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The moving image in education research:

Re-assembling the body in classroom video data

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Article published as

de Freitas, E. (2016). Re-assembling the student body in classroom video data. *International Journal of Qualitative Studies in Education, 29(4), 553-572.*

Abstract

While audio recordings and observation might have dominated past decades of classroom research, video data is now the dominant form of data in the field. Ubiquitous videography is standard practice today in archiving the body of both the teacher and student, and vast amounts of classroom and experiment clips are stored in online archives. Yet little to no research interrogates how this data partakes in the history of scientific cinema, assembling particular images of teacher and student bodies, nor how the digital nature of video devices might indeed challenge theoretical assumptions about social science more generally. This paper situates current video research practices within the history of scientific cinema and opens up the discussion about how these practices are linked to shifting structures of industrial labour. The paper uses the work of Gilles Deleuze – on art, cinema and the body - as a means of provoking the reader to consider new ways of working with the moving image.

Key words: Deleuze, video data, time-image, visual research, cinema, mathematics education

The moving image in education research:

Re-assembling the body in classroom video data

While audio recordings and observation might have dominated past decades of educational research, video data obtained from classrooms or design experiments is now a dominant form of data in the field.[i] International video projects have had a huge impact on teaching practice all over the world, and are used as resources in developing curriculum and instruction policy.[ii] Video has allowed researchers to zoom in on hands and faces, and to focus on any given moment, in order to study the micro-gestures of teaching and learning. Indeed, ubiquitous videography is standard practice today in archiving the body of both the teacher and student, and many of these videos are archived at various online sites, where vast amounts of classroom and experiment clips are stored.[iii] And yet we know very little about our own practices of collecting, watching and interpreting video data, and often proceed to use such data without examining the ways that video structures the kind of research we do (Hall, 2000). Moreover, as we turn to software analytics and algorithmic decoding of visual data, questions about how the digital nature of video data partakes in the assembling of a particular image of teacher and student need to be pursued. It may be that the body of teacher and student will become conscripted into particular gestural postures through the power of this moving image archive, much like the photographic archive was used in the nineteenth century to sort and normalize the deviant body (Sekula, 1986). But there are also initiatives under way that an-archive the body through digital devices, and these more experimental methods point to new ontologies of the social. Developments in anthropology and sociology, for instance, where film and photography have been used as pictorial equivalents of field notes, have moved towards experimental film tactics, questioning previously unexamined 'realist' assumptions about the moving image (Schneider & Pasqualino, 2013). These new methods begin to examine video research for how it is materially implicated in the production of new knowledge and new kinds of knowers, attending to the unique

qualities of *digital* nature of video data for how it mobilizes new social and cultural relations. This new focus has the potential to radically alter the way we do video research in education.

Although there have been recent attempts to draw attention to the technical constraints that video introduces into education research, there is a need to situate video practices within the history of *scientific cinema* more generally. Cartwright (1995) uses the term "scientific cinema" to reference an entire genre of film-making, pertaining to scientific inquiry, both in the hard sciences and the social sciences. In this paper I situate current education video research practices within this film-making genre, identifying characteristics of the genre that are exemplified in contemporary practice. I ask: what kind of body is assembled through video research in education? How does our use of the moving image contribute to a particular philosophical approach to the body? Exploring these questions sheds light on how research construes the material culture of classrooms and education more generally. I draw attention to how current video research practices produce an image of a human body with pre-given capacities, and I then explore alternative video research practices that might point instead to the *potentiality* of the human body. My argument uses theoretical tools from Gilles Deleuze - in particular his ideas on cinema and art - to show how video data might be reconceived. Deleuze argues that scientific cinema was originally neither science nor art, but part of a new way of thinking about movement that prized "any-instant-whatever which is equidistant from another" (Deleuze, 1986, p.6). I discuss how this attention to "any-instant-whatever" becomes newly inflected through digital technology. My aim is to show how video research is yet to take advantage of its digital medium, and thus I point to new directions for future video research practices. As Ruppert et al (2013) suggest, we need to explore the affordances of digital technology, to experiment with "how they collect, store and transmit numerical, textual, aural or visual signals" while tracking the links between these techniques and social and political institutions like education.

In the first section, I discuss recent attempts to develop methods for processing large amounts of video data, and in the second section I discuss how these video practices are linked to the history of scientific cinema and its role in the shifting structures of industrial labour practices. In the third section, I discuss examples of

current video research that focus on the body in teaching and learning. I focus on the case of mathematics education research because of its heavy reliance on video data, and the recent turn towards studies of embodied learning and gesture within the field. I argue that this work is dominated by a phenomenological approach to the body, and that such an approach is shaped and mobilized by the specific video research methods that are deployed. In the last sections I take up the work of Gilles Deleuze as a means of provoking the reader to consider new ways of working with the moving image.

Current approaches to video research

Video research in mathematics education is primarily focused on documenting evidence of student learning and teacher practice. One might divide the current practice into two branches: the first looks for the frequency of an event – say a gesture - across a number of videos, and uses quantitative analysis, the second examines more closely one event or case and analyzes it in detail (Borko et al, 2008). Because of the inexpensive nature of video recording, researchers are collecting reams of video data, and face the challenge of processing large data sets (Erikson, 2006; Goldman et al, 2007). Derry et al (2010) summarize the research project as first planning a study, and then "shooting original footage," and then dealing with the analysis (p.8). The goal for Jacobs et al, in a similar vein, is to "transform the video images into objective and verifiable information" (Jacobs et al, 1999, p. 718). The need for careful reflection on such a process is felt across the field. Powell et al (2003) reviewed a large spectrum of video research in mathematics education, and proposed a method that involves seven steps or phases for studying the development of learners' mathematical ideas. We can see in these methodological steps or phases an attempt to chunk temporal events in terms of narrative – indeed this seems a bias in their protocol. The phases are "viewing the video attentively, describing the data, identifying critical events, transcribing, coding, constructing a storyline, and composing the narrative" (p. 413). This seven-faceted cyclic method has been taken up extensively in the field, although very little attention has been paid to the complex ways in which "viewing" is tied to the technology. Moreover, identifying an 'event' is a highly

