-torus' farthest corridor, through the back of the Schwarz-p, and down the lower leg of the pair of pants. As they do so, they leave the adults behind, even moving temporarily out of sight.

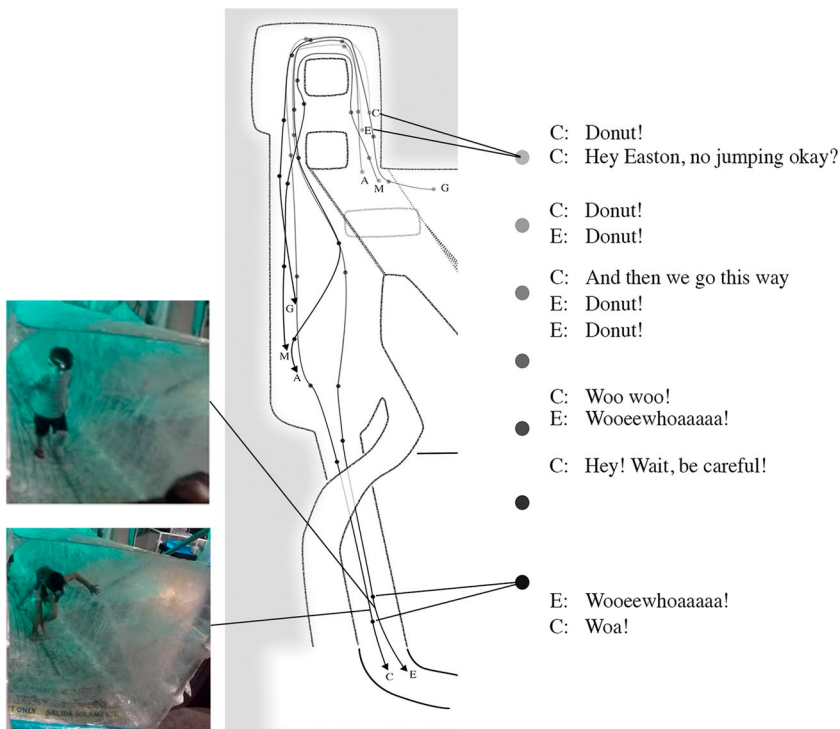


Figure 3. Example spatial transcript. Segment of first lap.

Such dynamic patterns of distance and proximity in families' walking can enact place through heterogeneously interwoven social interrelations. The coordination and inter-elaboration of talking and walking in this segment affirm a social affiliation between Chloe and Easton in distinction from the rest of the group. As they trail away from the adults, a close knitting of Easton's and Chloe's lines of movement produces a togetherness that is both social and spatial. Chloe's talk, 'And then we go this way,' spoken just as she and Easton exit the double-torus, further punctuates the present socio-spatial alignment between them and the emergent sense of a walking routine. The cousins' distinctive co-ambulation simultaneously produces a 'we' and an emergent spatial practice that is becoming uniquely theirs.

They are also enacting an inter-age caregiving dynamic. Chloe, somewhat performatively, takes on an interpretation of an adult role in her interactions with Easton. Her exhortation 'no jumping' isn't demonstrably instigated by any jumping on Easton's part. Instead, it is uttered just after she and Easton have taken the lead as an ambulatory pair, perhaps to establish publicly the caregiving responsibilities she is taking up in the 'we' developing with Easton as they gain distance from the adults. Ways of walking together and dynamic social relations mutually constitute one another as activity unfolds.

Moreover, Easton and Chloe continually negotiate their social dynamic through the micro-choreography of each's movements and talk in relation to the other's and to the material environment. This negotiation, in turn, is a significant component of Easton's emerging geography of Taping Shape. For instance, as they approach the lower leg, Easton positions himself to take the lead. Chloe quickly re-maneuvers ahead, extending an arm behind her and in front of Easton. Evoking the discourse of safety initiated during the family's first steps into the exhibition, Chloe exhorts Easton to 'wait' and 'be careful.' Enacting the exhibition as a safety-threatening place, she regains the lead and re-emphasizes an age-differentiated caregiving relation. Chloe configures Easton's 'being careful' as walking *behind* her, as if danger might lie ahead. In this way, young children's experiences of and movements through museum spaces can be intimately rooted in the co-emergence of place-making, walking together, and dynamic relations of social care with others.

