Video Data and the Learning Event: Four Case Studies

Ricardo Nemirovsky (chair), Elizabeth de Freitas, Kate O'Brien,
Manchester Metropolitan University
r.nemirovsky@mmu.ac.uk, L.de-freitas@mmu.ac.uk, kate.c.obrien@gmail.com

Molly L. Kelton, Washington State University, molly.kelton@wsu.edu
Jasmine Y. Ma, New York University, j.ma@nyu.edu

Francesca Ferrara, Giulia Ferrari, Università di Torino
francesca.ferrara@unito.it, giulia.ferrari@unito.it

Rogers Hall, Lauren Vogelstein, Vanderbilt University
r.hall@vanderbilt.edu, lauren.vogelstein@gmail.com

Nathalie Sinclair (discussant), Simon Fraser University, nathsinc@sfu.ca

Abstract: Video data is now used throughout the learning sciences as a common form of documenting learning events. Wearable cameras and real-time video feed-back have changed the research terrain. And yet scholars often use such data without examining the ways that video – as digital technology - structures and shapes the research findings, while enabling new insights into the event-nature of learning. This international symposium addresses this topic by (1) showcasing and analyzing innovative uses of video technologies in the study of learning, and (2) historically situating such video experiments within traditions of scientific cinema. The term 'scientific cinema' is used in media studies to describe all uses of the moving image in scientific study, beginning with the pioneering work of the Lumiére brothers in the 1890s. This symposium presents four contemporary case studies in which video is used innovatively to investigate mathematics learning experiences in three different countries (US, UK, Italy).

Symposium themes

The mass dissemination of recording technologies has always been pivotal for the emergence of innovative research methodologies in the social sciences (de Freitas, 2015, 2016; Schneider & Pasqualino, 2014). Over the last 15 years new facets of digital video have spread in society, not only through the availability of novel recording devices but through the pervasive growth of technical ecologies which made complex streams of digital video easily editable and communicable. These socio-technical innovations include action cameras (e.g. GoPro), streaming and generation of videos-of-videos (e.g. Skype), real-time diagramming (e.g. GPS drawing), eye-tracking and movement-tracking, and the assemblage of multiple video/audio sources (e.g. Multicam Editing). Scholars have begun to grapple with innovations in research methodologies as enabled and constrained by these digital recording devices (van Nes & Doorman, 2010). Derry et al. (2010) published a thorough review of video research, identifying principles for systematic selection from an extensive video corpus, analysis protocols, as well as discussing ethical issues with this kind of data. Software protocols for analyzing vast video archives are now deployed regularly, allowing researchers to annotate, code and sort images (Derry et al., 2010; O'Halloran 2013). But many of these software packages "mold" the data and reconfigure it, sorting and chunking it even before human eyes have seen it (van Nes & Doorman, 2010, p.6). The use of video analytic software without adequate attention to how such software is structuring the data becomes increasingly problematic as we begin to rely more and more on findings based on this data.

The question of what constitutes an event – as a unit of analysis - is brought to the forefront in video research, as scholars are able to examine activity at micro-scales of interaction, and trace micro-gestures or affective dispersal across a group. Derry et al. (2010) cite Lemke (2000) who claims that "events are time-analogs of objects. Like objects, they have underlying structures reflecting multiple parts and timescales" (p.7), but the pragmatics of this comment need to be investigated and opened up for further exploration. This symposium will present four case studies exploring the use of video data in studying learning events. All four papers focus on mathematics education, as a way of sustaining focus on a particular kind of content, although each delves into very different kinds of learning.

Powell et al. (2003) reviewed a large spectrum of video research in mathematics education, but most of this was tacitly realist in its use of video, without adequate consideration for how the specific ways that video structures the visibility of the event. The range of approaches to video collection and analysis includes Jacobs et al. (1999), who propose methods to "transform the video images into objective and verifiable information" (Jacobs et al., 1999, p. 718), and Hall, Nemirovsky, and Ma (2015) who see video creation and analysis as means to generate new images of teaching and learning. This symposium examines technical affordances and limitations of digital video technologies, such as action cameras, streaming, diagramming, and multicam editing, insofar as these become part of a learning event. Papers explore initiatives that interrogate social, educational, and methodological aspects of video-based research in the learning sciences, questioning previously unexamined 'realist' assumptions about the moving image (Schneider & Pasqualino, 2014).