situated act (de Freitas, 2013b). As Hall (2000) explains, the data is heavily influenced by the kind of video data collected: "the point here is simply that our technical arrangements for collecting primary data greatly influence the kinds of inferences we will be able to make later" (p.651). Philosophical questions about what exactly is produced in the act of "shooting original footage" need to be considered, and more attention paid to how bias is built into a coding of the moving-image in terms of a storyline.

These philosophical questions need to be explored as we develop multi-modal software to help researchers handle these large data sets. Indeed the digital nature of these data sets leads to all kinds of new archiving practices. Free software tools such as ELAN, developed by The Max Plank Institute for Psycholinguistics, allows one to code and annotate layers upon the film so that gesture and intonation and overlapping speech can be transcribed. More recently, in 2013, Kay O'Halloran and coworkers in the multimodal analysis laboratory in Singapore, have created software to try and map various kinds of movement in classrooms. Van Nes and Doorman (2010) claim to show how their "multimedia analysis software" will help researchers because the software can "act as a type of mould for organizing large amounts of data" as well as improve "trackability and reliability of the research" and "support theory generation and validation." (p.6). These authors use the software to organize the "raw data" into "quotations" with corresponding codes. Various "clips" will be sorted according to codes, and can be linked to other digital data, such as scanned student work or online work, which lends itself to quantitative analyses of these large data sets. All of this software development is occurring with little to no reflection on the way the technology actually participates in the construction of the data. There are attempts within the learning sciences to address these issues, such as Tobin & Hsueh (2007), who argue that classroom video data are "blurred genres that are simultaneously social scientific documents and works of art" (p. 79); while Hayes (2007) explores the power of aesthetics in school video ethnographies, attempting to direct viewers attention to the logic and technique of video production. These issues have

also been taken up in anthropology where concerns about representing 'others' have led recently to a more reflective approach to the use of video data (Glowczewski, 2014).

In 2010, Derry et al published a thorough review of video research in the *Journal of the Learning Sciences*, identifying principles for systematic selection from an extensive video corpus, analysis protocols and links to particular affordances of technology, as well as discussing ethical issues with this kind of data. The authors are particularly concerned that one needs to be systematic rather than arbitrary in selecting a clip or image. They conceptualize the video clip as being a video segment that represents an event. The selection process "determines which events are brought into focus for deeper analysis" (p.7). They aim to help researchers justify particular video selections, because what haunts such selections is the *indeterminacy* of the event. They 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 explored. Derry et al (2010) list examples of how one might identify an event, and these are of interest for their explicit focus on the *human agent* as the legislator of its participation: "Observed changes in types of behavior (e.g., laughing vs. talking), physical direction (turning toward the exit), the object of behavior (child puts down pencil, picks up toy), setting (in the dining room vs. in the kitchen), and tempo of activity (jogging vs. cool-down phase) ..."(p.7). Of note in the list above is how each indicator of a "chunk of time" is explicitly related to the actions of the human body. And yet why these actions and not others? What about when the human body is not the willful center of action? More recently, Herbel-Eisenmann et al (in press), have taken up Lemke's definition of an event to study the different time scales at play in education, attending to activities where human action isn't always central. In discussing this literature, my point is to draw attention to the need for further philosophical discussion about the role of digital technologies in producing a phenomenological image of the student/teacher body. In the section below, I discuss how the history of cinema is linked to physiological studies of human motility.

Situating this work within a tradition of scientific cinema

Cartwright (1995) argues that the scientific project of observing the movement of living bodies is linked to a tradition of laboratory instruments of graphic inscription and measurement. Scientific interest in embodiment, according to Cartwright, is indebted to techniques of motion recording and observation developed by experimental physiologists, like Lumière, in France and Germany in the nineteenth century. Indeed, many of Auguste 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 – indeed, hundreds of films in the Lumière's catalogues cover a vast array of activities or actualities of various kinds of bodily movement. This genre dominated the first decade of film, and seems to reflect a desire to fix and repeat the ephemeral nature of bodily activity. Cartwright argues that the cinematic apparatus is a cultural technology for the discipline and management of the human body. The long history of medical recording and documenting of the body is tied to the history of the cinema. But because narrative is such a strong coding habit, historical accounts of early cinema usually treat these early scientific experiments as a brief diversion before the emergence of the popular narrative film. She suggests instead that "scientific cinema" continued into the twentieth century and that the historical record needs to be set straight, and that studies of the human body in various disciplines, education for instance, need to reckon with this history. She maps "the history of the cinematic techniques that science has used to control, discipline, and construct the human body as a technological network of dynamic systems and forces." (p. 4). She traces the ways that cinematic tracking of the human body has been a "form of medical surveillance and social control". Of scientific cinema, Cartwright claims: "Its technical spectator and its filmed bodies make up an aspect of the cinematic apparatus that breaks in crucial ways with paradigms of cinematic technology and spectatorship generated in film scholarship around narrative and pictorial film texts and genres" (p.8). This scientific tradition is one that has produced

"human life" as a dynamic entity to be tracked and studied within an experimental paradigm, somewhat at odds with narrative genres.

