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Coordinating Distributed Memory: An Environmental Engineer's Proposal-Writing Process Using a Product Calculator

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Abstract

This case study of an environmental engineer's proposal-writing process reveals how the engineer (Beatrice) reifies, archives, and accesses her distributed memory across physical and digital sources in order to write proposals. Based on the authors' observations of Beatrice's proposal-writing process and their interviews with her, they arrived at three key conclusions: Beatrice distributes her memory across multiple physical and digital sources, the (spreadsheet) product calculator helps Beatrice to manage her cognitive load and relieve her working memory, and the product calculator allows Beatrice to reassemble her distributed memory and coordinate her cognition.

Keywords

engineering communication, proposal writing, distributed cognition, memory

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Over a decade ago, Bazerman and Prior (2003) argued for the importance of examining writing processes: "To understand writing, we need to explore the practices that people engage in to produce texts as well as the ways that writing practices gain their meaning and functions as dynamic elements of specific cultural settings" in order to focus on "what texts do" (pp. 2–3). Around the same time, Beaufort (2004, 2007) claimed that process knowledge is one of the five knowledge domains of writers. The writing process domain includes "knowledge of how to get discipline-specific writing tasks accomplished (meta-knowledge of cognitive processes in composing and phases of writing projects)" (Beaufort, 2007, p. 221). Further, she argued for writing instruction that made explicit such knowledge of the writing process. Beaufort's (2007) longitudinal case study examines one student throughout his undergraduate career and 2-years postgraduation during his employment as an engineer. To situate her study, Beaufort succinctly reviewed earlier studies of engineering writing:

> As for *writing processes* of engineers, several studies have documented that there is no single model of the ways in which engineers produced texts. Selzer (1983) observed that one engineer composed a routing progress report in a linear fashion, with little revision or recursive drafting. In most cases, the format of documents are fixed by the company which influences the ways in which engineers approach writing tasks. Winsor (1989) observed documents being drafted and then revised by committees through several iterations. (p. 111)

Although Beaufort's work is more current than Selzer's (1983) or Winsor's (1989) engineering communication studies, none of these studies account for changes in engineers' digital composing and textual practices when these practices are mediated by computers. Further complicating the study of engineering writing is the fact that engineers often do not recognize or value the role that writing plays in their working knowledge and practices because, as Winsor (1990) has noted, the core engineering practice is to construct useful objects. In other words, engineers focus on engineering. They are concerned with how these useful objects are constructed, not the time-consuming documentation that initiates or supports that construction (Sales, 2006). As Winsor (1990) noted, despite spending hours on such documentation, engineers do not value their written products: "Engineers tend not only to see their own knowledge as coming directly from physical reality without textual mediation, but also to devalue the texts engineers themselves produce, seeing them as simple write-ups of information found elsewhere" (pp. 58–59).

Among the documents engineers produce is a major genre of technical communication: proposals (Killingsworth & Gilbertson, 1992). According to Sales's (2006) e-mail survey of the working engineers in her case study, engineers write proposals about 33% of the time (p. 40), yet, she observed, scholarship "yields little specifically on proposals," and current inquiries into proposal writing are "not representative of the time and effort spent on proposals by engineers" (p. 193). Furthermore, she argued, although there are some important engineering proposal studies, more are needed. We agree. Sales's (2006) study and those that preceded it provide us with several working assumptions about engineering writing: Engineers and scientists write, the writing genres they employ differ from those used in other fields, and a common writing genre that engineers produce are proposals, which require both time and financial investments. And as our case study participant, Beatrice, revealed, the time it takes to write a proposal must be balanced and optimized for financial gain.

In our initial work with Beatrice (a pseudonym), the environmental engineer at the center of our case study, she confirmed our assumptions about the time and financial investment required for the proposals she develops. She also verified that her proposals are not always successful with clients. For Beatrice, who has worked as an environmental engineer for over 15 years, proposal development is a time-consuming but integral component of her work at a for-profit specialty chemical engineering firm. It is her central writing task, as it is of many environmental engineers. Our case study investigated Beatrice's proposal-writing practices. She develops proposals as part of her commission-incentivized work at a chemical engineering firm. If her proposals for products are selected, she earns commission. Environmental engineering is only one of the environmental and chemical solutions that her firm offers.