Like any other technical apparatus, video technology brings with it a particular way of producing subjects. The danger is that we are all too likely to treat the video image as a recording of "raw data", indexical of a given time-space relationship, as though it were a transparent realist representation of an event. Symposium presenters situate their work within the history of scientific cinema, a term from media studies that describes any use of the moving image in scientific study. Cartwright (1995) shows how scientific cinema has been part of the history of the moving image since its invention in the 1890s by the Lumière brothers. The early film makers, like Lumière, were experimental physiologists who were interested in recording the movements of the human body. Indeed, many of Lumière's contemporaries regarded his invention of the cinematographe as a key contribution to physiology. The Lumière laboratories manufactured film stock and equipment for science - hundreds of films in the Lumière's catalogues cover a vast array of different studies of bodily movement. During the early 20th century, scientists interested in the movement of the human body in various contexts – including formal and informal learning contexts – relied on moving image data to theorize about learning. By historically situating the ongoing work of the symposium members within this tradition, we hope to better understand the potential innovation (and limitations) that the digital nature of video allows today.

Symposium papers share a focus on the movement of bodies during learning events, exploring how the body is reconfigured in video data. This focus is pursued differently in each paper, studying the way the human body is both produced and recruited in different kinds of learning events. The challenge these papers explore is how to develop methods of inquiry that mobilize digital video innovatively, and with awareness of its power to structure what we see. Each set of authors explores: How does video help us plug into the heterogeneous duration of an event? What can we do – as researchers – that might allow us to study video data for the crystalline structure of a learning event? The symposium aims to address the conference theme by closely examining the specificity of the digital. We take inspiration from Wanono (2014) who describes how her work in anthropology has taken up new aesthetic-political perspectives that reflect the digital technology she is using. She uses programming as a creative language to re-assemble the pixels in her documentary video, using particular tactics that reflect her theoretical and political concerns. The aim of this symposium is to take on this challenge of thinking more innovatively about digital video research, while focusing on the complex temporal individuation of bodies during learning events.

The symposium will open with a 5 minute introduction to questions and themes, and set the stage for the four papers (each 20 minutes, including video data), followed by 25 minutes for the discussant and audience discussion.

Paper 1: Graphing, Measuring, and Feeling Force: Using Multiple Video Feeds in Complex Learning Events

Ricardo Nemirovsky, Elizabeth de Freitas, and Kate O'Brien

This paper focuses on a teaching experiment in the UK with a group of 12 students, aged 11 years. The group participated in four 1.5 hour sessions where they worked with a variety of force sensors connected to computers generating real-time numerical and graphical displays. The goal of this study was to investigate student learning about physical force as an intensive (rather than extensive) quantity. Forces are typically learned through their effects, and tend to be associated with action. Research suggests that many students associate force with speed rather than acceleration. We revisit some of this previous research, but direct attention to how the differential intensity of force is an embodied experience. We used computer webcams and screen capture software, as well as wearable GoPro cameras and wall-mounted cameras to build a video-rich environment. As part of the sessions, real-time and slow-time video data were folded into the experiments, allowing students to investigate the otherwise invisible concept of force. This paper presents data from this research experiment, and shows how video was used to open up multiple temporalities in the learning event.

Our data analysis is microethnographic: a collection of techniques and approaches tracing the moment-by-moment bodily and situated activity, encompassing talk, gesture, facial expression, body posture, drawing of symbols, manipulation of tools, pointing, pace, and gaze (Erickson 1996, Goodwin 2003, Erickson 2004, Stivers & Sidnell 2005, Streeck & Mehus 2005). Our data sources include: four GoPro cameras head-held by children, two electronic bracelets recording temperature, skin electric conductivity, and heart pulse, one hand-held camcorder, three wall-mounted GoPro cameras, one for each team, screen capture videos of force vs. time graphs generated by using force sensors.