Having reached an official 'exit,' Chloe and Easton stand outside the packing-tape environment and glance down the exit corridor. 'Exit Only' signs are posted but go unnoticed by the cousins. Without discussion, they quickly re-enter the lower leg, maintaining proximity to one another; their walking re-appropriates an official exit into a place for turning around, prolonging immersion in the tape structure. Here, we see how walking can become a way in which young children might varyingly acknowledge, contest, or (in this case) ignore official directives and designer-intended uses of space. The practice of turning around and walking back up the lower leg becomes an important part of the developing spatial routine. Easton ultimately repeats this move, sometimes insistently, with each lap, routinizing a move that subverts official attempts to direct visitor pathways.

Enacting competence to walk, slide, and be guided

As Chloe and Easton emerge from the lower-leg opening into the Schwarz-P, they re-encounter the adults. Here Chloe reports, 'Okay I officially do not fit in that.' Indeed, a comparison of the cousins' bodily movements in the lower leg reveals that the two inter-articulated walks were qualitatively *distinct* in terms of their biomechanics in relation to the material structure. To avoid hitting her head, Chloe had to hunch forward with arms out for balance as she stooped through the tunnel (Figure 3). In contrast, Easton could walk upright there, with a distinct ease to his gait compared to Chloe's. Age- and size-differentiated physical demands produced divergent experiences, with Easton positioned as having a distinctive physical competence in this space. Easton's emplaced competence is meaningfully noted by others throughout the visit. For instance, during a later lap, Chloe tells Margo that Easton 'just gets to walk around and we have to bend down.' Thus, while Taping Shape is, at times, produced as a place where Easton may encounter danger, it is also a place where he can enact a differentiated competence to maneuver through the exhibition's tight spaces.

This highlights how children and families can take up immersive exhibition designs in ways that are highly significant for the construction of young children's competencies, particularly when the maneuverability of those designs varies across co-participants.

Angie now directs the cousins to the upper leg's more-difficult-to-see opening:

A (to C and E) Did you try to go in there? Go in this one.

Chloe, announcing decisively, 'I'm going,' enters the upper leg, crouching and bracing herself through another narrow, upward-sloping passageway. At this point, the ambulatory pairing between Chloe and Easton becomes temporarily interrupted. As Easton turns to follow Chloe into the upper leg, he is stopped by Margo, Granny, and Angie, who all encourage him to remove his socks to lessen the slipperiness of the ground:

M Hey Easton do you want to take your socks off?
G Yeah take your socks off
A Wanna take your socks off buddy so it's not slippery
E Yeah

Easton stops walking and agrees, and Angie kneels to remove Easton's socks.

Horton and Kraftl (2006) remind us that 'material things – even, or especially, the smallest, *daftest*, most mundane, most throwaway, most humdrum, *everyday*, taken-for-granted-things – matter profoundly' (p. 73). The removal of Easton's socks highlights the importance of everyday materials – and the contingent ways they interface with exhibition materials – in shaping children's museum geographies. Removing Easton's socks substantially reconfigures the tactility and friction between his feet and the floor. To the extent that a visit to Taping Shape is *about* the physicality of moving through it, this amounts to a significant reconfiguration of Easton's ambulatory sense- and place-making in ways that encompass affects associated with sweaty feet and sticky sensations. This suggests that one way in which mundane, throwaway things might matter for children's geographies is in how those things partake in shaping, enabling, and interrupting children's movements and the meanings associated with those movements.

Now barefoot, Easton resumes walking through the upper leg, arriving at the top of the slide. Here he finds Chloe standing at the bottom, facing and directing him, 'Hey Easton, slide on your butt.' Easton complies, participating in a joint guiding-and-being-guided practice with Chloe by sitting and sliding down to join her. In doing this, Easton not only further displays physical agility to negotiate the exhibition, but also a socio-spatial competence to move in alignment with others.

'I want to do it again!': thickening meshworks

Just outside the tape structure, with the adults making their way down the slide behind, Easton announces, 'I want to do it again!' For the remaining visit, Easton's drive to 'do it again' heavily drives how he and his family walk and make sense of the exhibition. Each of the next seven laps includes elements of repetition and variation on the previous laps, but all include: (a) entering through the official entrance and walking to the farthest end of the double torus, then (b) proceeding down and back up the lower leg, and (c) sliding down and out of the upper leg (Figure 2). With each iteration of this emergent spatial routine, Easton – in interaction with others and the environment – layers new meanings into how he experiences and practices the space, co-producing 'thick lines' (Lee and Ingold 2006, 77) for walking and re-walking Taping Shape.