To situate Beatrice's work, we sought to learn more about environmental engineering. Although *environmental engineering* is a newer term to describe a formal field of engineering study, according to Vesilind, Morgan, and Heine (2010), the practice of environmental engineering has a longer history. Potable water has been a necessity since the beginning of civilization. Making water drinkable and consumable and ensuring that excrement does not pollute water sources are tasks that have been assigned to the environmental engineer—tasks that involve sanitation and sanitary practices, especially since the emergence of public health agencies and knowledge about water-borne illnesses. Concerns about water, at state and local levels, contribute greatly to the need for more environmental engineers. Environmental engineering in the 21st century not only involves natural resource sustainability practices but also cleaning up the environmental messes of yesterday, both locally and globally (Vesilind, Morgan, & Heine, 2010). Faced with these global environmental challenges, environmental engineers attempt to remediate and preemptively address these issues. As Beatrice has told us, environmental engineers use proposal writing to recommend how environmental problems can be remediated once they have been identified. These proposals, and the writing processes that lead to their production, essentially make air breathable, soil usable, groundwater drinkable, and, ultimately, life livable. In environmental engineering, then, proposal writing is integral to promote and enact suggestions for soil, air, and groundwater bioremediation.

Moving forward from Sales's (2006) study that focuses on the product (the proposal), we opted to study Beatrice's composing processes as she produced proposals. Our aim in studying these processes, like Selzer's (1983) over two decades ago, was to more fully articulate their nuances and details beyond the more commonly identified writing process stages: planning, arranging, writing, and revising. Like Leijten, Van Waes, Schriver, and Hayes's (2014) case study of a professional communication designer's cognitive processes while constructing a proposal, our case study examines the multiple technologies Beatrice deploys to develop a proposal and considers how these technologies support her work. Our case study[1] was guided by one research question: How does Beatrice use computer-based writing technologies in her writing process in order to create proposals? To answer this question, we examined Beatrice's writing process using a contextual inquiry methodology including participant observation, interviews, and textual analyses as our primary data-collection methods.

Simply, our case study analysis revealed an interaction and distribution of cognition across multiple physical and digital technologies. Further, it revealed that one artifact encapsulates the distributed cognition work that Beatrice performed: the product calculator,[2] which reassembled—and reembodied—her knowledge as an environmental engineer.

Distributed Cognition, Memory, and Work

Cognition, as Hutchins's (1995) work argues, exists within sociocultural systems, and these systems affect what we can know and remember. Included within these systems are tools that assist us with cognitive activities. In the introduction to *Cognition in the Wild*, Hutchins wrote that "the relationship between cognition seen as a solitary mental activity and cognition seen as an activity undertaken in social settings using various kinds of tools is not at all clear" (p. xiii). To explain how social settings and the people and tools within them assist individual cognition, Hutchins developed a descriptive theoretical framework called "distributed cognition"; according to this framework, cognition can be distributed in three ways:

- "across members of a social group"
- through "coordination between internal and external (material or environmental) structure"
- "through time in such a way that products of earlier events can transform the nature of later events" (Hollan, Hutchins, & Kirsh, 2000, p. 176).

Although we cannot see a participant's internal cognitive processes, "a great deal of internal organization is directly observable" as behavior (Hutchins, 1995, p. 129). Additionally, this behavior is observable within environments and while using tools that researchers can see and investigate. Extending these notions about distributed cognition, Angeli (2015) theorized that those who work in "unpredictable workplace environments" externalize memory within these settings (p. 11). Distributed cognition, in these settings, is externally shared with observable artifacts and behaviors: "People use their external environment and artifacts to minimize workload, say, by using notes for a research paper. People then refer to these artifacts to restructure and remember information to complete a task, such as writing a research paper" (p. 9). In other words, to enable memory, individuals distribute (or transfer) information to objects, tools, or artifacts; when that information is needed, individuals search for and locate these objects, tools, or artifacts to use the information. This process requires individuals to remember or reembody information, moving it from the object in which it is stored back into their working memory.

Our case study builds on Angeli's (2015) work by considering how cognition and memory function within an environmental engineer's work within a distributed workplace. Previously, Spinuzzi (2007) identified distributed work as coordinative and polycontextual, the "splic[ing] together [of] divergent work activities (separated by time, space, organizations, and objectives)" and ultimately including "more and different types of communication" (p. 266). Distributed work looks like a process; however, distributed work "is performed by assemblages of workers and technologies" (Spinuzzi, 2007, p. 268), and, we add, the distributed worker (like Beatrice) is required to coordinate the assemblage of digital technologies and the work they enable.