Building on Henri Bergson's (1889, 1996) distinctions between time and duration, and between extensity and intensity, and later reworkings of these ideas by the philosopher Gilles Deleuze, this paper explores the work that video does in learning about invisible forces. We propose that three kinds of temporalities were woven together through the use of video. Our use of video opens up the learning event to reveal: 1) Parallel temporalities in the synchronous depiction of the same events recorded from different perspectives, 2) Graphical temporalities in the juxtaposed screen capture alongside the wearable GoPro, and 3) Recursive temporalities in that students watched and reflected on these videos as they were replayed to them at various speeds. We weave these three temporalities together as part of the rich differential fabric of the event. For instance, in session 4 a group of children travelled in an elevator moving up and down while one child stood still on a force platform or scale. As the force measured by the scale was recorded on a graph of force vs. time, the elevator's glass doors were videotaped with a webcam to keep track of its movement and stops. Later, in the classroom, the whole group watched and discussed the video of the graph and of the glass elevator's doors. At times these videos were played in slow motion. As children and instructors watched and discussed these videos, additional videos with the whole group where recorded for subsequent study. These other dimensions are not spatial in the typical sense, in that they follow Bergson's attempts to create a "new empiricism" that might study duration without representing it in terms of sensory-motor action.

Based on the case study, this paper elaborates on how the video data furnishes parallel, graphical, and recursive temporalities which together create a productive medium to learn about the intensive nature of force and its relation to movement. The use of video allowed students and researchers to investigate the conjunction of heterogeneous temporalities in the working sessions, unpacking learning events in terms of their temporal complexity.

Paper 2: Reflections on Video-Based Techniques for Studying Bodies On-The-Move in an Immersive Mathematics Exhibition

Molly L. Kelton and Jasmine Y. Ma

We present video-based methods developed to study visitor learning in Taping Shape, a large, immersive geometry exhibition installed in a US science center, with the **objective** of investigating a technical ecology for recording, analyzing, and representing collective sense-making on-the-move in immersive-scale mathematics environments. We critically reflect on our own methods of viewing and mapping complex multi-video assemblages of mobile mathematics learners.

Extending scholarship on family learning in museums (Ellenbogen, Luke, & Dierking, 2004), our **theoretical framework** drew on theories for understanding walking and movement as forms of place- and sense-making (Hackett, 2015; Lee & Ingold, 2006), as well as scholarship that views sensual experience and material exchange as genuine constituents of mathematical thinking and learning ((Nemirovsky, Kelton, & Rhodehamel, 2013).

Data come from a video-based field study (vom Lehn, Heath, & Hindmarsh, 2002) of visitors to Taping Shape. The unusual geometries of the 3000-square-foot immersive mathematics exhibition presented numerous data collection challenges, including the inexistence of any single panoptic vantage and visitors' mobility as they explored the space. Our records come from multiple video technologies, including stationary 3rd-person cameras and wearable 1st-person cameras.

While **methods of analysis** included multimodal microanalysis (e.g., Erickson, 2006; Jordan & Henderson, 1995) we critically departed from its more orthodox articulations. Specifically, our theoretical framing pushed us to resist viewing events as having official boundaries or representing (a)typical phenomena. Instead, we treated video-recorded events as pointing backward and forward along experiential trajectories. To understand collective family-group activity, we repurposed video-editing software for multi-camera synchronization and viewing (see Figure 1).

Figure 1. Screen capture from multi-camera software environment. 1st-person camera views are shown for four members of a multi-generation family group inside a region of the exhibition shaped like a double torus.

Analysis was conducted through online collaborative viewing sessions during which we focused on one or two 1st-person camera angles at a time. Extending interactionist methodologies for studying learning on-the-move (Hall & Stevens, 2015), we crafted techniques for spatial transcriptions that coordinate representations of verbal and nonverbal interactions with spatio-temporal maps of members' pathways through the exhibition (see Figure 2).