To examine this thickening process in the meshwork, we now turn to Easton's fourth lap. Upon entry, Easton and Chloe walk again in a closely interwoven arrangement, with Easton just behind Chloe. In resonance with – or conscientious re-uptake of – the pairing the cousins established during earlier laps, there is a re-affirmation of a 'we' between them. The thickening of ambulatory lines is not simply a matter of re-walking individual trajectories, but also of ongoing re-negotiations of dynamic socio-spatial inter-relations. In considering how families walk and re-walk places

together, it is not just lines that thicken, but also how those lines come together, interact, or trail apart.

'This is a weird place': extending meanings along divergent lines

As Easton continues the route through the double torus, Chloe, just ahead, reaches the farthest torus hole. This time, she stops, turns to Easton, touches a taped surface, and announces, 'Whoa! Easton look it this is weird.' Margo and Easton each take up Chloe's bid to attend to the torus hole differently. Margo leverages Chloe's interest to initiate a conversation about the torus' shape and name, joining with Chloe at a relevant label. Easton, however, darts beyond, following the now-routine pathway out of the double torus, breaking his pairing with Chloe. Easton reframes Chloe's guiding invitation by forging ahead while appropriating Chloe's language, exclaiming as he walks, 'That's weird – This is a- This is a weird place. This is weird.' Easton's talk doesn't merely echo Chloe's but rather, through its inter-elaboration with his walking, extends the sense of 'weird' beyond the torus hole to encompass being in a 'weird place' more broadly. He expands the meaning of Chloe's talk by threading it along a walked pathway to additional regions. Thus, while stopping and co-examining exhibits and labels is often taken as a key locus of museum sense-making – as it may be for Chloe and Margo now – Easton's actions demonstrate a different way in which this practice might matter for young children: Easton leverages Chloe's and Margo's moment of stationary mutual orientation to assert his agency, breaking the close pairing with his elder cousin and taking the lead, while re-appropriating the language of Chloe's (failed) directive.

'Excuse me': spatial routine as a tool for countermovement

As Easton enters the lower-leg tunnel, Margo and Chloe, walking toward him, call his name and exhort him to go down the slide instead. Although Easton pauses and looks back, he quickly resumes walking, saying, 'No I'm gonna go back,' as he reaches the end of the tunnel. Easton's walk and talk resist Chloe's and Margo's attempts to guide his movements, in contrast with Easton's uptake of the practice of being led through the exhibition in Lap 1, and his reframing of Chloe's invitation to look at the 'weird' torus hole just above. Re-walking the spatial routine is taking on momentum for Easton, serving as a resource for asserting his ambulatory agency.

The agency Easton asserts here extends beyond his own movements to those of Margo and Chloe, who change course and follow him into the lower leg. Easton is not only ahead but also influencing others' movements through his own. As Margo proceeds down the lower leg, she says, 'Alright let's go check- let's go check out the other part, the exhibits that go with this,' referring to the tabletop exhibits that accompany the immersive structure. Yet, just after, Easton arrives and changes direction at the turnaround point he and Chloe co-established on their first lap. Easton's performance of the turnaround contests Margo's bid to exit, insisting instead on continuing the lower-leg spatial routine. Easton's turnaround also produces a practical dilemma: Easton now walks back up the tunnel while Chloe and Margo proceed in the opposite direction. This creates a confrontation of lines – a counter-movement that is at once a corporeal conundrum and a bodily, on-the-move manifestation of contested participation frameworks (Goodwin 2007) for the group's present activities. As he and Chloe near one another, Easton leans against the wall, skirts past her, and reiterates, 'I'm gonna go back.' Then, as Easton and Margo approach one another, both Margo and Chloe attempt to direct Easton to reverse course:

- M Uh oh turn around!
- C Come here Easton!

