Designing New Media Education Research: The Materiality of Data, Representation, and Dissemination

by Rick Voithofer

The current historical moment is marked by the gradual transition from a print culture to a digital new media culture, and this shift carries material effects for how education research contexts are perceived and represented. This discussion uses the concept of materiality to demonstrate how the conceptualization of inquiry through digital representations can be theorized through the histories and discourses of multiple media, computer technologies, research methodologies, epistemological positions, new literacies, and current social and cultural contexts to highlight emerging concerns in education research. Paying attention to the design of materiality encourages scholars to reflect on how inscription technologies influence the ways in which research is conducted and communicated.

Although educational inquiry is an evolving practice in which questions, theories, and methods have been undergoing accelerated diversification over the past three decades (Donmoyer, 1996; Guba & Lincoln, 1994; Lather, 2000; Phillips & Burbules, 2000), the textual structures in which research results are typically communicated and represented in academic journals in education have changed little despite the growth of, and possibilities of, inquiry and dissemination by electronic authoring and publishing (Pea, 1999; Robinson, 2004; Walker, 2004). The slow processes of this textual transition are explained in the work of scholars who observe that the adoption of media innovations are modeled after preceding and co-existing technologies (Bolter & Grusin, 1999; McLuhan, 1964). As academic publishing in education gradually changes from a print culture to a digital new media culture, it is important to continue to theorize, study, and historicize emerging relationships between new media and academic inquiry in order to ensure the ability of education research to respond to changing social, pedagogical, technological, learning, and cultural contexts.

The Materiality of Representation

In what follows, I use the concept of materiality to demonstrate how the conceptualization of inquiry through digital representations can be theorized through the histories and discourses of multiple media, computer technologies, research methodologies, epistemological positions, new literacies, and current social and cultural contexts to highlight emerging concerns in education research. The convergence of these histories and discourses through materiality offers one way to advance the discussion of how education research can maintain relevance within the context of changing pressures on education to address the multiple literacies (e.g., computer, media, communication, information, social, visual) that emerge as a result of the growing diffusion of new media (Kress, 2003; Lankshear & Knobel, 2003; New London Group, 1996).

Research can be considered a practice of the representation of questions, theories, methods, data, analyses, and interpretations, during which inclusions and exclusions occur as the narrative of inquiry is constructed and communicated. While the postmodern critique of representational neutrality, coupled with discussions about the breakdown of the distinction between real-world and virtual experiences through electronic communication and simulations, have made it difficult to discuss representation without close and situated considerations of producer and reader positionality, addressing the materiality of representation can advance the discussion of the conceptualization and communication of research.

Hayles (2002) introduces the concept of "material metaphors" to describe the interaction between words and physical artifacts, particularly "inscription technologies"—devices that "initiate material changes that can be read as marks" (Hayles, 2002, p. 24), such as books, computer screens, and videos. Paying attention to materiality encourages scholars to reflect on how inscription technologies influence the conceptualization and communication of research. As Denzin (2002) observes, "Our interpretive practices have a material effect on the world; there is a materiality to the text. . . . We change the world by changing the way we make it visible" (p. 483). The shift to a new media culture reshapes how research is conceived and represented, much like the move from an oral to a print culture through writing-restructured consciousness (Ong, 2002). According to Hayles, a text's instantiation through inscription technologies influences readings in ways that cannot be separated from the meanings of its semiotic elements, including visual interface(s), words, images, video, and sound. She notes that interacting with a text's materiality is influenced by the interplay between the text, author, and reader (Gitelman, 2003). The consequence of this interplay is that a text's materiality cannot be determined in advance. Because each text exists in its own type of materiality, Hayles stresses the need for media-specific analysis

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(MSA), a form of media analysis and design that moves away from the language of a generic "text" to a more specific discourse that centers on inscription technologies (e.g., screen, page, interface, code).

Using the idea of a "technotext," Hayles presents a class of literary artifact that reveals its own means of production and exposes the relationships between the production and reception of a text. A technotext illuminates the connections between the imaginative world that it generates and the material apparatus embodying that generation as a physical presence. Technotexts invite critical evaluation, discussion, and innovative action in response to the embodiment of both the form and content of a text (Hayles, 1992, 1999). An embodied text positions itself in time, place, space, physiology, and culture by offering the reader a view beneath the constructed façade of a text.

As ontological lenses, new media represent space and time in various embodied syncopations. An example of moving through these multiple temporal and spatial "attentional worlds" (Lemke, in press) might include the following new media experiences in a short period on a computer: analyzing the video of a classroom interaction; listening to an Internet radio report about the 50th anniversary of *Brown v. Board of Education;* seeing the arrival of an e-mail from an old friend; hearing an instant message alert from a student; and glancing at an open Web page depicting a desired vacation spot. Each of these windowed worlds invokes places that the new media researcher's body has been in, is in, and may be in and situates time in the past, present, and future. What meanings can one make when these attentional worlds have different spatial and temporal flows? How education research studies and represents these attentional worlds are questions that confront multiple aspects of research, knowledge, and media design.

Education researchers (The Design-Based Research Collective, 2003), literacy scholars (New London Group, 1996), media creators (Laurel, 2003), and learning theorists (Perkins, 1986) who engage in a systematic, iterative, and reflective approach to the creation of media, research, and knowledge have used the idea of "design" to illustrate their praxis. In this context, I employ design as a way to address a material and embodied approach to the creation of new media education research. Integrative attention to multiple discourses, including hypermedia, new media studies, computer literacy, film theory, visual design, human–computer interfaces, and visual culture, can lead to the design of research technotexts that embody their own critical concepts.

The following discussion complements and continues work by scholars who have presented ideas for alternative representation of research findings (Eisner, 1997; Tierney & Lincoln, 1997) and for the democratization of scholarly writing and the communication of education research, and calls by stakeholders for greater links between education research and practice through the use of communication technologies (Arnold, 1996; Burbules & Bruce, 1995; Pea, 1999; Willinsky, 2000, 2002). I address how the design of materiality and embodiment are central considerations for the move from print to new media epistemologies and ontologies in education and research.