As I will show in the next section, this history of early scientific cinema sheds light on current video research practices in education. In the late nineteenth century, there was widespread and concerted effort in physiology and other sciences to isolate the instant and make "an invisible time optically legible"(Doane, 2002, p. 45). This was part of a desire to know what happens within the duration of a fraction of a second, and thus to go beyond the limits of regular perception. Etienne-Jules Marey is often considered the scientific precursor of the cinema in this regard, analyzing the walking figure, for instance, in a sequence of discrete snapshots that demonstrated the exact sequence of positions entailed in the flowing movement of the walker. Such movement expressed duration and life, and Marey wanted to cut into time, to slice it up. His technique was called "chronophotography" (see figure #1). The method actually disembodied the movement by dislocating it from the body to which it had originally seemed to adhere. Marey's "graphic method" was considered a new kind of language of the body, a way of showing how physiology had to attend to the interrelation between various motor mechanisms and bodily events.

Figure #1: Marey's graphic method (public domain image)

Because of the results were often confusing, merging multiple images rather than conveying sequential images, Marey began to simplify that which was studied – dressing the moving figure in black,

with white markings on the arms and legs, so as to reduce the amount of information that was recorded. This was termed "geometric chronophotography" and it was preferred because it resembled the graphic tracing of a continuous line.

> In geometric photographs, thanks to the great number of the images, the discontinuity of the phases almost entirely disappears, and the actual path followed by each point of the body can be seen represented almost as a continuous curve. (Marey, as cited in Doane, p. 60).

In Marey's work there was a tension between wanting to capture the exactitude of the spatial positions but not being able to do so without extensive temporal exposure. In not being able to get multiple positions in the one frame, Marey might loose sight of the sequencing of the movement. The legibility of the image was affected by the desire to capture the continuity of time, to capture the moving image and indeed the moving body. Marey experimented with moving film, but he always preferred a directly graphic method because "its record of a movement left no temporal gaps, and its inscription therefore allowed complete continuity." (Doane, p. 59). Even with his chronophotography, he didn't like the "lost time" that seemed to haunt the method of a discontinuous series of images. There was a tension between his aim to capture the continuous flow of movement and his desire for a legible record of the event. Many in 1895 saw Lumiere's invention as an extension of earlier photographic techniques of Marey and Muybridge, in other words, a new experimental technique that could be integrated into laboratory practice, alongside other practices of inscription and visualization, in the study of movement. In the late 1890s many of these physiological films – documenting bodily movement – would be screened for public audiences as well.

But Marey distrusted the burgeoning cinema because it seemed to present only what the human senses could already perceive, rather than get under perception at the fundamental motility of bodies: "Cinema produces only what the eye can see in any case. It adds nothing to the power of our sight, nor

does it remove its illusions, and the real character of a scientific method is to supplant the insufficiency of our senses and correct their errors." (Marey, quoted in Doane. P.61). We hear in this quote Marey's desire to substitute the inadequate human senses with an apparatus that might go beyond vision, to "renounce the representation of phenomena as they are seen by the eye" and to 'see' in new ways that broke with common sense. In other words, rather than simply aim for copying and resemblance, scientific cinema must offer a diagram of movement, to capture the motor engine of mobility. There is an uncanny echo of the aims of early cinema in contemporary video studies in mathematics gesture studies. As we will see below, one can hear the same desire in contemporary phenomenological approaches to the body, where sequences of video stills are meant to capture the pre-linguistic "I can" of the body. And although the technology of video is different from film, one finds today the continued use of graphic coding or diagramming literally written over the moving-image. Like the early use of the cinematographe, video studies of student and teacher movement are meant to reveal how the body knows before language and conscious intent have been formulated. As discussed below, gesture studies in education research often aims to show how mathematical concepts are embodied before they have been named, relying on video data to make visible the emergence of conceptual knowledge. Just as Marey wanted to show movement without any temporal gaps, but had to contend with the limitations of the photographic plate, videographers today hope to slow time down and examine movement in the minutest detail, slicing up the video image into as many discrete cuts as possible.

The use of film motion studies in physiology in the late nineteenth century was linked to a scientific fascination with involuntary movement. Cartwright (1995) argues that this link was forged in relation to the logic of the kymograph and its trace, which generated a kind of seeing that differed from other modes of cinematic spectatorship. The kymograph, which means literally "wave writer", was invented by German physiologists in the 1840s. It was initially used to record changes in blood pressure, speech sounds, muscular contractions and other physiological processes. Physiologists and neurologists in the

nineteenth century were particularly interested in movements of the body that were not willed or intentional. This focus on the unexpected movement of the human body reveals a fascination with unconscious action. For instance, the famous Edison/Dickson 1894 film entitled: *Kinetoscopic Record of a Sneeze* was hugely popular amongst both scientists and laypeople. The film documents the act of a sneeze, which was at the time considered to entail a momentary cessation of the heartbeat, and considered the perfect example of a totally involuntary movement. These and other similar films of the time were spectacles of corporeality, viewed in laboratories or at professional meetings, while frame analyses were published in professional journals. Forty-five frames of the film were reproduced for Harper's Weekly in 1894 (see figure #2).

Figure #2: 1894 record of a sneeze (public domain image)

Early scientific cinema was interested in apparently unconscious movement. This fascination for unconscious movement fueled interests in mass industrialization and standardization. Doane (2002) shows how the early cinema was part of the restructuring of time and contingency in capitalist modernity. Early cinema promised to capture the immediacy of a fleeting moment, the "duration of an ephemeral smile or glance" (p.3), and also the potential for capitalizing on such knowledge. For instance, in 1914 Frank B. Gilbreth, a disciple of Taylor (of Taylorism) created "cyclographs" or a "chronocyclograph" in which the movements of someone were recorded with the aim of creating an archive of efficient motion. In one case, an expert surgeon is tying a knot, in another a woman is folding a handerchief, another a man

is working a drill press. In each case, the body's movement was recorded by attaching a small electric light to the limb and using time exposure to generate a representation of the movement as a continuous line in space (see images # 3 & 4). He then translated the lines into wire models of what he called "perfect movement". These were examples of the scientific search for a representation of time in visual terms that exceeded the capacity of the human body to perceive. As Foster (2004) suggests, the "archival impulse" often serves attempts to regulate and govern the unruly body within a "society of control" (21-22).