Again, Easton re-asserts his trajectory in physical and interactional friction with his family members' directives. Easton says, 'Excuse me,' as he turns sideways to maneuver around Margo and continue up the lower leg. Moving past Margo's adult body poses a greater challenge than did passing

Chloe, heightening the physical palpability of Easton's refusal to exit. Yet, layered over the salient physicality of their opposing movements, Easton utters the polite, everyday turn-of-phrase, 'Excuse me,' contextualizing Easton's opposing trajectory not as an act of direct confrontation but rather as a mundane passage. Easton's 'excuse me' presupposes a warrant for his line of movement, one that we suggest is partially grounded in the routinized quality of the pathway he is re-walking. Conversely, by leveraging his expertise in the everyday negotiation of shared space, Easton can attribute an unre-marked-ness to his line of movement, allowing him to squeeze past – literally and interactionally – Margo's opposing trajectory.

Discussion

Our analysis shows how interrelated social, spatial, and material dynamics shaped Easton's meaning-making in Taping Shape. Rather than treat Easton as simply a child learner, and distinct from or 'other than' adult visitors (Birch 2018), we considered how Easton's explorations were constructed together with his family. We highlighted that tensions between prevalent constructions of children – as innocents or, alternately, disruptors – produced verbal, material, and spatial interactions that included adult and elder-child guidance and supervision. However, we also illuminated the agency and expertise with which Easton negotiated these directives. In talk and movement, Chloe and Easton took up caregiving discourses: protecting Easton from possible dangers of new spaces, shaping fun for Easton, and managing potential impulses to run or jump. At the same time, Easton responded to family members' directives variably, agreeing to participate (taking off socks), reframing them (taking up Chloe's 'weird' while forging ahead), or resisting them altogether (finishing the lower-leg routine against Margo's and Chloe's directives). The confluence of social relations at play in these place-making moments cannot be described as the inevitable result of societal, institutional, and familial systems, but rather what Massey (1998) called 'constellations of temporary coherence' (p. 124–125), deftly negotiated by participants.

We also elucidated the roles that young children play in shaping their own museum geographies, and the tactics and resources deployed in pursuing their interests, particularly in spaces designed for learning. Rasmussen (2004) distinguished between 'places for children,' official spaces for children maintained by adults, and 'children's places,' places children find and make meaningful. Our analysis highlights how Easton and Chloe established meaningful ownership over the exhibition, through place- and meaning-making developed over multiple passes of a thickening spatial routine. This spatial routine was both shaped by and a resource for Easton's ongoing verbal and non-verbal collaboration and negotiation with family members. Further, Easton and his family mutually shaped his competence in the exhibition, highlighting and leveraging his embodied belonging and expertise on unstable surfaces and narrow passageways.

Attending to children's museum geographies might inform institutional and disciplinary assumptions about what is or should be central in designing for children's learning. The emphases in museum research and exhibition design on features like labels, adult talk, and 'ideal' interactions with exhibits at times neglect children's agentic and strategic participation. Our analysis takes into consideration these institutional concerns shaping the exhibition while bringing children's experiences to the fore (Holloway et al. 2010). We showed how Easton actively negotiated his experience of Taping Shape as he navigated the exhibition, demonstrating embodied expertise, taking the lead, agentially being led, and engaging with the material structure in personal and unanticipated ways. For example, the turnaround routine in the lower leg became important, allowing Easton to resist others' pleas to exit.

We propose to extend Rasmussen's (2004) argument about children's places beyond fixed locations to include ambulatory routines that are 'owned' by children. Hackett (2016), in her analysis of children's multiple museum visits, argued that they developed 'embodied traditions in specific locations around the museum' (p. 177). We build on this by looking carefully at not just specific locations, but also the pathways and movement between them. Indeed, within Taping Shape's

immersive environment, the very notion of ‘between’ is troubled. Instead, meaning is made *along* thickening lines (Ingold 2007) of collective and co-articulated movement, even during a single visit. Further, our micro-analysis illuminated how children’s places might be constructed within a meshwork where adults and children alike contributed to place-making. Easton’s embodied competence within Taping Shape was made salient in comparison with his older cousin and adult family members’ relative *incompetence*.

We wonder how further studies of intergenerational walking might expand our understandings of walking practices in relation to children’s place-making, in particular in educational spaces. Mathematics exhibitions and immersive interactives are now an important part of contemporary science museums. This work contributes to a greater appreciation of young children as competent co-creators of the significance of these spaces for themselves and their families. This work also identifies the critical roles played by embodied movement, material exchange, walking, and walking together in children’s immersive exhibition geographies.