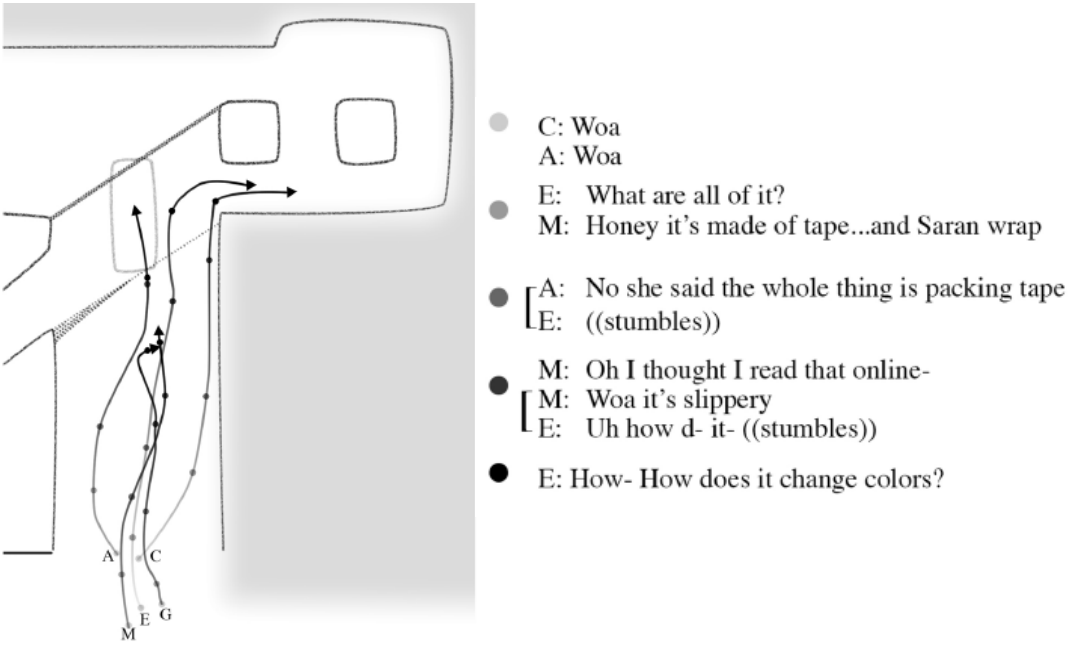

Figure 2. Excerpt of spatial transcript representing a family's coordinated talking and walking in the exhibition.

Results, in the form of **methodological reflections**, address the increasing use, and under-theorization, of wearable cameras in studies of learning on-the- move. While it is tempting to assume wearable cameras provide a more intimate vantage, our analysis leads us to question a simplistic mapping of 1st- and 3rd- person camera angles respectively onto 'intrinsic' and 'extrinsic' perspectives on experience. Additionally, in developing spatial transcriptions, we encountered a tension between (a) representing trajectories of multiple moving bodies in interaction and (b) representing the multiplicity of the body in terms of multi-modal expressions of hands, eyes, feet, etc. Finally, our attempts to stay with continuous flows of time and movement were imbricated with a countervailing desire to discretize participants' pathways (evidenced by the dots in Figure 2, placed at 5-second intervals), echoing the slicing up of movement in early scientific cinema (de Freitas, 2016).

This paper's **significance** lies in advances to understandings of emergent video-based methodologies for studying immersive mathematics learning environments. While these spaces afford opportunities for encountering mathematics in unprecedented ways, they also raise important methodological questions with respect to research on learning about mathematical objects by moving through them.

Paper 3: Collecting and Capturing Movement in the Mathematics Classroom: Assembling the Researcher and the Digital

Giulia Ferrari and Francesca Ferrara

This paper discusses a case study in Italy with a class of grade 7 students aged 12 years. The study is part of a medium-term classroom intervention concerning mathematical activities with graphing motion technology. The class worked on the creation of couples of real time graphs, which capture spatio-temporal relationships associated to movements. These movements occur with pairs of students who move two controllers simultaneously in front of a sensor, in a wide interaction space. The main aim of the intervention was to learn function by means of a graphical approach. Classroom interactions were filmed using two mobile cameras to capture activity from different points of view. Additional data comes from recordings of the graphical window. Therefore, the combined videos capture two students creating motion graphs, the classmates seated all around watching them, and the computer screen displaying real-time graphs (e.g. Figure 3).