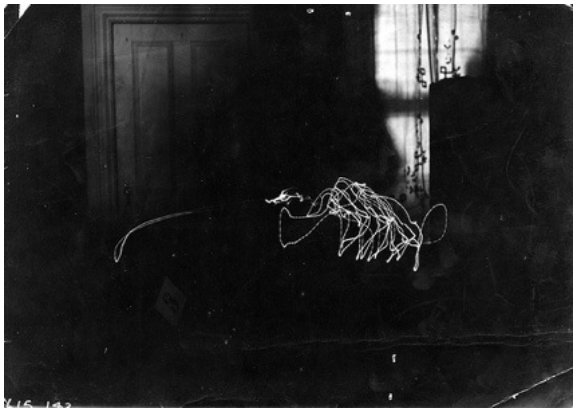

Figure #3: Surgeon sewing (Public domain image)[1]

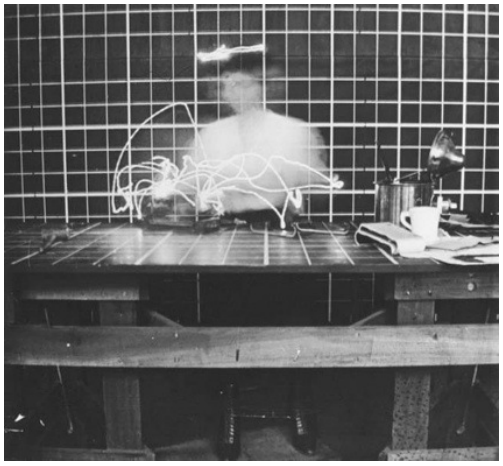

Figure #4: Motion efficiency study, 1914 (Public Domain image).[2]

[1] *: "Chronocyclograph of surgeon sewing." circa 1915. Collection: Frank B. Gilbreth Motion Study Photographs (1913-1917). Repository: The Kheel Center for Labor-Management Documentation and Archives*

According to Doane, these studies of gesture were related to the massive externalization and standardization of time in the West during the nineteenth century, through the shifting structures of industrial labour. By the early twentieth century, the standardization of factory labour relied on the use of such films for improving productivity. Film and photography were the technologies that could capture the fugitive moment, the ephemeral fleeting instant, and shed light on the capacities of the human body. The indexicality of this technology was a way of linking it to contingency and chance – in that it captured any moment whatsoever. This link between the technology of the moving image and the capture of contingency was part of the rationalization and abstraction of time that fueled Taylorism and other capitalist flows. As Doane states regarding the indexicality of film, the recording of events was meant to tap into the "signature of temporality" (p. 16). Scientific cinema was enlisted to capture that contingent presence and code the body's gestures, and this, I will argue below, has continued in contemporary video studies of the body in mathematics education. What is definitively different between film and video, however, which I will discuss in the later sections of this article, pertains to the indexicality of film and how it lacks the potential for digital decomposition and re-assemblage of images. Montage – as developed by Eisenstein and other early film-makers – is also a re-assembling of images, more or less experimental in its relation to human perception, but montage is never an *obliteration* of the image through digital decomposition. In the next section, I discuss particular examples of video research, focusing on gesture studies in mathematics education. I also argue that the desire to decode bodily movement as willful and rational – as embodied cognition - is served by the technique of frame-by-frame analysis.

Case study of video research: The body in mathematics education

Alongside this reliance on video data has been an increased interest in the role of the body in learning mathematics, and a particular focus on gesture and movement. This pursuit has taken on many

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[2] *National Museum of American History, Behring Center, Division of Work and Industry Collection.* These three last images found at http://we-make-money-not-art.com/archives/2012/05/the-chronocyclegraph.php.

different forms, each of which makes different contributions to the study of the human body and how it interacts with the material and social contingencies of mathematics. For instance, gesture studies has become a central focus of research on the body in mathematics teaching and learning. In a 2012 special issue of *The Journal of the Learning Sciences* on embodied learning in mathematics, guest editor Reed Stevens advocates the study of gesture as one among many "modal resources for producing meaning and action within interaction", while also examining the way that gestures are often "designed" for purposes of communication and pedagogy (p. 340).

Much of this research is in conversation with the work of Lakoff and Núñez (2000), and the embodied cognition paradigm, which focuses on how conceptual knowledge is mapped onto the sensorimotor system. Embodied cognition claims that the semantic content of mathematical concepts can be understood in terms of the way human bodies function in the world. Sheets-Johnstone (2012) critiques the phrase "cognition is embodied" because of the way it demotes the body to a vessel or container of some higher act of cognition. Indeed, much of this research abides by a conceptualist approach whereby one interprets the material actions of students and teachers as external simulations of some prior or primary internal conceptualization. This conceptualist approach prizes an interior mental space where internal acts of synthesis occur. Núñez (2009), for instance, suggests that mathematics teaching would improve if we paid more attention to the "embodied cognitive mechanisms, such as image schemas, conceptual metaphors, notation systems and co-speech gesture production" (p. 310). This approach is also aligned with phenomenology, in studying the pre-conscious activity of the body. Accordingly, Núñez (2009) claims "the study of gesture production and its temporal dynamics is particularly interesting because it reveals aspects of thinking and meaning that are effortless, extremely fast, and lying beyond conscious awareness (therefore not available for introspection)." (p. 319). The following is a subset of video frames published as evidence of how gesture and speech and inscription are combined by expert mathematicians as they explain concepts.