To build a foundation for this discussion, the next section offers a definition of new media, a description of various theories of new media that address materiality, and elaborations of specific materializations of new media, including hypertext, visual culture, video, and human–computer interfaces.

New Media Defined

In using the phrase "new media," it is important to avoid the reductive "futurological tropes" of (a) *supercession,* in which a claim is made that a new medium subsumes its predecessors (e.g., communication and information technologies make books completely obsolete); and (b) *transparency,* in which a new medium is heralded for its capacity to mediate reality less than existing media do (e.g., a virtual field trip to an art museum is heralded as a more accurate representation of the museum experience than a book about a current exhibit) (Duguid, 1996). Instead, the term new media is employed to describe a historical period in which an emerging medium, such as virtual reality, is not yet accepted as natural. It marks a period that inspires diverse technotexts, productions that are self-conscious about their own materiality. In that interval, society is more likely to question the myths and conventions of existing media while defining the semiotic systems, interpretive communities, and normative epistemologies of a new medium (Gitelman & Pingree, 2003). During this gradual process, an old medium may find new functions as an emerging technology occupies the cultural and discursive spaces of its predecessors (Thorburn & Jenks, 2003) (e.g., radio became more specialized after the emergence of television).

More specifically, I contrast new media with more established media in terms of changes in production and reception that are occurring through the convergence of text, video, film, animation, audio, photographs, and 2D and 3D graphics that are combined (i.e., authored, linked), stored (i.e., organized, manually and automatically indexed), and presented (i.e., searched, retrieved, and displayed through a graphical interface or metaphor) on some form of video monitor (e.g., personal computer, laptop, personal digital assistant, cellular phone) and that are transferred over distributed wired and wireless electronic networks. Although access to computer hardware and software resources and levels of technical skill vary among scholars, Internet-connected devices represent an increasingly taken-for-granted tool for education researchers. Whether for gleaning data and reference sources from the Internet; communicating with collaborators and participants; processing statistical data; collecting, coding, and synthesizing qualitative data; writing research interpretations; or authoring data summaries in multiple media, the computer is a primary tool for many education researchers.

The adoption and diffusion of new media are integrated within existing historical trajectories of inquiry while simultaneously creating new social and cultural arcs. To connect these existing and emerging arcs, I build from the work of new media theorists to illustrate how the interwoven histories and discourses of computers and media influence the conceptualization and communication of education research.

Theories of New Media

During the 1980s and 1990s, media theorists began to examine the epistemological and ontological effects of information and communication technologies. Much of this scholarship originated at the Massachusetts Institute of Technology and focused on using new media to collaborate in the construction of knowledge through hypermedia (Barrett, 1994, 1991), to create con-

structionist learning communities (Bruckman, 1998), to develop user-guided narrative experiences (Davenport, 1994), to explore how cyberspace changes storytelling (Murray, 1997), to analyze video data on the computer for research and community building (Goldman-Segall, 1989, 1991, 1999), and to show the influence of new media on how individuals construct and perform computer-mediated identities (Turkle, 1984, 1995).

Other research centers that featured prominently in the development and theorization of new media in learning include the Institute for Research on Learning and the Center for Innovative Learning Technologies (CILT).[1] Founded in 1986, the Institute for Research on Learning focused on the development of technology tools to support learning and working as a collaborative activity. Since 1997, CILT has developed and studied new media tools for K–14 learning that involves visualization and modeling, ubiquitous computing, assessments for learning, and community tools. CILT has concentrated a great deal of its work in the areas of science, mathematics, technology, and engineering education by creating frameworks for online collaborative learning, visualization of data, and design research.[2]

Much of this initial scholarship on new media portrayed cyberspace as a realm where embodiment, time, and space were made irrelevant (Negroponte, 1996). From this early experimentation, often framed in Information Age utopianism, came second wave new media scholars who, in recent years, have further contextualized the materiality of new media as a site for the development, construction, and performance of knowledge and culture.

Under the rubric "digital materialism," Manovich (2001) identifies five primary ways in which new media are sites for the computerization of culture: (a) numerical representation, (b) modularity, (c) automation, (d) variability, and (e) transcoding. Because all new media are expressed through "numerical representation" (i.e., digitization) and therefore can be manipulated and programmed, they lend themselves to individual customization, or, as Everett (2003) notes, to a "system of discursive absorption whereby different signifying systems and materials are translated and often transformed into zeros and ones for infinite recombinant signifiers" (Everett, 2003, p. 7). Through "modularity," media objects (e.g., words, pictures, videos, sounds) can be combined (e.g., authored) without losing their individual characteristics, therefore allowing for all of the objects in a study to be perpetually recombined in various configurations and presented through diverse interfaces (e.g., a traditional journal article, a hypertext, a documentary video). "Automation" can be seen in Web pages that are dynamically generated by user-defined queries[3] and preprogrammed interactions; in software agents to simplify complex processes (e.g., a document creation wizard in a word processing program that leads someone through the construction of a visually complex document);[4] storing and retrieving media information; and searching and indexing large amounts of data by using word processors, database and spreadsheet programs, statistical software packages, qualitative research software, and Internet search engines.

Because of their numerical nature, new media and their modular structures possess "variability" that is derived from human or machine manipulation, or both. Examples of variability include media databases (e.g., case databases [Kolodner, Schwarz, Barkai, Neumand, Tcherni, & Turbovsky, 1997] and learning objects [Wiley, 2002])[5] that separate content from presentation. Variability also includes using information about and from the reader to generate content and media composition,[6] branching interactivity through tree structures (e.g., Web sitemap), hypermedia and hypertext, periodic updates (e.g., updating websites or software), and scalability (i.e., granularity) represented in the amount of detail presented in the media.

Finally, "transcoding" describes the blending of computer languages (e.g., how computers model the world in bits, bytes, variables, data structures, computer logic, algorithms, interface metaphors [*desktop, folders,* etc.]); media languages (e.g., visual composition, video editing, genre, structure, aesthetic); and other human discourses (e.g., educational, political, social, cultural, and research languages). For example, Carolan and Natriello (2005) transcode the languages of computer data and networks, of sociology, of "science," of mathematics, and of social network theories of individuals and collectives. Integrating these languages, they mine publishing data in order to understand clusters and connections in the communication of educational knowledge. How computer and research discourses are integrated will instigate important conversations, as all phases of education inquiry from research sites (e.g., e-learning) to dissemination are increasingly digital and interconnected.