Note

1. Names are pseudonyms.

Acknowledgements

This research was supported by the Informal Mathematics Collaborative project funded by the National Science Foundation through Grant DRL-1323587. We also thank Nicole Ferry, the Fleet Science Center, the InforMath team, and our research participants for their contributions to this work.

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This research was supported by the Informal Mathematics Collaborative project funded by the National Science Foundation through grant DRL-1323587. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

- Birch, J. 2018. “Museum Spaces and Experiences for Children – Ambiguity and Uncertainty in Defining the Space, the Child and the Experience.” *Children’s Geographies*. doi:10.1080/14733285.2018.1447088.
- Dancstep, T., J. P. Gutwill, and L. Sindorf. 2015. “Comparing the Visitor Experience at Immersive and Tabletop Exhibits.” *Curator: The Museum Journal* 58 (4): 401–422.
- de Freitas, E., and S. J. Bentley. 2012. “Material Encounters with Mathematics: The Case for Museum Based Cross-Curricular Integration.” *International Journal of Educational Research* 55: 36–47.
- Ellenbogen, K. M., J. J. Luke, and L. D. Dierking. 2004. “Family Learning Research in Museums: An Emerging Disciplinary Matrix?” *Science Education* 88 (S1): S48–S58.
- Eloff, I., J. G. Maree, and L. H. Miller. 2006. “The Role of Parents’ Learning Facilitation Mode in Supporting Informal Learning in Mathematics.” *Early Child Development and Care* 176 (3-4): 313–328.
- Erickson, F. 2006. “Definition and Analysis of Data from Videotape: Some Research Procedures and Their Rationales.” In *Handbook of Complementary Methods in Education Research*, edited by J. L. Green, G. Camilli, and P. B. Elmore, 177–191. Mahwah, NJ: Lawrence Erlbaum.