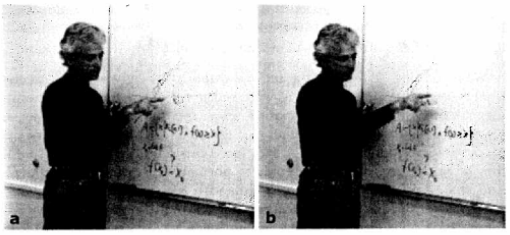

Figure 11.6. "... they go out ..."

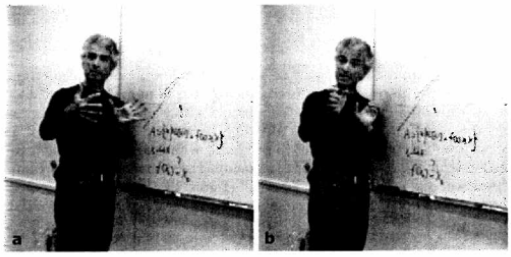

Figure 11.7. "Every set that is bounded has an edge."

Figure #5: Núñez, 2009, p. 324

Nemirovsky et al (2012a, 2012b) also draw on phenomenology to study the body in mathematics, drawing especially on the work of Merleau-Ponty, where bodily activity is studied in its own right, rather than a reflection of an interior mental concept, and where "mathematical insights developed by learners are expressed in and constituted by their perceptuo-motor activities" (Nemirovsky et *al*., 2012a, p. 311). Nemirovsky et *al.* (2012a) speak of perceptuo-motor possibilities immanent to the situation and focus on the human capacity to intend or intuit or imagine these possibilities with reference to a "state of readiness to notice, move, react, expect, and so forth" (p. 292). In prizing the phenomenological body, these researchers tend to construe the body as that which *knows* mathematics in some pre-verbal way. Below is an example of the kind of video capture that is identified as an eventful gesture, and worthy of attention. The following images were inserted into a transcript in Nemirovsky et al (2012b) to show how a boy was explaining to his mother how to use a motion-capture device to construct a diagonal line on a screen:

Figure 7. Silas says, "then you then the um."

Figure #6 (Nemirovsky et al, 2012b)

Roth (2010, 2011, 2012) also draws on the phenomenological tradition, using Merleau-Ponty's concept of the flesh and its impersonal pre-linguistic "I can", diffracted through the "material phenomenology" of Michel Henry, to study teacher and student use of communicative gestures. Below is a series of six images from a video of a professor writing on a blackboard and explaining a concept. These stills can be generated by any basic video software, often offering up to 24 captures per second, although high-speed cameras will offer significantly higher calibration.

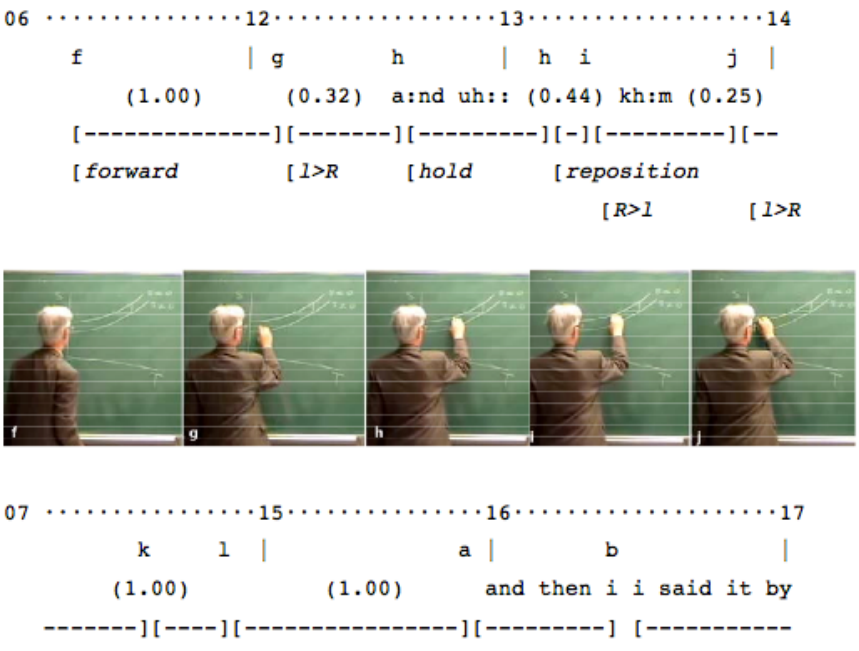

Figure #7: (Roth, 2012, p. 221)

Each of these researchers sets up a different approach to the body, and yet they share, with many others in the field, myself included, a focus and emphasis on video data, and a basic technique of frame analysis. Below is a sequence of images from my own work, exploring the power of gesture in creating new mathematical concepts.

Figure 8: (Sinclair, de Freitas, Ferrara, 2013, p. 244)

Because video data is visual, and because we are interested in evidence of learning or thinking, frame-by-frame analysis charts the unfolding movement of the body as inherently communicative. Focus is on how the body comes to communicate, through gesture or other bodily movement, where communication is considered broadly (Hwang & Roth, 2011). This approach, however, tends to produce an image of the human body as an organic whole whose pre-reflective movements serve the larger *rational* goal of communication. As my own research has come to rely heavily on video data, I have become more and more concerned with how video frame analysis produces a phenomenological image of the student and teacher body. I find myself turning to the work of Deleuze (1992, 2005) and Colebrook (2014) where materiality and embodiment is recast in less human-centric terms. As part of a recent theoretical movement to address the non-human turn within the posthumanities, my aim is to question practices in the 'social' sciences, including these video practices, for how they produce particular images of the human.