Further, we consider Beatrice's work distributed because she works remotely from her home office; thus, she is separated spatially from her employer. By definition, distributed workplaces are enabled by the mobile knowledge worker who might work from home, a hotel lobby at a conference, and a traditional workplace all in the same week or even day. Spatially distributed work is not confined to the typical workplace, and it is empowered by digital technologies (see Spinuzzi, 2007, for a treatment of the history and future of distributed work). When work is spatially and temporally distributed, knowledge, cognition, and memory become distributed too. But a distributed workplace, such as Beatrice's, provides a complex and rich physical and digital environment to examine engineering writing processes. Additionally, by studying writers in these spaces, we can, as Van Ittersum (2009) noted, learn more about "sustainable digital memory practices" (p. 262) and explore engineering proposal writing as distributed, fragmented work.

Technology plays an important role in distributing cognition, memory, and work. For example, Hutchins's (1995) work examines cognition among sailors as they navigate with instrumentation. These sailors distribute their memory among each other and depend on one another to perform complex calculations as they navigate. Winsor (2001) recognized thinking as a distributed activity in which technological tools and language genres interact for knowledge workers:

> Thinking [is] not as an action that takes place wholly inside an individual's head but rather as an activity that is distributed among the individual, other people, the physical environment, and the tools the person uses, including language and such language structures as genres. (p. 7)

Therefore, according to Winsor, engineers' knowledge is not just in their heads but distributed across material resources such as calculators, computers, and even document templates. Similarly, Angeli (2015) determined that EMS (emergency medical services) first responders use three kinds of memory: professional, individual, and collaborative. These first responders create artifacts and distribute memory on any surface they can to reduce their heavy cognitive workload while working with patients.

Other scholars have considered the symbiotic relationship between human memory and computer memory storage and retrieval. Regarding this relationship, Chun (2011) noted that "computer memory, as a constantly regenerating and degenerating archive, does not simply erase human agency, but rather makes possible new dreams of human intervention and responsibility" (p. 10). This relationship, however, is not without problems. Over 35 years ago, Flower and Hayes (1981) suggested that retrieving information from long-term memory, which involves, first, "getting things out of it—that is, finding the cue that will let you retrieve a network of useful knowledge" and, second, "reorganizing and adapting that information to fit the demands of a rhetorical problem," is challenging (p. 371). Van Ittersum's (2009) more recent study of the role of digital sources in memory also echoes this problem: "Although new technologies provide the means to remember, in a sense, anything stored in their electronic parts, users' experiences often fall short of computer-mediated instant recall" (p. 259). Considering the affordances and constraints of both human and digital memory, we turned to Beatrice to learn how she deployed digital technologies to manage information during her proposal-writing process.

The Environmental Engineer at Work

For our foray "into the wild," as Hutchins (1995) called his study of "human cognition in its natural habitat" (p. xiii), we chose to observe Beatrice in her workplace home office. Her home office is in an east-facing nook (see Figure 1), surrounded by windows on three sides and plants on the windowsills. It includes an ergonomic chair, laptop holder that brings her computer screen closer to eye level, a USB-connected keyboard, and a wireless Bluetooth mouse. To the immediate right of her main desk and computer area is a stand containing other office items: business cards, collected at meetings and conferences, annotated on the back with the environmental remediation needs of these potential clients; a printer–copier–fax machine and paper to print; and other items used to conduct the business of being an environmental engineer who typically works remotely from her firm at home, meetings, or conferences.

We used purposeful sampling to select Beatrice as the participant for our case study. Koerber and McMichael (2008) recommended purposeful sampling for researchers seeking to identify participants who have particular characteristics (p. 464). With the consent of Beatrice and the environmental engineering firm she worked for, we began our research. To maintain anonymity, we could not show (or reveal specifics of) the actual documentation or texts Beatrice supplied. Thus, our curiosity to study Beatrice's proposal-writing process was tempered with our clear understanding of the