In developing their theory of new media, Bolter and Grusin define a medium as "that which appropriates the techniques, forms, and social significance of other media and attempts to rival or refashion them in the name of real" (1999, p. 66). The evolution of media is driven by a consistent motivation to create more accurate ("real") representations of sensory reality. Bolter and Grusin explain this process of media appropriation by using the term "remediation" to depict the "double logic" of new media to transform other media by presenting themselves[7] as refashioned and improved versions of older media (e.g., print, film, photography)—multiplying media while simultaneously erasing traces of mediation. Through "immediacy," new media claim to offer the experience of "really being there" as the presence of the media becomes transparent. While each medium strives for transparency through claims of authenticity and promises of immediacy, readers are led to increased awareness of the hypermediation of experience according to Bolter and Grusin.

"Hypermediacy" illustrates how various media are brought together without a linear beginning, middle or end—much as the windowed space of the computer-graphical user interface represents multiple planes that are heterogeneous, each window offering a unique verbal and graphical point of view to an attentional world (e.g., a digital video window, a word processing window, an e-mail window, and a Web browser window that are used for personal or professional ends, or both). Hypermedia are always a form of remediation in which media that were introduced historically earlier are imported into a digital space to refashion and represent them. In hypermediacy the elements are often removed from their original context and remediated in the process (e.g., modularity). Even though new media strive for immediacy and transparency, they also remediate in their effort to suppress the limits of representation and achieve the real. In contrast to immediacy, which is transparent, hypermediacy is opaque and contained through the metaphors of human–computer interfaces. "In every manifestation,

hypermediacy makes us aware of the medium or media and (in sometimes subtle and sometimes obvious ways) reminds us of our desire for immediacy" (Bolter & Grusin, 1999, p. 34).

Every remediation is always tied to the technology that a new media is trying to erase. Therefore, all mediation is remediation. So, for example, older media can remediate newer media (e.g., a print article about new media). Hayles calls these diverse and complex associations between media "Medial Ecology"—likening them to the relationships of organisms living within the same ecotome and exhibiting "mimicry, deception, cooperation, competition, parasitism and hyperparasitism" (Hayles, 2002, p. 5). A common way of representing this ecotome is through hypertext structures.

Hypertext

Since the publication of Bush's (1945) "As We May Think," authors have imagined and created electronic texts that rupture linear, hierarchical presentations of textual information and narrative forms in ways that more closely approximate the nonlinear experience of human thought, learning, memory, history, and emotion (Ulmer, 1989). Hypertext is currently most commonly represented by electronic texts with cross-referenced, nonsequential links to the various components of a text or media called "nodes" (Bolter, 1991; Landow, 1997). A node is a basic unit of information (e.g., page, topic, sentence, or frame), an anchor point, corresponding to one or more screenfuls of information that are the beginning and end points of a hyperlink (Nelson, 1982). Hypertext identifies not only a textual structure but also an approach to knowledge construction that has implications for education research by challenging traditional, linear methods of data representation, analysis, and reporting.

Barrett (1994) notes how knowledge construction with hypertexts is a social process of collaboration and co-construction that frames the materiality of a text as an epistemological process. Electronic hypertext avoids the finality of traditional print and makes it possible to depart from the main axis of a research text to explore other commentary, definitions, raw data, footnotes, audit trails, and referenced citations. In this sense, texts become less authoritative and more contingent and situated. It is not hard, as Gaggi (1997) comments, to "imagine that over time the effect of hypertext will be to subvert the very sense of a primary text with a defined beginning, a dominant axis of movement, and a clear end" (p. 102). This effect introduces numerous challenges to the design of new media education research, which I will address later.

Hypertext has received a great deal of scholarly attention as a transformative genre, and some would argue that its importance has been overstated in recent decades. Nevertheless, it remains an area worthy of continued theorization, as a new generation of readers, students, and, ultimately, researchers form their epistemologies and ontologies through hypermediacy (Rideout, Roberts, & Foehr, 2005). This generation makes sense of its own materiality and embodiment in a world steeped in visual culture.

Visual Culture: The Development of Visuality

As Kress observes, describing the difference between print and visual culture, "The world told is different from the world shown" (Kress, 2003, p. 1). Assuming a society in which visuals continually remediate human experience, the study of visual culture examines how individuals and groups understand the visual in daily life. Mirzoeff (1998) defines visual culture as a "tactic with which to study the genealogy, definition, and functions of postmodern everyday life" (p. 3). This tactic is based on the premise that visual culture is now a prominent site of cultural and historical change. At this site, new grammars are developing that use the elements and structures of visuals, including color, perspective, framing, and composition, to communicate meaning independently of the grammar of words (Kress & Van Leeuwen, 1996).

As the twentieth century saw the development of visual culture through a succession of representational technologies—photography, narrative and documentary film, medical and scientific imaging, television, video, virtual realities, and so forth—"visuality" developed as a way to describe how seeing is culturally framed in technologies, communities, and institutions. Visuality is formed at the intersections of visual media, sensory perception, and power. Images are an important channel through which ideologies are remediated and onto which ideologies are projected (Sturken & Cartwright, 2001. p. 21). Engaging the language used to produce, read, decode, and understand visuals, visuality highlights how technologies, media, and ideologies broaden, magnify, and limit what can be observed. This is clearly expressed in the metaphoric place of the visual in social scientific methods.

"Modern empirical methods in the social and educational sciences are largely predicated on the eye as giving truth" Popkewitz (1997, p. 20). And yet, as Fischman (2001) notes, education research has, by and large, eschewed the study (and corresponding epistemological debates) surrounding visual culture.[8] This paradox has lead to education researchers' developing methodologies that translate visuals into text (e.g., through coding), while generally avoiding the study of the perception and reception of visual culture and downplaying the epistemological consequences of word–image relationships in both the collection of data and the reporting of research results. Denying full consideration to these reception and epistemological issues leads this paradox into the conflation of seeing with knowing. As quantitative methods make perceptions, opinions, attitudes, and thoughts visible through statistics, and qualitative methods engage in naturalistic studies of human processes that are directly visible through the eye, "looking, seeing and knowing have become perilously intertwined" (Jenks, 1995, p. 1).