Belief in the body: Deleuze and the time-image

How does current video documenting of gestures relate to the history of scientific cinema? How is this new cinema of the body different from the early scientific cinema of sensory-motor bodies? Or is it simply a continuation of some of the same phenomenological goals? If the early scientific cinema was fixated on movement, and in particular aberrant movement, is it the case that current video research pursues this same interest? And to what aim? Although the early cinema served the science of physiology, the videos under discussion here serve educational research. How is this practice a response to other changes in education? If video recording in classrooms has been normalized, as part of a surveillance control state, how might the new interest in "lesson plays" and "lesson rehearsals" and even "teacher scripts" be a part of this cinema of the body, while also part of the massive standardization of teaching? Indeed classroom video supports standardization across education (Borko et al, 2008; Brophy, 2004; Frederiksen et al, 1998). Perhaps the MOOC, in its present form, is a massive overtaking of education through video, in which the best performer will become the global-teacher. And yet, simultaneously, video allows us to zoom-in on the micro-activity of the body, as in gesture studies research, and seems to reflect a desperate need to get at the body before speech and code, to reach and affirm the human body before it is entirely disassembled through distributed networks of digital becoming. Perhaps this focus on the micro-world of gesture and the body is part of an antidote to the macro-massification of capital, a desperate attempt to *believe in the human body*. In this section, I turn to Deleuze's work on the history of cinema, and focus in particular on his claims that a new kind of cinema – and more generally a new kind of relationship to the moving image – has emerged alongside this belief in the body. In *Cinema 2: The time- image* (1989) Deleuze suggests that a new kind of belief in the body emerged in post-war Western culture:

> The modern fact is that we no longer believe in this world. We do not even believe in the events which happen to us, love, death, as if they only half concerned us. It is not us who makes cinema; it is the world which looks to us like a bad film. … The link between man and the world is broken.

> Henceforth, this link must become an object of belief: it is the impossible which can only be restored within a faith. Belief is no longer addressed to a different or transformed world. Man is in the world as if in a pure optical and sound situation … What is certain is that believing is no longer believing in another world, or in a transformed world. It is only, it is simply, believing in the body. It is giving discourse to the body, and, for this purpose, reaching the body before discourses, before words, before things are named: the 'first name", and even before the first name. (Deleuze, 1989, p. 171-172)

One can see in video-based gesture studies this same desire to reach the body "before discourses, before words" (p. 172), to let the body speak or express itself without code. And yet much of this same research aims to code what was once considered asignifying, and eventually recommends particular kinds of body movements that will facilitate learning. Rather than simply accept this as an indisputable good, we must ask how this research continues the work of early scientific cinema in the massification of labour in the nineteenth and early twentieth centuries. Perhaps this is proof of Virilio's thesis, as described by Deleuze, that the movement image was from the beginning linked to the organization of "ordinary fascism" (Deleuze, 1989, p. 165). The "movement-image", according to Deleuze, feeds our desire to interpret motor-activity in terms of mechanical cause and effect, and will always serve the control state. It therefore seems urgent that we interrogate the way current video research practices in education align with the early scientific cinema, as this research is all too often taken up as part of the erasure of contingency in teaching and learning. But the quote above from Deleuze is meant to point to how the movement-image is no longer trusted or viewed in the same way by contemporary Western cultures, and that new post-war cinemas reveal new ways of thinking about the body.

Deleuze points to a new kind of cinema that breaks with the tradition of the movement-image, a cinema of the body that reconceives the movement-image as the *time-image*, a new kind of cinema that connects with bodies in radically different ways. In this new cinema, says Deleuze, the human body is no

longer the obstacle that "separates thought from itself", but rather a body of indeterminate potentiality, a body that links with the non-human. Deleuze says of this historical and artistic period, "we must believe in the body, but as in the germ of life, the seed which splits open the paving stones, … which bears witness to life in this world, as it is"(Deleuze, 1989, p. 173). This new body forces us to think what is concealed from thought – that being *life itself, beyond the phenomenological image of life*. As an example of this new cinema of the body, he cites film makers such as Cassavetes whose characters will "secrete their stories". In examples such as Faces or Shadows, characters are constituted gesture by gesture, posture by posture. Godard also will be described by Deleuze as producing a cinema of uncontrolled and indeterminate bodies. Similarly, the feminist film-maker Chantal Akerman will focus on the potentiality of the body, aiming to show "gestures in their fullness" (Deleuze, 1989, p. 196) – bodies secreting their story rather than performing it. Deleuze will announce that "to think is to learn what a non-thinking body is capable of, its capacity, its postures." (Deleuze, 1989, p. 189). This emphasis on "the non-thinking body" is in stark contrast to those advocating for "embodied cognition", where the body is prized for its ultimate rationality as a thinking body. The challenge is to study the force of the body without always interpreting bodily actions as enacting rationality in varying degrees.