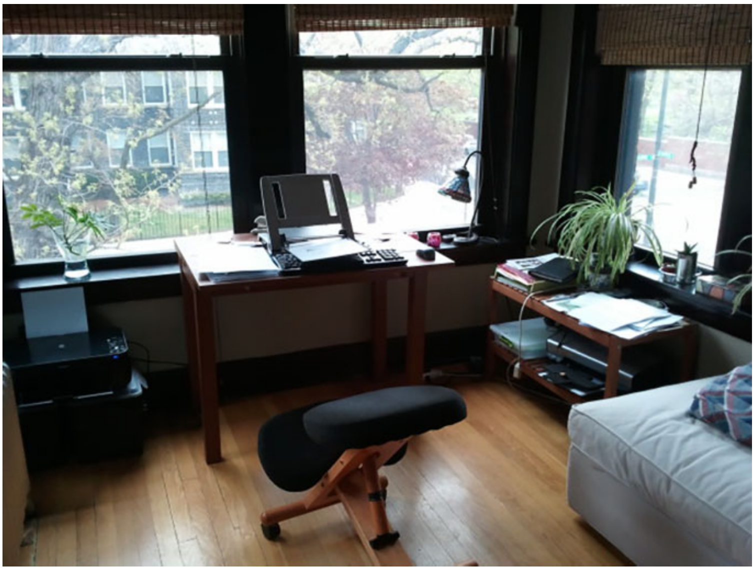

Figure 1. Beatrice's home-office workspace.

exclusive access that we were allowed and the proprietary information contained in textual artifacts.

Although qualitative methodologies, including rhetorical analysis, have been used to examine environmental impact statements (e.g., Bazerman, Little, & Chavkin, 2003; Dayton, 2002; Miller, 1980; Rude, 1997; Waddell, 1995) and other engineering writing (e.g., Winsor, 1990, 1992, 1999), we employed contextual inquiry in this case study. *Contextual inquiry* entails workplace observations and interviews with participants (Beyer & Holtzblat, 1997), researcher–participant coexploration of issues, and a specific inquiry focus (Raven & Flanders, 1996). We chose contextual inquiry as our research methodology because it takes the epistemological position that the observed participant is the expert and that the observer is the apprentice (Goodman, Kuniavsky, & Moed, 2012; Kuniavsky, 2003; Spinuzzi, 2013), which was completely accurate in this case. Observing and interviewing Beatrice also allowed us to ask questions as participant–observers.

Contextual inquiry is an in situ field methodology akin to Hutchins's (1995) "cognitive ethnography," which he described as happening "in the wild" (p. 371). Further, he defined culture as a process—"a human cognitive process that takes place inside and outside the minds of people" (p. 354). Writing processes, observed practices studied as culture, do not exist irrespective of their environments. As such, there are embodied, lived realities to consider and comply with. As in other field studies (Angeli, 2015; Bivens, 2017), data collection can be interrupted by life and life's urgencies; our methodological practices need to be responsive to their contexts. In her recent fieldwork on memory and EMS Communication, Angeli (2015) faced obstacles in accessing her desired data set in the wild. She was limited by the scope allowed by the institutional review board. Similarly, we were limited in our data collection by the lack of access to sensitive, proprietary practices and texts and our promises of anonymity to both Beatrice and her firm. To minimize this limitation, we triangulated our observations, Beatrice's interview responses, and the textual artifacts.

During observations and interviews, we used hand-recorded, double-entry field notes, recording the time, the writing task, and the computer-based writing technology and other resources that Beatrice used. We observed Beatrice in her home-office workplace immediately near her workspace (see Figure 1). The observations, made over 2 days, each in a different month, lasted about 2 hours each for a total of 4 hours of observation. During this time, we observed her complete work on five proposals, which demonstrated the role of the product calculator in her writing. Further, our observations allowed us to observe Beatrice's processes from beginning to end of proposal development. Beatrice worked almost solely on proposals during our observations, which made for proposal-concentrated observations. After each observation, we interviewed Beatrice based on what we observed. Our semistructured interview questions (see the Appendix) reflected Beatrice's writing tasks as well. Due to the proprietary and detailed information discussed and the requests of Beatrice and her firm to remain anonymous, we used only handwritten notes to record these interviews.

In addition to our observation and interview notes, we analyzed textual artifacts that Beatrice supplied. The artifacts included the documents used to create a proposal (proprietary client-supplied data and e-mail messages), a request for information (RFI), the response to the RFI, and the actual proposals. Further, Beatrice used and shared a Microsoft Excel™ spreadsheet calculator, which we refer to as the product calculator, to streamline her proposal-writing process. The spreadsheet, or product calculator, is a template of her own design; it includes embedded calculations into which Beatrice inserts site specifications. Not only does the calculator play a significant role in Beatrice's writing process, its output is a written, legally binding deliverable for the client that can be archived for future use.