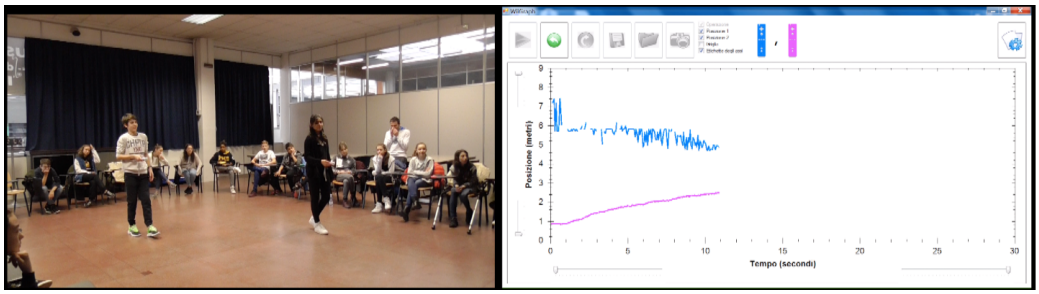

Figure 3. Combined videos with two data sources

Our analysis is devoted to capturing and tracing the moving bodies and choreographies of collective movement in order to better grasp the potentiality of the individual and collective body as a center of indeterminacy and understand dynamic aspects of temporality as duration (in line with the vision of Bergson, 1896/1988). In the style of early scientific cinema, the assemblage of the data helps us examine the event and the entanglement of mathematics and the learning bodies, as numerous unanticipated contingencies get incorporated (de Freitas, 2016). In so doing, we hope to offer a vision of the body primarily as an expressive body. The actions of such a body are not mere communicational and cognitive representations of rational thinking, but are an actualization of the qualitative kinaesthetic dynamics and "gradient information" (Sheets-Johnstone, 2011) experienced by students through change.

This perspective calls for the development of experimental methodologies to enrich research practices based on video recording and the subsequent use of professional video editing software (Derry et. al, 2010). For example, Multicam Editing Software (e.g. Final Cut Pro) allows for automatic pairing of video sources that have been recorded simultaneously from different angles. The software works through audio synchronization, which uses audio waveforms to compare and match different sources over time. Therefore, it creates video displays that—through the audible— embrace multiplicity of points of view around a learning event, assembling the researcher and the digital in new ways.

In this paper, we present these new ways of assembling with the data by discussing how synchronized multiple video streams help us: (1) make apparent distributed and unexpected dimensions of the classroom event; and (2) re-assemble complex learning events which involve a multiplicity of bodies simultaneously active in the classroom. We also delineate how the integration of videos from multiple sources may question the very act of seeing, interpreting, and learning of students, educators, and researchers. In addition, it addresses current issues emerging from theories that portray bodies as dispersed across auditory, visual, digital, kinaesthetic, and material dimensions (e.g. de Freitas and Sinclair, 2014).

Paper 4: How did they do that? Using video-elicited re-enactments to invite ensemble learning in mathematical activity

Rogers Hall and Lauren Vogelstein

Video recordings are commonly used as data for analyses of learning and teaching mathematics and a wide variety of other conceptual practices (Derry et al., 2010; Hall & Stevens, 2015). We report on research that uses video records both as the object of mathematical exploration and as data for understanding how learning and teaching are organized in that exploration. We focus in particular on using video-elicited re-enactments both to create and to analyze ensemble mathematical activity (Ma & Hall, in press).

As *object*, we used video records found in wide media circulation to create environments for exploring and learning mathematics. The "found object" in this paper is an episode selected from the television coverage of dance performances in opening ceremonies of the 2016 Rio Olympic Games (Figure 4, left). As *data*, we captured and analyzed video records of four-person ensembles (called "quartets"), who used their bodies and physical props (e.g., 7' x 7' square Mylar™ sheets) to re-enact what Rio performers were doing in the found video object (Figure 4, right). The quartets we studied used re-enactments to pose and answer basic questions concerning "How did they do that?" in found video from the Rio performance. We also used video-elicited re-enactments of our own to analyze what quartets were doing as they explored the original video object (Vogelstein, Hall & Brady, 2017).