While new media proliferate and as the number of media analysis tools increase,[9] the digitization of culture and transcoding into technical language must evolve to be critically integrated into educational inquiry. For as Jenks (1995) warns, " 'observation' drags behind it an excess baggage of ontological and epistemological assumption," with origins in modernism and positivism (Jenks, 1995, p. 1). Jenks depicts three levels of how visuals are used in social scientific observation including selection, abstraction, and transformation. "Selection" describes what is focused on in making a research observation. "Abstraction" involves altering the size and prominence of an observation in relation to the initial context. "Translation" is what researchers turn observations into after selection and abstraction to present the results and interpretations of an inquiry. Images become infinitely malleable when they are freed from their original context. Jenks asserts that researchers are creating another world, different from that which is being studied, when they engage in the processes of visual data collection and dis-

semination. The communication of research is not isolated from the subjects and contexts about which it reports, but instead it creates cultural products that feed back and affect the very milieu that they represent.

Various visual media, including photographs, video, and electronic texts, are increasingly being employed by qualitative researchers as cultural productions to represent sites of social interaction and as examples of ethnographic knowledge. Visuals, however, can be used as more than illustrative, archival, or documentary data to study issues of status (Margolis, 2000), place (i.e., schools), and surveillance (Emmison & Smith, 2000). Cautioning against using visuals to reinscribe empirical certainty through methodological overdetermination, and rejecting the grafting of existing research methods onto visuals, Pink (2001) argues that new methodologies are necessary for visual analysis. Such methodologies would not merely involve translating visual into verbal representations but would support methods that construct the visual as a type of knowledge that embraces its constructedness through the subjectivities of the creator (MacDougall, 1997). This kind of approach would acknowledge that visual technologies change ways of seeing and change reader self-understandings (Lury, 1998) and would be characterized by collaborations between researchers and participants, as well as between visuals and media producers. These collaborations could reduce the distance between a discipline and the subject of study, not only by submitting visuals to verbal analysis but also by treating them as new knowledges to be critiqued (Chaplin, 1994). For example, Marcus (1995) suggests the cinematic technique of montage as an alternative to academic writing for representing the various locations of culture and individuals within culture by creating conceptual relationships between visual ideas that would seem unrelated if depicted in isolation.

Video

Video[10] represents a convergence technology in which various media can be combined and analyzed. According to Tochon's (in press) semiotic perspective, video is becoming its own language, a system of signs that not only represents a cross-section of reality but also acts as an epistemological tool to transform society. From the first efforts to use film to collect anthropological data (Mead & Bateson, 1952) to recent uses of collaborative digital video to construct contextual understandings of learning (Goldman-Segall, 1991; Pea, 2003), video has an established history in research. It is important that the history of video and film, especially of those aspects that address materiality, be connected to future technical and methodological developments in education research. Although it is beyond the scope of this article to fully summarize the breadth of film theory, it is worth strategically outlining its role in understanding the materiality of video and film.

Film theory has engaged with aesthetics, linguistics, phenomenology, semiotics, narratology, deconstruction, poststructuralism, psychology, feminism, and psychoanalysis to study how video frames knowledge and how viewers create knowledge with video. The evolution of these theories has demonstrated the capacity of video as a time-based medium to mirror, distort, reproduce, challenge, and transgress the various institutions, subjectivities, social discourses, inequities, and psychic states that influence learning. Of particular interest to education researchers using video is examining the ways in which film theorists have demonstrated how this medium remediates representation. Even though there is little agreement among video and film scholars about the location(s) of remediation (e.g., the viewer's psyche, the apparatus of creation or viewing, social institutions), the questions that have been asked, addressed, and debated are important to return to and develop when engaging with the materiality of video.[11] For example, while some theorists have shown how structural elements such as shot selection, editing, lighting, camera angle, and audio contribute to the meanings that are made (Bordwell & Thompson, 2003) with film, others have argued that these structures cannot be considered a linguistic system where a convention like a close-up or cross-dissolve means the same thing in every video (Metz, 1981). The evolution of creating, disseminating, and analyzing video through digital technologies has offered education researchers new prospects and challenges.

Digital video reproduction software such as Apple's QuickTime, Microsoft's Media Player, and Real's RealPlayer[12] not only include the capacity to reproduce sound and video but also are containers for multiple media that include several video, audio, text, and animation tracks (i.e., modularity), all of which can be displayed in various combinations based on input from the individual playing the movie or on the conditions set by the producer (i.e., modularity and variability), or both.[13] As examples of new media, digital video technologies can embed media and can also import content from several simultaneous networked sources. Through these properties, digital video can incorporate multiple types of textual, numerical, audio, and graphical data to create "dialogical" and "polyphonous" accounts with multiple explanatory paths[14] or research interpretations.

The computer was first used to both produce and analyze video in the early 1990s (Roschelle & Goldman, 1991). Today, free and commercial computer programs in growing numbers are available to analyze video data. One significant evolution of digital video analysis has been the shift in its use from a tool to recreate the past to an approach toward the construction of collaborative knowledges (Tochon, 1999). For example, Noyes (2004) used video diaries to study the impact of various fields (e.g., sociological contexts), including school, family, and peer groups, on learning and educational trajectories. Olivero, John, and Sutherlad (2004) suggested the use of videopapers[15]—computer-generated texts that integrate video, text, and images—to bridge the divide between education research and practice. Goldman (2004) demonstrated how the organization, analysis, and presentation of online digital video can support the diffusion of a "perspectivity meme," an idea that promotes learning through systemic curricular reflection. Media-specific analysis and use of video in research will need to continue to address the changing role of video from a record-keeping medium to a knowledge-building tool. A significant aspect of video-specific analysis will be to understand how video production, analysis, and collaboration tools affect the knowledges that they frame through the physical and visual interfaces that they offer to both the author and the viewer of a video.