Such a challenge requires new methodologies, and new ways of using video. For Deleuze, the "time-image" of the new post-war cinema begins to show us how we might do this, in contrast to the sensory-motor images of earlier cinema, where characters acted and events and cameras followed. The new cinema deploys pure optical or sound signs, akin, he suggests, to how impressionism entailed a conquering of a purely optical space. Hitchcock was the harbinger of this cinematic shift, because of the way he included the viewer in the scene - and indeed in the plot - so that the main character now "records rather than reacts"(Deleuze, 1989, p. 3). An important part of this shift in cinema relates to how the sensory-motor situation is displaced and becomes "any-space-whatever" without a unified cause of action. The question of objective or subjective perspective looses currency, as an impersonal optical

situation comes to dominate and replaces the focus on motor action. The movement of the time-image is thus less deterministic, becoming instead truly aberrant and inflected with chance. The early cinema of sneezes produced an organic image of the body, following the sensory-motor and the action image, and was drawn to the study of aberrant movement, involuntary movement apparently without function. Deleuze suggests that the aberrant movement in early cinema was recognized but warded off, until aberration became valid in itself, as in the postwar time-image. The two kinds of moving image have radically different relationships with time: In the movement-image, time is represented in sensory-motor moving bodies, while in the "time-image" time is *directly* linked to movement. In other words, movement is not an "indirect" representation of time, but is materially coupled with time. In the time-image, movement designates "time as its direct cause" (Deleuze, 1989, p. 41). Although there is not adequate space here to develop this aspect of Deleuze's approach, this work sheds considerable light on how we might rethink the nature of time and memory in learning theory more generally (de Freitas & Ferrara, 2014).

The crucial part of this new cinema is that the cut is no longer a rational cut that marks the end of one scene and the beginning of another, but an "irrational cut" that belongs to neither. This concept of the irrational cut is taken from the history of mathematics - Dedekind cuts – which were an invention by Richard Dedekind in 1858 to define the real number system rigorously, using ordered sets. Each real number – part of the continuum – was to be uniquely identified with a cut. In the case of a rational number, the number belonged to one of the two sets on either side, but in the case of an irrational number, it belonged to neither. It was always on the outside, as Deleuze says, of both sets, which made it strangely unreachable and yet adequately defined. In this sense the "irrational cut" in the new cinema is truly the place of constitution where a body is produced – "This may be the first case of a cinema of constitution, one which is truly constitutive; constituting bodies, and in this way restoring our belief in the world, restoring our reason …"(Deleuze, 1989, p. 201).

It is essential to note, however, that the time-image is not constituting the *presence* of the body, since the new cinema works the "dancing seeds" and "luminous dust" of becoming, it perturbs perception and produces "the genesis of an unknown body"(Deleuze, 1989, p. 201). Like the irrational number, this body is produced in absentia. The early scientific cinema might have glimpsed this radical unknown body, but it is through contemporary cinema that we begin to grasp the prospect of a new kind of unrecognizable body. Here Deleuze refers to Jean-Louis Schefer in *L'homme ordinaire du cinéma* and his thesis that the object of cinema is "not to reconstitute a presence of bodies, in perception and action, but to carry out a primordial genesis of bodies in terms of their white, or a black or a grey (or even in terms of colours), in terms of a 'becoming of visible which is not yet a figure, which is not yet an action.'"(Deleuze, 1989, p. 201). Such a body is no longer contained within conventional organic boundaries, but is dispersed across a field of light or energy, an unthinking body without the usual sensory-motor skills. This is no longer a phenomenological body that is the source of its will and action, but instead a Bergsonian body – a zone of indiscernability. Deleuze's cinema books will draw extensively on the seminal work of Henri Bergson. Bergson's theses on the body are meant to offer an alternative to dualisms of mind and matter that fail to explain the relationship between these two substances. Whether it be rationalists who privilege the human mind or empiricists who privilege perception, any philosophy that invests in *immaterial* thought and *material* action, says Bergson, will fail to overcome the paradoxes of dualism. These paradoxes result from a flawed understanding of the nature of space and time – and reflect a tendency to imagine the human body as the center of a determinate will. Deleuze – following Bergson - points to the undecidability of the body, "the non-choice of the body", "the body without organs". These expressions are meant to convey the ways in which human bodies are not simply enacting cognition. Instead Deleuze demands that we follow the flow of intensity that contracts – provisionally - into a body. This is a body that is constantly assembling, dissembling and re-assembling.

Concluding Remarks and Provocations

Most research on classrooms now relies on video data. As with all research practices in education, a particular image of the human body is produced through the use of video, and there is a need to examine the ways in which this kind of data is linked to the socio-economic history of scientific cinema. *Video research in the learning sciences* (Goldman et al, 2007) raises related concerns, pointing to the "dark legacy of imperialism in education research" and asking that we change "our practices and beliefs about what we are doing when we use video in our research today." (p. 7).

This paper poses the question to those using video data in their research as to how they might begin to explore Deleuze's concept of the time-image in their work. Such an approach doesn't have to abandon all movement, to embrace immobility, although this may occur, but movement might also "be exaggerated, be incessant, become a world movement, a Brownian movement, a trampling, a to-and-fro, a multiplicity of movements at different scales. What is important is that the anomalies of movement become the essential point instead of being accidental or contingent" (Deleuze, 1989, p. 128). How might our video-research practices begin to embrace the pure optical and sound images of modern cinema, demanding that we perceive movement not simply or only as a sensory-motor image, but also grasp the multifarious temporal dimensions of the image, dimensions that never stop growing? 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 bodies in duration without representing them in terms of sensory-motor action (de Freitas & Ferrara, 2014). This kind of time-image "must be read in terms of its internal relations rather than, or in addition to, its relation to that which it describes. The camera, whether it be moving or fixed, must become "questioning, responding, objecting, provoking, theoremizing, hypothesizing, experimenting …" (Deleuze, 1989, p. 23).