- Fors, V., Å. Bäckström, and S. Pink. 2013. "Multisensory Emplaced Learning: Resituating Situated Learning in a Moving World." *Mind, Culture, and Activity* 20: 170–183.
- Goodwin, C. 2007. "Participation, Stance and Affect in the Organization of Activities." *Discourse & Society* 18: 53–73.
- Guberman, S. R., R. J. Flexer, A. S. Flexer, and C. L. Topping. 1999. "Project Math-Muse: Interactive Mathematics Exhibits for Young Children." *Curator: The Museum Journal* 42 (4): 285–298.
- Hackett, A. 2014. "Zigging and Zooming all over the Place: Young Children's Meaning Making and Movement in the Museum." *Journal of Early Childhood Literacy* 14: 5–27.
- Hackett, A. 2016. "Young Children as Wayfarers: Learning about Place by Moving through It." *Children & Society* 30: 169–179.
- Hall, T. 2009. "Footwork: Moving and Knowing in Local Space(s)." *Qualitative Research* 9: 571–585.
- Hall, R., and R. Stevens. 2016. "Interaction Analysis Approaches to Knowledge in Use." In *Knowledge and Interaction: A Synthetic Agenda for the Learning Sciences*, edited by A. A. diSessa, M. Levin, and N. J. S. Brown, 72–108. New York: Routledge.
- Holloway, S. L. 2014. "Changing Children's Geographies." *Children's Geographies* 12: 377–392.
- Holloway, S. L., P. Hubbard, H. Jöns, and H. Pimlott-Wilson. 2010. "Geographies of Education and the Significance of Children, Youth and Families." *Progress in Human Geography* 34: 583–600.
- Holloway, S. L., and G. Valentine. 2000. "Children's Geographies and the New Social Studies of Childhood." In *Children's Geographies: Playing, Living, Learning*, edited by S. L. Holloway, and G. Valentine, 1–26. London: Routledge.
- Horton, J., P. Christensen, P. Krafft, and S. Hadfield-Hill. 2014. "'Walking ... Just Walking': How Children and Young People's Everyday Pedestrian Practices Matter." *Social & Cultural Geography* 15: 94–115.
- Horton, J., and P. Krafft. 2006. "What Else? Some More Ways of Thinking and Doing 'Children's Geographies.'" *Children's Geographies* 4 (01): 69–95.
- Ingold, T. 2004. "Culture on the Ground: The World Perceived through the Feet." *Journal of Material Culture* 9: 315–340.
- Ingold, T. 2007. *Lines: A Brief History*. London: Routledge.
- Ingold, T. 2011. *Being Alive: Essays on Movement, Knowledge and Description*. London: Routledge.
- James, A., and A. Prout. 1995. "Hierarchy, Boundary and Agency: Toward a Theoretical Perspective on Childhood." In *Sociological Studies of Children*.
- Jordan, B., and A. Henderson. 1995. "Interaction Analysis: Foundations and Practice." *Journal of the Learning Sciences* 4: 39–103.
- Kelton, M. L., and J. Y. Ma. 2018. "Reconfiguring Mathematical Settings and Activity through Multi-Party, Whole-Body Collaboration." *Educational Studies in Mathematics*.
- Krafft, P. 2014. "What Are Alternative Education Spaces - And Why Do They Matter?" *Geography* 99: 128–138.
- Leander, K. M., N. C. Phillips, and K. H. Taylor. 2010. "The Changing Social Spaces of Learning: Mapping New Mobilities." *Review of Research in Education* 34: 329–394.
- Lee, J., and T. Ingold. 2006. "Fieldwork on Foot: Perceiving, Routing, Socializing." In *Locating the Field: Space, Place, and Context in Anthropology*, edited by S. Coleman, and P. Collins, 67–85. Oxford: Berg.
- Lefebvre, H. 1991. *The Production of Space*. Cambridge, MA: Wiley-Blackwell.
- Ma, J. Y. 2017. "Multi-Party, Whole-Body Interactions in Mathematical Activity." *Cognition and Instruction* 35: 141–164.
- Ma, J. Y., and C. Munter. 2014. "The Spatial Production of Learning Opportunities in Skateboard Parks." *Mind, Culture, and Activity* 21: 238–258.
- MacRae, C., A. Hackett, R. Holmes, and L. Jones. 2018. "Vibrancy, Repetition and Movement: Posthuman Theories for Reconceptualising Young Children in Museums." *Children's Geographies*. doi:10.1080/14733285.2017.1409884.
- Marin, A. M. 2013. "Learning to Attend and Observe: Parent-Child Meaning Making in the Natural World." Doctoral diss., ProQuest Dissertations & Theses Global. (1491167252).
- Massey, D. 1998. "The Spatial Construction of Youth Cultures." In *Cool Places: Geographies of Youth Cultures*, edited by T. Skelton, and G. Valentine, 121–129. London: Routledge.
- Massey, D. 2005. *For Space*. London, UK: Sage.
- Middleton, J. 2010. "Sense and the City: Exploring the Embodied Geographies of Urban Walking." *Social & Cultural Geography* 11: 575–596.
- Nemirovsky, R., M. L. Kelton, and M. Civil. 2017. "Toward a Vibrant and Socially Significant Informal Mathematics Education." In *Compendium for Research in Mathematics Education*, edited by J. Cai, 90–101. Reston, VA: NCTM.
- Nemirovsky, R., M. L. Kelton, and B. Rhodehamel. 2013. "Playing Mathematical Instruments: Emerging Perceptuomotor Integration with an Interactive Mathematics Exhibit." *Journal for Research in Mathematics Education* 44 (2): 372–415.
- Nespor, J. 2000. "School Field Trips and the Curriculum of Public Spaces." *Journal of Curriculum Studies* 32: 25–43.
- Rasmussen, K. 2004. "Places for Children – Children's Places." *Childhood* 11 (2): 155–173.
- Tscholl, M., and R. Lindgren. 2016. "Designing for Learning Conversations: How Parents Support Children's Science Learning Within an Immersive Simulation." *Science Education* 100 (5): 877–902.

- Valentine, G. 1997. "'Oh Yes I Can.' 'Oh No You Can't': Children and Parents' Understandings of Kids' Competence to Negotiate Public Space Safely." *Antipode* 29: 65–89.
- Valentine, G. 2000. "Exploring Children and Young People's Narratives of Identity." *Geoforum* 31: 257–267.
- Vandermaas-Peeler, M., K. Massey, and A. Kendall. 2016. "Parent Guidance of Young Children's Scientific and Mathematical Reasoning in a Science Museum." *Early Childhood Education Journal* 44 (3): 217–224.
- vom Lehn, D., C. Heath, and J. Hindmarsh. 2002. "Video-Based Field Studies in Museums and Galleries." *Visitor Studies Today! V* (III): 15–23.
- Yin, R. K. 2009. *Case Study Research: Design and Methods*. Thousand Oaks, CA: Sage.