Human–Computer Interfaces

Human–computer interfaces describe the various embodied ways that an individual interacts with media, including input and output devices (e.g., mouse, keyboard, scanner, remote control, monitor, joystick, printer); the visual metaphors through which new

media content are presented; and the various modalities in which one accesses and manipulates digital information (e.g., pull-down menus, icons, desktops, folders, files, virtual tools, word processors, spreadsheets, image manipulation software, Web browsers, statistical programs). Johnson describes interfaces as the "buffers, translators, [and] tour guides" (Johnson, 1997, p. 32) of new media cultures. While it is possible to talk about the difference between content and interface, it is important to realize that, consistent with theories of materiality, the two can never be totally separated. To change the interface is to change content, and vice versa.

Manovich (2001) contends that, because digital devices are being used to transmit increasingly diverse forms of culture, computer interfaces are "cultural interfaces" that shape and delimit the creation and experience of one's social worlds. He notes that interfaces operate as representations of existing cultural forms and media, emphasizing some, such as the desktop and film, at the expense of others. "Cinematic means of perception, of connecting space and time, of representing human memory, thinking and emotion have become a way of work and a way of life for millions in the computer age. Cinematic aesthetic strategies have become basic organization principles of computer software. The window into a fictional world of cinematic narrative has become a window into a datascape" (Manovich, 2001, p. 86).

If one separates content from interface, it is no longer necessary to lock the content of a research article into the presentation structure. One way to think about this is through metadata that can be defined as textual, visual, and audio tags that are associated with a particular new media module or node, such as a video clip or portion of a research text, in order to index it. The indexes, in turn, can be used to guide individualized interfaces for readers.[16] An example of this quality can be seen in video analysis tool called Diver,[17] developed at the Stanford Center for Innovations. Diver allows a researcher to create unique paths, or Dives, of viewing through a 360-degree panoramic audio–video recording. From a single video segment of a particular recorded activity, multiple infinitely variable Dives can be produced.

As new cultural metaphors evolve, so can the interfaces that present a research report. An author or publisher can never fully anticipate the literacies of every group that will read an article; however, through the flexibility of content and interface autonomy, new interfaces can be developed to better accommodate different audiences. An example might be a research text in education that finds an unexpected readership among legal scholars. To better integrate the article into legal discourses, a new interface could be created for that audience.

Designing New Media Research

The following discussion illustrates how the concepts described so far—including numerical representation, modularity, automation, variability, transcoding, remediation, immediacy, transparency, hypermediacy, hypertext, visual culture, video or film theory, and interface—might be considered together through the concept of design in an education research technotext. A research technotext is one in which form and content are co-designed and the textual structure provides some sense of its constructedness.

It should be stressed that technotexts are not the exclusive domain of electronic media. Even the design of a printed book or research report can benefit from attention to text as being not simply words on a page, but material elements that shape the reading experience.[18] For example, a significant component in the interface of research technotexts is the type that is selected, and yet this is often narrowly considered in the design of research dissemination. Typography can communicate and ground words in specific places and times. Typefaces have meanings that emerge from particular historical periods, regions, schools of thought, aesthetic conventions, and theories of meaning and readability. While the connection has been largely lost, type possesses an embodied origin beginning as the representation of bodily gestures. "The history of typography reflects a continual tension between the hand and the machine, the organic and the geometric, the human body and the abstract system" (Lupton, 2004, p. 13). The selection of type in the design of a research text can communicate something about both the author and the content of a text.

Discourses of Design

"Design," a praxis that grounds many of the discourses of research, media production, and new literacies, suggests a cycle of planning, creation, reflection, and adjustment for the construction of research, media, and knowledge. The language of design in these three areas involves making new uses of existing resources, including research methods, theoretic frameworks about learning and knowing, aesthetic conventions, narrative structures, media genres, theories of curriculum, and semiotic grammars (e.g., video, interface, hypertext). The use of these available resources is never a simple matter of mimicry. Employing conventions is an unpredictable and dynamic process that always involves some degree of transformation of those conventions (New London Group, 1996). A design convention such as the use of a narrative genre never means quite the same thing across contexts. Choosing which design resources to transform presents an ever-present and evolving question for education researchers. If the earlier observation is correct and this is a time of epistemological and ontological transition influenced by the widespread diffusion of information, media, and communication technologies, the divisions between design resources are unclear and open for experimentation and debate across shifting disciplinary borders.

Computer-based media production tools, no longer the exclusive domain of production professionals, are becoming accessible, in price and ease of use, to a growing number of discourse communities. It is now possible, for instance, for an educational psychologist, an ethnographic filmmaker, and a visual anthropologist to capture and create multiple media representations of classroom learning by using the same media capture and authoring tools. How members of each of these three discourse communities might document learning through digital video would depend in part on their unique and overlapping design resources.

For instance, an ethnographic filmmaker working in the digital realm may possesses knowledge of aesthetics and graphic design, producing network-delivered video and animating text and graphics to support the filmmaker's deep understanding of the use of video to construct a dramatic representation of the learning context. By contrast, a visual anthropologist, less concerned with dramatic structure, flow, and progression, may bring multiple design

resources to demonstrate how the visible world affects culture and communication in learning. The educational psychologist might draw upon design discourses about teaching and learning that would suggest where to point the camera and what to include during the editing process. The video documentation produced from the design resources of people in each of these fields could, of course, look quite different as a result of different producer training and concerns. However, because each of these individuals is increasingly more likely to use a computer for documentation and presentation, a common set of design resources, constrained by the interface metaphors and technical discourses of the production software, infuses the process of documentation and representation in each of the three disciplines. The computer presents epistemological constraints as it offers opportunities for representation. Searching for and exposing these constraints while engaging in collaborations across multiple design communities reveals the importance of designing new media technotexts.

In the final two sections, I address how the design of education research can be informed by the concepts of materiality and new media. The first of these sections, on the materiality of data, will examine the notions of data granularity, abstraction, and transformation. The second will focus on the representation of research. As the processes of research design and implementation become increasingly digitized and collaborative through communication technologies, the distinction between doing research and reporting research may increasingly blur. The separation and overlaps in the final sections are responsive to current practices and future possibilities.