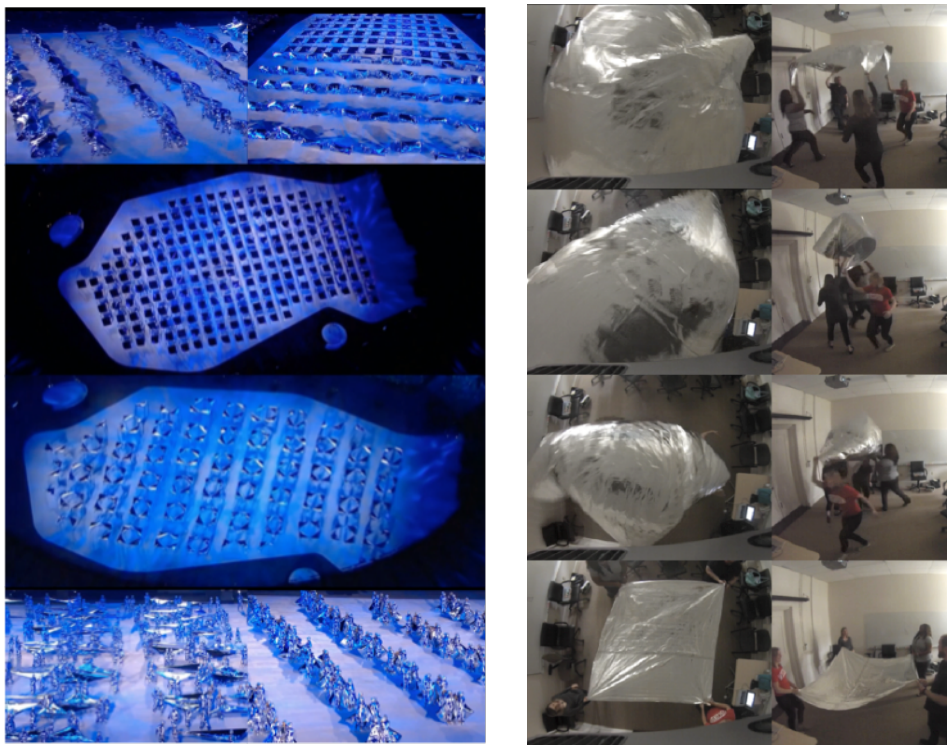

Figure 4. (left) Video stills from television coverage of the opening ceremony for the Rio 2016 Olympic Games. Quartets in the "found" video used square, reflective sheets to create a dynamic array visual forms. (right) Video still images (toon sequence) from above and to the side as a quartet (PhD scientists, now middle school STEM educators) enacted a double reflection of their Mylar™ square prop.

Video-elicited re-enactments, both by study participants and analysts, involved forms of *doing* that led to explanations and new discoveries beyond what was possible by only *viewing* the found (or recorded, for research purposes) video. The first part of our paper shares findings from close analyses of video-elicited re-enactments of mathematical activity by ensemble quartets. The second part of our paper argues for re-enactment as a powerful addition to methods of interaction and multi-modal analyses of learning and teaching.

We captured video recordings of talk and activity in an ensemble performance space, treated as a clinical interview in which research participants were asked to make things together. Cameras and microphones were positioned to capture different perspectives on re-enactment, as quartets alternated between closely

inspecting the Rio video (*viewing*) and enacting their own efforts to create dynamic visual elements they found in the recordings (*doing* through re-enactment). We asked quartets also to explore expressive possibilities with props to create movement sequences with interesting visual and mathematical qualities. Our approach theorizes learning as consequential shifts in how people participate in conceptual practices that also change during their participation (Hall & Jurow, 2015; Lave, 2012). Our design based research seeks to create new forms of mathematical activity that combine cultural activities from everyday life with formal schooling (Hall, Ma & Nemirovsky, 2015; Ma, 2016, 2017).