To analyze our case study data, we used grounded theory analytical practices (Charmaz, 2014; Glaser & Strauss, 1967; Lindlof & Taylor, 2011). In doing so, we iteratively coded data. As we sought to distill our codes into an explanatory narrative of our data, we worked through multiple coding schemes, seeking connections that could explain Beatrice's process-oriented writing practice as well as her use of technological aides. After we finished collecting our data via contextual inquiry, we used analytical reduction to focus on the role of memory and cognition in Beatrice's proposal-writing process. These two aspects (memory and cognition) specifically were exemplified in the product calculator that Beatrice used to compose proposals.

The Product Calculator

For Beatrice, writing proposals was time-consuming. Hence, when our research commenced, Beatrice remarked that she had finished the template for the product calculator and had recently started using it. According to Beatrice, creating and using the product calculator made the proposals "pretty much autogenerated." Although she did not discuss the exact moment she decided to create the product calculator, she clearly was still iteratively developing and tweaking it based on, for example, the location of the site, the currency particular to that site, or discounts based on volume (instances for which we observed her amend the product calculations). In other words, Beatrice had created the product calculator, but it could not account for every context in which she wrote a proposal. The calculator was still evolving.

Figure 2 displays an annotated, blurred representation of the first page of a proposal that Beatrice wrote for a client in Northern Europe. Before the proposal existed as a PDF, though, it was calculated in a template spreadsheet—the product calculator. Beatrice created the product calculator (in Excel) as a storehouse for her prior experience. In turn, the calculator created an observable artifact of her work as an environmental engineer.

But Beatrice did not describe the product calculator in those terms. She explained that she entered site information in the product calculator. The previously entered calculations then determine the product need and pricing. We observed that as Beatrice entered site information in the product calculator, she returned to client-supplied site maps and chemical studies. A complicated text for a nonexpert, the product calculator synthesizes bits of

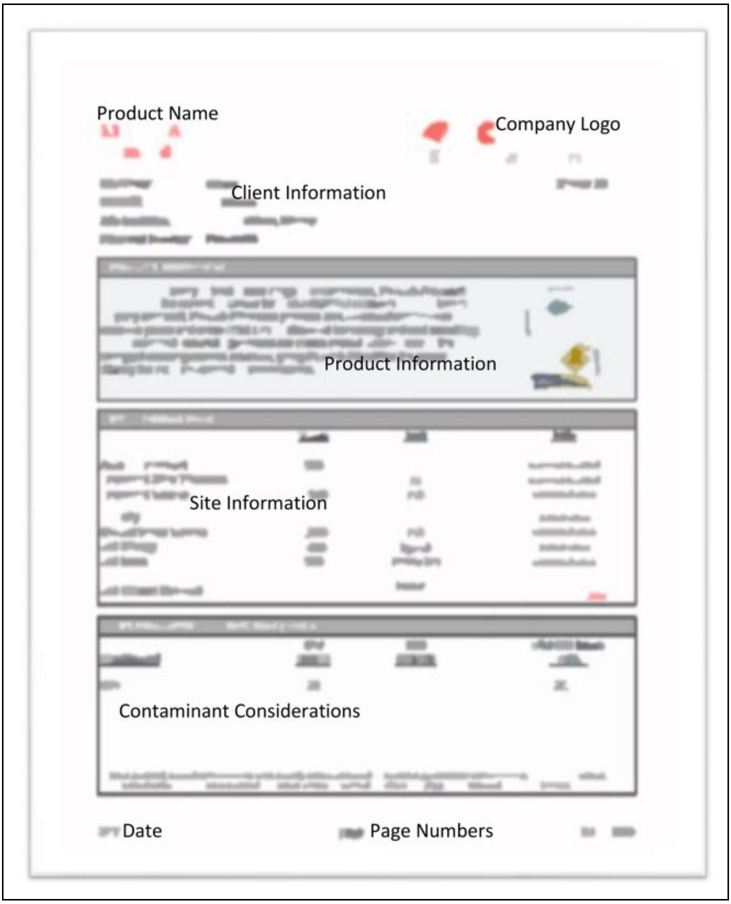

Figure 2. A blurred screenshot of the product calculator as a PDF.

information about a particular available product for remediating, for example, an abandoned gas station's soil. It calculates the amount of contamination that can be treated with the product (and without causing further harm to the soil) along with the estimated costs for the product and shipping. It includes assumptions about the potential sites to remediate as well as notations about whether default or calculated values are based on unknown variables or client-supplied studies of the site. The product calculator also includes known contaminants, geochemical data, and stoichiometric calculations.