Design and the Materiality of Data

Thinking about data sources in the conceptualization of education research benefits from seeing data as new media modules—autonomous elements that can be manipulated (i.e., through the variability of numerical representation) and searched (i.e., by means of electronic automation) on the basis of various factors, such as metadata, that are determined by the researcher. The process of collecting, storing, analyzing, and manipulating data on the computer involves the practice of digitization (i.e., numerical representation). Three components of data representation previously mentioned by Jenks (1995) are relevant to the design of new media data collection and analysis: selection, abstraction, and transformation.

Through selection the researcher decides what data are relevant to a study based on the research questions, theoretical framework, and available research resources, including time, materials, funds, and researcher training. The increasing capacity and lower cost of the computer to store large amounts of information can tempt a researcher to capture large quantities of data. Data oversaturation can be prevalent in the process of studying online learning environments or in the learning that occurs on the computer where screen movement, typing, and time on computer tasks can generate large amounts of detailed information. A way to approach the design and selection of new media data is through theorizing data granularity.

Lippman (1989) coined the term *granularity* in relation to interactivity in new media to define the point at which the interaction with a new media text (e.g., a word, a page, a video or audio segment, a part of computer game) can be interrupted by a reader. Extending this definition, Goldman-Segall (1989) used "content granularity" to describe the smallest unit of video necessary to attain "thick descriptions" (a context-rich interpretation of "actors"). In planning a study, researchers determine the data granularity that they require to answer research questions, as well as determining, with dissemination editors, the depth to which the reader should be allowed to enter into the data. A simple example can be the use of a digital camera to capture visual documentation from a school. A digital camera is capable of recording more detail than is generally offered through a graphic on a website or a photograph in a book or journal article. Often this means reducing the size and resolution of a digital image or cropping it to better fit it on a Web page or printed page. These processes remove visual information that the reader may find useful.

Decisions surrounding data granularity address whether to include raw data[19] and complete interview transcripts in a research report. These decisions are not dictated by space considerations and reader interest alone but involve numerous issues, including participant confidentiality; the implications of identity-hiding techniques (e.g., face blurring or blocking in video); informed consent, when worldwide viewing of media data is possible through the Internet; and the intellectual property rights of lessons, books, and pedagogies captured through visual media (U.S. Department of Education, 2002).

Another concern in relation to data granularity is the researcher's increased responsibility to articulate how dense data, theoretical frameworks, and research methodologies have been selected, abstracted, and transformed for the report. Traditionally, shorthand terminologies such as validity, reliability, trustworthiness, and triangulation have been used in support of parsimony in the reporting of research. But as multiple (media) data sources and mixed methodologies are incorporated into research projects, researchers will need to be more explicit and reflective in reporting the process of data abstraction in the transition to electronic dissemination.

Abstraction describes how data are encoded for analysis by, for example, assigning alphanumeric codes to survey answers, interview transcripts, video clips, and images. Pink's (2001) call for new discourses to represent visual data, mentioned earlier, raises the question of how to develop nonreductive languages for the abstraction of multiple media data that do not conflate "seeing" (as Jenks warns) with "knowing." Exploring the limits of visuality and visual culture through aesthetic techniques such as video editing was offered as one response to this question. Another possibility is to continue to develop metaphors related to the new media characteristic of variability. As was previously mentioned, variability shows how new media can adapt on the basis of input from human or machine manipulation. The computer database is a common gateway to variability.

Defining databases as a collection of elements that one can view, navigate, and search, Manovich (2001) considers them to be a dominant cultural form among all new media, shaped by two aspects of computer ontology—data structures and algorithms. The computer requires both of these processes to operate, but they are highlighted differently in their material manifestations. Data storage and retrieval interfaces (e.g., most websites and CD-ROMs) emphasize data structures, whereas narrative interfaces, such as computer games, are more algorithmic. Algorithmic

databases possess an underlying hidden structure that someone must discover by building a mental model through transcoding (e.g., learning the logic and rules of a video game), while data storage databases offer a more explicit interface based on a structured collections of objects.

Examples of how researchers have used the technologies of new media to explore data granularity, abstraction, and databases to document the complexities of learning can be found in recent studies being conducted by design researchers. Design research is an approach to developing and studying theory-driven pedagogical interventions in situ (Barab & Squire, 2004; Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003). Barab, Hay, and Yamagata-Lynch (2001) used action-relevant episodes (AREs)—learning occurrences delimited by a change in theme, activity, subject, or resources—as the basic level of data granularity for documenting learning across time and space. In this study, AREs were recorded in a data structure database as nodes to represent the historical development of learning. Also using AREs as a foundation for granularity, Hay and Shaw (2005) captured and synchronized video, screen, biometric, and computer use, data, and metadata that were analyzed through collaborative software accessible through a Web interface. Both studies grapple with the challenges of abstracting and transforming large amounts of multiple media data and are constrained by the interfaces and design discourses of Web browsers, computer windows, media-editing programs, and database software. In this process of abstraction and transformation, the researchers develop new languages of data transformation that are hybrids of computer, media, research, and pedagogic design resources.

Design and the Materiality of Representation

The communication of research findings and interpretations has been undergoing significant changes in recent decades as a result of the postmodern critique of the representational neutrality of social science research; epistemological challenges to traditional dissemination forms; and the broadening social, cultural, political, and pedagogical concerns of education researchers, among other things. As a result of these changes, the discourses that define what it means to be an educator, student, or education researcher have shifted and continue to be in motion. The portrayal of this movement demands evolving forms of representation. In this final section I will touch upon how attention to the material design of representation in light of historical and current discursive trends in education and education research could affect the evolution of research dissemination.