We report several findings. First, participants found video records rich in detail, but recognized these offered a limited perspective and only partial access to techniques involved in ensemble performance. What could not be seen (or heard) while *viewing* became a deeply engaging problem for quartets to work out while *doing* (i.e., during re-enactments). Second, quartets with different backgrounds (i.e., middle school students, STEM educators, and professional dancers) explained "how did they do that" in ways that drew from familiar cultural practices (e.g., how task formats signal mathematical concepts in school textbooks). Third, discoveries made while doing (re-enactment) went well beyond what was possible while viewing found (or recorded) video alone. For example, while using Mylar™ sheets as a 1:1 scale model of props in the found Rio video, reenactments allowed participants to explain not only what Rio performers (or study quartets) were doing, but also to make discoveries about with *might* be done with the set up consisting of ensemble-plus-props. This included necessary aspects of technique (e.g., that thumb and index finger grips on corners of the Mylar™ sheet cycled between "up" and "down" positions during complex performance routines) and discoveries about new, expressive possibilities that had interesting mathematical meanings (e.g., "gathering" the Mylar™ sheet as a handy transition point during geometric transformations, or "billowing" the sheet in ways that made novel, extra-planar shapes and opened up new ways of operating together in the ensemble).

Finally, analysts' bodies are rarely used in systematic analysis of the interactive organization of learning and teaching (e.g., Erickson, 2004, proposes choral readings of transcripts, augmented with scored rhythm or beat). We argue that ensemble re-enactment is a powerful but underutilized method for interaction analysis in learning sciences research. Much as archeologists re-enact tool use or hypothesized cultural practices in relation to the built environment (e.g., using sun, moon, star and building alignment as an agricultural calendar), we and our research participants made discoveries about the expressive possibilities of ensemble-plus-prop set ups that went well beyond a typical, seated viewing of found video recordings. As a matter of method, we recommend closer attention to reenactments that place analysts' bodies into the very cultural activities of interest in their analysis. Linked to the organizing theme of this symposium on the history of film and in scientific visualization and discovery, viewing and doing (re-enactment) together are more powerful than viewing alone.

References

Bergson, H. (1889/1971). *Time and free will: An essay on the immediate data of consciousness*. London, UK: George Allen and Unwin.

Bergson, H. (1896/1988). *Matiére et mémoire*. (N. M. Paul & W. S. Palmer: Matter and Memory, Trans.). New York, NY: Zone Books.

Cartwright, L. (1995). Screening the body: Tracing medicines visual culture. University of Minnesota Press.

de Freitas, E. (2015). Classroom video data and the time-image: An-archiving the student body. *Deleuze Studies*, *9*, 318-336.

de Freitas, E. (2016). The moving image in education research: Reassembling the body in classroom video data, *International Journal of Qualitative Studies in Education*, *29*, 553-572.

de Freitas, E. & Sinclair, N. (2014). *Mathematics and the body: Material entanglements in the classroom*. New York, NY: Cambridge University Press.

Derry, S.J., Pea, R.D., Barron, B., Engle, R.A., Erikson, F., Goldman, R., Hall, R., Koschmann, T., Lemke, J.L., Sherin, M.G. & Sherin, B.L. (2010). Conducting video research in the learning sciences: Guidance on selection, analysis, technology and ethics. *The Journal of the Learning Sciences*. *19*, 3-53.

Doane, M. A. (2002). *The emergence of cinematic time*. Cambridge, MA: Harvard University Press.

Ellenbogen, K. M., Luke, J. J., & Dierking, L. D. (2004). Family learning research in museums: An emerging disciplinary matrix? *Science Education*, *88*(S1), S48- S58.

Erickson, F. (1996). Ethnographic microanalysis. In N. H. Berger and S. McKay (Eds.), *Sociolinguistics and language teaching* (pp. 283-306). Cambridge, UK: Cambridge University Press.

Erickson, F. (2004). *Talk and social theory*. Cambridge, UK: Polity Press.

Erickson, F. (2006). Definition and analysis of data from videotape: Some research procedures and their rationales. In J. L. Green, G. Camilli, & P. B. Elmore (Eds.), *Handbook of complementary methods in education research* (pp. 177- 191). Mahwah, NJ: Lawrence Erlbaum Associates.

Goodwin, C. (2003). The semiotic body in its environment. In J. Coupland & R. Gwyn (Eds.), *Discourses of the body* (pp. 19-42). New York: Palgrave/Macmillan.