This paper invites discussion about how our current video practice serves particular kinds of learning theories and particular phenomenological images of the human body. These practices have inherited a set of data conventions from the history of early scientific cinema, a set of conventions that

were used in the capitalist over-coding of the human body during twentieth century industrialization of labor. Drawing on ideas from Deleuze, I have argued that we need to move beyond these cinematic conventions, so that we can begin to map new ontologies of the social and engage with the radical thought of the time-image. I have used these ideas to experiment with software analytics in other publications, showing how a particular algorithm lends itself to the study of the time-image (de Freitas, 2015). In this paper, I am more focused on the specific conventions and interests of gesture study research in mathematics education, and the need to rethink how we document bodies in classrooms. Mathematics classrooms are often places of ritual; socio-cultural studies have often critiqued school mathematics for how it disciplines bodies through such ritual. On the other hand, within anthropology, ritual is studied as a way of communing with an impersonal time, a way of plugging into Bergson's duration. Visual ethnographers record ritual actions in an attempt to understand this aspect of impersonal dispossession. For this very reason, taking on the notion of the experiment became important in visual anthropology in the 1970s (Glowczewski, 2014; Schneider & Pasquolino, 2014). For instance, Rundstrom (*The path*, 1971) created a film about the ritual of Japanese tea ceremony that deploys all sorts of avant-garde devices that disrupt the realist narrative, including superpositioning of images and jarring montage. I believe that video research in education might better attend to the study of mathematics ritual through the use of experimental film practices. An entire history of avant-garde experiments with the moving image could be used as a resource for the making of new cinematic conventions in scientific cinema in our field. A vast array of experimental filmmakers could be tapped for inspiration, from Dziga Vertov or Maya Deren, Michael Snow or Stan Brakhage, Bill Viola or Dan Graham. Maya Deren's work in particular is interesting for those interested in ritual, because of her focus on the induced trance that often accompanies ritual. Researchers might turn to her methods as they consider how to convey the ritual-like experience of school mathematics. Ritual performances reveal a kind of "possession" by which people are put into a trance-like condition. In mathematics education, we've used

the term "ritual" to indicate the lack of significant meaning in school mathematics, but perhaps looking at ritual through Deren's eyes might shed more light on how it compels one to participate, as a form of impersonal dispossession. Deren's interest in performance developed during the surrealist period, and she considered viewers as participants in a kind of ritual trance. "For Deren the purpose of a film was to plunge spectators into a second state and reveal to them an unfamiliar world" (Pasqualino & Schneider, 2014, p. 6). The anthropologist Jean Rouch (Les Maitres fous) spoke of a "ciné-transe" that used the camera and editing to bring the spectator into the highly ritual activity under study, enticing them to see the event through the eyes of the possessed. Since 2005, filmmaker Ben Russell has been making a series of films (*Trypps*) exploring trance induced by music, ritual, dance or drug. All of these examples from the history of film might inform the way we study ritual in mathematics classrooms.

Experimental film makers have also developed methods for exploring the complexity of memory and the archiving of the image, in some cases actually physically scoring or burning the film, an act that makes coding into literal destruction and alteration (Peter Delpeut's *Lyrical Nitrate*). Stop-motion animation, in which non-animate objects appear to move, could prove to be an incredible cinematic experiment for studying the strange dispersal of agency in classrooms, where non-human agents as well as concepts partake in the distributed agency of a learning event. Finally, experiments that tap the digital nature of video offer up all sorts of new techniques, attending to the materiality of video (the pixel) rather than film (the grain). Wanono (2014) 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. As she realized how reliant social scientists were on video, she also realized "the embarrassment of social sciences regarding the technical apparatus of our research" (Wanono, 2014, p. 186). As a knowledge-production device, the software for video processing has to be taken up and played with experimentally. Attention to technique and machinic processes can help us

better communicate the political and social concerns and questions that fuel our research: "digital code is, in fact, both a physical input into a system and a symbolic expression needing interpretation" (Wanono, 2014, p.188). The work of the new media theorist Lev Manovich, with twitter data and video archives, shows the power of tools from computer science in the fight to reclaim digital data for alternative purposes. As computational culture saturates life, and we become increasingly immersed in screen culture, a new political-aesthetic emerges: "Now, from 2012, many digital artists are engaged in this challenging reconstruction of the real. They are inspired by different aesthetic languages, political analysis, social backgrounds, but are also convinced of the necessity to introduce queer objects into the field, to challenge its boundaries and limitations." (Wanono, 2014, p. 194).

Inspired by these artists and the ideas of Deleuze, this chapter advocates for a new experimental paradigm in video research. Such experimentation seems urgent as we rely increasingly on software to mould our video data, and as the human body is increasingly recruited and its value tapped in new ways. Studies of the movement of bodies in mathematics classrooms are an important site for such experimentation precisely for this reason. The very same technologies that serve the control society and the archiving and conscripting of bodies for human capital can and must be appropriated and mutated in an attempt to break with confining conventions of embodiment. Deleuze shows how we might rethink the body as a Bergsonian "zone of indeterminacy" through the time-image or the crystal-image of post-war film. He also points to the need for a new experimental method that takes up the time-image using advanced digital methods (Deleuze, 1989).

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[i] For instance, a survey of articles from the last five years in the top 10 journals in mathematics education revealed that over 70% of the research used video data in some form (de Freitas et al, in press).

[ii] As an example, consider the ongoing project, Trends in International Mathematics and Science Study, which fuels changes in pedagogy worldwide. In the early TIMSS projects, camera operators were simply instructed to adopt the perspective of a "good student" paying close attention to what was happening in class (Derry et al, 2010, p. 13).

[iii] Rutgers University, for instance, houses the Robert B. Davis Institute for Learning video collection which contains more than 3,500 hrs of recordings that document children's mathematical thinking (Maher, 2005, 2008, cited in Derry et al).