Transforming data for analysis and representation to an audience can take the form of summaries through tables, charts, narratives, synthesizing statements, and summative condensations; or it can manifest in interpretive genres such as fictional vignettes (Graue & Walsh, 1998), portraiture (Lawrence-Lightfoot & Davis, 1997), dance, poetry, autoethnographies (Bochner & Ellis, 2002), and ethnodramas (Saldaña, 2003). Engaging in many of the design processes of social science research, including surveying, interviewing, participant and nonparticipant observation, member checks, and the analysis of documents (Barone, 2003), arts-based researchers are a discourse community that has a history of theorizing the material design of embodied and embodying research texts. Research choreographers, for example, enter into a practice of "sorting, sifting, editing, forming, making, and remaking" movements (Cancienne & Snowber, 2003, p. 237) to present an embodied representation of findings that acknowledges the somatic experiences of teaching and learning. The design of choreography, like research, is a remediation of the world guided by conventions and the breaking out of conventions. Arts-based researchers in education have worked at the borders of academic, aesthetic, and representational design resources in order to connect the embodied and emotional experiences of learning with larger social and cultural contexts. Because materiality is a central concern of arts-based researchers, the design resources of this community offer numerous theories, methods, and evaluative principles for the creation of research technotexts. One illustration of this can be seen in developing theories about how to design the representation of voice through multiple media.

Voice can be described as a channel of communication that personalizes and contextualizes the representation of verbal, textual, and mediated information in space and time (i.e., embodies it). Using descriptors such as tone, volume, pitch, silence, cadence, rhythm, inflection, expressiveness, and emotion, the design of the representation of voice presents a unique opportunity for new media researchers.

Autoethnographic texts and performances offer illustrations of how arts-based research resources can guide the material design of voice in new media. With its origins in the crisis of representation in anthropology, autoethnography is attentive to situating the researcher's voice among those that are relevant to the evolution of a study, including participant, reviewer, editor, and reader voices. Informed by "research on oral and personal narratives in performance and communication studies, situating the socio-politically inscribed body as a central site of meaning" (Spry, 2001, p. 710), autoethnographies model one way for new media researchers to situate technotexts in time and space. A "new autobiography" genre in documentary film, for example, explores hybrids of experimental and documentary video forms that study how fragmented and hybrid voices are staged by bodies in social, historical, and political processes (Behar, 1993; Nichols, 1994).

Presenting the multiple voices that contribute to the creation and evolution of a research project is an example of what Harnad (1991) calls "scholarly skywriting," in which a published product is presented alongside revisions, commentary, and reviews (e.g., blogs).[20] Issues of voice in new media dissemination revolve around whose voices to include and through which format to include them. Researcher voices might come in the form of an audit trail or record of the research process that includes the decisions, choices, and thought processes made by the researcher(s). The audit trail can show how the inscription devices (Latour & Woolgar, 1979) (e.g., questionnaires, interview transcripts, test scores, video and audio data, computer logs) translate an observation into something recordable by making visible the process of creating narratives about the recordings. The manner in which voices are made visible in a new media text is a direct concern of interface design.

Designing the interface of education research dissemination introduces issues similar to those raised by computer interfaces. Typically, the interface of a research report has been the journal article, a genre heavily invested in print culture. Characterized by a linear text, academic journal articles generally are divided into sections

that convey the processes, results, and conclusions of an inquiry. New media interfaces to education research can separate parts of the data or text, allowing the author(s) to present the same information through different visual metaphors and multimedia discourses.[21] The balance that must be found in creating interfaces for research dissemination exists between idiosyncratic metaphors that complement the goals and design resources of the researcher(s) and the literacies and investments of those who will read the new media research report. The capacity for readers to make sense of an interface is dependent on the design of tools, maps, and strategies that link its different elements.

Designing links involves creating connections between the research text, keywords, media, footnotes/endnotes, commentary, citations, and other sources internal and external to the main text. A new media report that is created to grow over time through the inclusion of comments by the reader, reviewer, editor, and author challenges the notion of a main text.[22] Determining how to frame the linkages in a hypertextual research report emerges as a new responsibility for authors of research to be disseminated electronically. One way to theorize linking is through Deleuze and Guattari's (1983, 1987) construction of rhizomatic inquiry, which is based on multiple principles: "cartography" and "decalcomania," among others. These two principles state that the rhizome is not a tracing mechanism but is rather a map with multiple entry and exit points.

Alvermann (2000) observes that "maps unlike tracings, are always becoming; they have no beginnings and endings, just middles. It is by looking at middles that we begin to see how, in perspective, everything else changes" (p. 16). Once the map is created, Alvermann goes on to say (paraphrasing Deleuze and Guattari), one must put the tracing back on the map. "By inspecting the breaks and ruptures that become more visible when the more stable tracing is laid upon the always becoming map, we are in a position to construct new knowledge, rather than merely propagate the old" (Alvermann, 2000, p. 16). The challenge ahead will be to design tracings that allow the readers of research to make sense of the linkages in a research report to make informed pedagogical, policy, curricular, and assessment decisions. The consequence of not developing these mappings will be singular texts that lead to what Aarseth (1997) calls "ergodic aporia," a bewildered and claustrophobic attempt by the reader to make sense of hypertextual nodes.

One way to consider designing hypertextual mapping is to rethink how large studies are often parceled out for different publication venues. A hypertextual reimagining of this dissection would create connections between the modular components of a study through author- and reader-created paths and maps. Author-created maps through the study could be targeted for particular areas such as policy or curriculum, while reader-produced maps would facilitate the use of research in ways that were not necessarily considered or anticipated by the author(s).

Conclusion

The topics that I have raised surrounding the materiality and design of education research have highlighted three existing and emerging trajectories of digital technologies: (a) technical qualities and discourses of electronic representation (i.e., numerical representation, modularity, automation, variability, and transcoding); (b) the histories and perceptual characteristics of new media (i.e., remediation, immediacy, transparency, hypermediacy); and (c) how these technical qualities, various histories, and ways of perceiving are reflected through specific materializations, including hypertext, video, visual culture, and human–computer interfaces. The struggle to make sense of these trajectories in a time of tremendous technological innovation parallels the paradigmatic expansion of education research in recent decades. The representational fragmentation that has taken place through media proliferation and epistemological diversification has resulted in rapid remediations of inquiry and media forms. The consequences of these social processes have been the emergence of numerous discursive constellations and design resources that have largely developed in isolation.