Hackett, A. (2016). Young children as wayfarers: Learning about place by moving through it. *Children & Society*, *30*, 169–179.

Hall, R., & Jurow, A. S. (2015). Changing concepts in activity: Descriptive and design studies of consequential learning in conceptual practices. *Educational Psychologist*, *50*(3), 173-189.

Hall, R. & Ma, J. (in press). Learning a part together: Ensemble learning and infrastructure in a competitive high school marching band. *Instructional Science*.

Hall, R., Ma, J. Y., & Nemirovsky, R. (2015). Re-scaling bodies in/as representational instruments in GPS drawing. In V. R. Lee (Ed.), *Learning technologies and the body: Integration and implementation in formal and informal learning environments* (pp. 112-131). New York, NY: Routledge.

Hall, R., & Stevens, R. (2015). Developing approaches to interaction analysis of knowledge in use. In A. A. di Sessa, M. Levin, & N. J. S. Brown (Eds.), *Knowledge and interaction: A synthetic agenda for the Learning Sciences*. New York, NY: Routledge.

Jacobs, J. K., Kawanaka, T., & Stigler, J. W. (1999). Integrating qualitative and quantitative approaches to the analysis of video data on classroom teaching. *International Journal of Educational Research*, *31*, 717-724

Jordan, B., & Henderson, A. (1995). Interaction analysis: Foundations and practice. *The Journal of the Learning Sciences*, *4*, 39-103.

Lave, J. (2011). *Apprenticeship in critical ethnographic practice*. Chicago, IL: University of Chicago Press.

Lee, J., & Ingold, T. (2006). Fieldwork on foot: Perceiving, routing, socializing. In S. Coleman & P. Collins (Eds.), *Locating the field: Space, place, and context in anthropology* (pp. 67-85). Oxford, UK: Berg.

Ma, J. Y. (2017). Multi-party, whole-body interactions in mathematical activity. *Cognition & Instruction*, *35*, 141-164.

Ma, J. Y. (2016). Designing disruptions for productive hybridity: The case of walking scale geometry. *Journal of the Learning Sciences, 25*, 335-371.

Nemirovsky, R., Kelton, M. L., & Rhodehamel, B. (2013). Playing mathematical instruments: Emerging perceptuomotor integration with an interactive mathematics exhibit. *Journal for Research in Mathematics Education*, *44*, 372-415.

Pasqualino, C. & Schneider, A. (2014). Experimental film and anthropology. In A. Schneider & C. Pasqualino (Eds.), *Experimental film and anthropology* (pp. 1-24). London: Bloomsbury Press.

Powell, A.B., Francisco, J.M., Maher, C.A. (2003). An analytical model for studying the development of learners' mathematical ideas and reasoning using video tape data. *Journal of Mathematical Behavior*, *22*, 405-435.

Sheets-Johnstone, M. (2011). *The primacy of movement*. (2nd Ed.). Amsterdam: Benjamins.

Stivers, T., & J. Sidnell (2005). "Multimodal interaction." *Semiotica 156*(1/4): 1-20.

Streeck, J., & S. Mehus (2005). Microethnography: The study of practices. *Handbook of Language and Social Interaction* (pp. 381-404). K. L. Fitch and R. E. Sanders. Mahwah, NJ, Lawrence Erlbaum Associates.

van Nes, F. & Doorman, M. (2010). The interaction between multimedia data analysis and theory development in design research. *Mathematics Education Research Journal*, *22*, 6-30.

Vogelstein, L., Hall, R. & Brady, C. (2017, June). *Embodied mathematical technologies: Making sense of ensemble-based embodied mathematical thinking and learning*. Paper at the 47th Annual Meeting of the Jean Piaget Society, San Francisco.

vom Lehn, D., Heath, C., & Hindmarsh, J. (2002). Video-based field studies in museums and galleries. *Visitor Studies Today*, *V*(III), 15-17.

Wanono, N. (2014). From the grain to the pixel, aesthetic and political choices. In A. Schneider & C. Pasqualino (Eds.), *Experimental film and anthropology* (pp. 183-198). London: Bloomsbury Press.