As education research evolves to make connections between these constellations and resources, new methods of conducting research and training researchers will emerge that integrate existing and emerging fields of knowledge. For example, the ability to transcode the technical language of computers and media production into new discourses of research is central to the preparation of future researchers, who increasingly will publish through online sources. This training must parallel the development of heuristics to continually interrogate the impact of integrating new technical languages (e.g., computer, visual, and new media languages) into research discourses. Media-specific analysis, as Hayles suggests, is one way to encourage researchers to question how the inscription devices that form their scholarship frame the processes of conducting and communicating educational inquiry. When the language of description and representation changes, so does the object that is being described. If Eisner is correct when he says, "We tend to seek what we know how to find" (Eisner, 1997, p. 7), then how new media education researchers are taught to transcode will structure the questions asked through educational inquiry and the methods by which the questions are answered.

NOTES

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[1] For more information, visit http://www.cilt.org/.

[2] For a summary of CILT's history, see http://www.cilt.org/events/2003/aera_2003_reflections.html.

[3] An example of a searchable repository of online learning materials can be found at http://www.merlot.org/.

[4] Of course, there are costs associated with this form of automation. Tufte (2003) warns about how the limitations of a tool such as PowerPoint can shape and distort the communication of research.

[5] For more information about learning objects, see http://www.reusability.org/read/.

[6] For an example of an essay with interactive activities that shows how computers redefine line and composition in drawing, visit http://www.berzowska.com/xy/. Each successive reading of the text allows for a different exploration of the concepts discussed.

[7] While I use the term "new media" as the subject of some sentences in this article, I employ it as shorthand to describe the intersection of technical, social, economic, and cultural forces that interact during both the creation and interpretation of media.

[8] In the field of education, visual culture typically has been relegated to art education.

[9] Examples of some current media analysis tools can be found at the following Web addresses (program names are given first, followed by the url):

Diver—http://diver.stanford.edu/

Transana—http://www.transana.org/

Qualrus—http://www.qualrus.com/Qualrus.shtml

NVivo—http://www.qsrinternational.com

HyperResearch—http://www.researchware.com/

AnnoTape—http://www.annotape.com/

Atlas.ti—http://www.atlasti.de/

Sign Stream—http://www.bu.edu/asllrp/SignStream/index.html

Visibility—http://www.lessonlab.com/visibilityplatform/overview.efm

The Observer XT—http://www.noldus.com/products/index.html

[10] I use the terms "video" and "film" interchangeably. The difference between the two is narrowing with the evolution of digital video technology that is now capable of simulating the look of film.

[11] Minh-Ha (1992) is one example of how critical film theory has been put to use to challenge the authoritative voice of traditional ethnographic film.

[12] Information about each of the three digital video technologies mentioned can be accessed on their respective websites:

http://developer.apple.com/quicktime/

http://www.microsoft.com/windows/windowsmedia/default.aspx

http://www.real.com/

[13] This input can include direct manipulation from a person playing the video, such as clicking on a link; or it can be information that the video player automatically communicates to the video server, such as the speed of the Internet connection of the computer on which the player is installed.

[14] An example of this interactivity and modularity can be seen in "Delay" (http://pixeldeep.net/daphne/htms/index.htm), an interactive video that investigates how the relationship between viewer and viewed can change in an interactive movie (Damie, 2005).

[15] Information about VideoPaper Builder can be found at http://vpb.concord.org/.

[16] The use of metadata to search for and organize information (e.g., text documents, e-mails, PDFs, instant messenger transcripts, media) is now being integrated into the core architecture of Apple's OS X (Tiger) and the upcoming Microsoft Windows Vista. Both operating systems have the capacity to create virtual folders that are automatically updated to include all items that fit a particular query, such as "authentic assessment." A growing number of programs already provide this functionality, e.g.,

Google Desktop—http://desktop.google.com/?promo=mp-gds-v1-1

Copernic Desktop Search—http://www.copernic.com/

Yahoo! Desktop Search—http://desktop.yahoo.com/

[17] Additional background and application information about Diver are available at http://diver.stanford.edu/.

[18] An example of a print-based technotext can be found in the design of Hayles's *Writing Machines,* which brings attention to the book as a physical artifact. It uses changing fonts and other graphic techniques to guide the reader and point out its own materiality. The companion website to *Writing Machines* (http://mitpress.mit.edu/e-books/mediawork/titles/writing/writing_book.html) offers Web-specific alternative mappings of the concepts addressed in the book.

[19] With the advent of the raw picture format, digital cameras can capture details that the eye cannot see. The processing of raw images as research data requires specialized technical and aesthetic knowledge (http://www.northlight-images.co.uk/article_pages/why_use_raw.html), in addition to understanding of the conceptual and methodological underpinnings of a study.

[20] Web logs, or blogs, are regularly updated and chronologically presented website postings of an author's reflections, thoughts, opinions, work(s) in progress, and so forth. Often, blogs have a feature that allows readers to respond. For links to scholars who blog, see http://rhetorica.net/professors_who_blog.htm.

[21] See http://www.iath.virginia.edu/wax/englishStart.html for an example of how a single interface may present different versions of the same work, or http://sunsite.cs.msu.su/wwwart/ for an example of how different interfaces can show the same information.

[22] An example of this is the rapidly growing diffusion of wikis (http://wiki.org/wiki.cgi?WhatIsWiki). Wikis are websites that allow users to create and edit Web content. Users can not only add content to a wiki site but edit the contributions of others while tracking all the changes that are made. As a genre, wikis are emerging as an approach to creating multi-authored encyclopedic knowledge (http://en.wikipedia.org/wiki/Main_Page) that is constantly evolving. A research wiki could provide one structure for a technotext in which its constructedness is implicit in its design.

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AUTHOR

RICK VOITHOFER is an Assistant Professor of Social and Cultural Foundations of Education at Ohio State University, School of Educational Policy and Leadership, 104 Ramseyer Hall, 29 West Woodruff Avenue, Columbus, OH 43210-1177; voithofer.2@osu.edu. His areas of interest include technology and equity, educational new media production, and cultural studies of educational technology.

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