The many factors to both remember and consider—the cognitive load—when writing a complex proposal eventually prompted Beatrice to create the product calculator as a means of managing that load. She simply could not remember all of this complex information, but financial constraints did not allow her the time to do research for every proposal. According to Lanham (1991), memory can be classified into two kinds: “natural and artificial. Natural memory is self-explanatory. Artificial memory is trained using one of the ‘memory-theater’ mnemonic methods” (p. 179). As a mnemonic strategy, the product calculator supported her proposal invention by promoting recall from her previous proposal-writing experiences.

Beatrice expertly managed the product calculator’s complexity. The product calculator—a mnemonic tool—reflected her ongoing use. For example, when she hovered over a cell on the product calculator, a notation would sometimes pop up to remind Beatrice of a previously stored bit of information in the calculator—a distributed memory. The distributed memory, as a cell annotation, allowed Beatrice to operationalize her distributed memory as a distributed cognitive practice that is only possible with her expert use.

Coordinating Distributed Memory

Throughout our observations, Beatrice’s writing process was iterative and discursive. She frequently returned to the invention stage as she accessed data needed to enter on the product calculator and write a proposal. As she worked, she employed a variety of technologies, such as the product calculator and an Internet search engine. She employed these systems as she searched for content, accessed it, and then deployed it in her working proposal draft. These actions, we found, are comparable to the proposal writer’s actions that Leijten et al. (2014) described: “When LTM [long-term memory] fails (or is not the preferred ‘source’), writing processes may be interrupted by the need to search external sources” (p. 326). In this case, Beatrice, unable to recall details from legacy proposals, employed technologies to search, locate, and access the content she needed. Then she concluded her proposal-writing process with an activity not traditionally identified as part of the writing process: by archiving the resources she created, accessed, or used when writing. When asked about this step, she explained that she archived information in case she needed it for future proposals. To manage the information and navigate the complex proposal purposes, Beatrice distributed her memory across multiple physical and digital sources. These three distinct actions—which we call reifying, accessing, and archiving—illustrate how Beatrice distributed and used her memory during her proposal-writing process.

Reifying Distributed Memory

Defined as making the abstract concrete, *reifying* describes how Beatrice concretizes or codifies information to make it visible and usable. It is a means and an activity she engages to remember both calculations and other content necessary to reduce her cognitive workload and complete a proposal successfully. Like Angeli's (2015) first responders, through reifying, Beatrice lightens her heavy cognitive workload by distributing her memory. And as Hutchins (1995) has pointed out, in the wild, cognitive tasks are completed or held outside the body.

Among the knowledge that Beatrice held but could not always articulate was her practice of using resources—both technologies and texts—to develop her proposal. But we observed her drawing on multiple physical and digital resources to complete her task. Although she used her memory to recall which texts were necessary to complete her tasks, where these texts were located, and what content to gather from them, and because this use was often tacit, she was not always aware of her choices or actions.

As we described, among the most obvious ways that Beatrice uses reified distributed memory is with the product calculator. To reify her knowledge, Beatrice inserts notes into the template that remind her of the experience she has gained during proposal development. When she hovers over particular cells in the calculator before entering data into the cells, she is able to read rationales, cautions, and other information embedded there. In other words, her calculator includes specifications and parameters she must both include and apply—bits of her distributed digital memory. With a template that serves her tacit knowledge and memory as it guides current proposal development, the product calculator is a tool she uses to reassemble her distributed memory gained through years of experience as an environmental engineer. Its content is a record of her memories and experiences from past proposal development that promotes or perhaps substitutes for her long-term memory recall during proposal development.

Furthermore, when Beatrice uses the product calculator, she enters new information based on the remediation site's data and generates the proposal by calculating the quote to remediate the site. She saves the quote—the proposal—as a PDF, which she then sends to the potential client. The product calculator not only reassembles her distributed memory and enables her writing process, but its product is also the written, legally binding deliverable for the client. Most important for future work, the PDF is a text that can be archived for future reference.

Accessing Distributed Memory

Similar to the term “searching” used by Leijten et al. (2014), *accessing* describes how Beatrice uses previous texts (e.g., legacy documents), Internet search engines and pages, the RFI, and other textual resources in order to gather content for the proposal. To describe comparable moves in their case study, Leijten et al. defined “searching” as “[retrieving] information from external sources, such as the Internet, dictionaries, thesauri, related documents from self and others, emails from collaborators, other software applications, etc.” (p. 326). As we observed her, Beatrice accessed external sources throughout her proposal-writing process.

During observations, we recorded multiple instances of Beatrice accessing prior documentation (e.g., PDFs of prior proposals saved in the product calculator). At one point, while she was working on the proposal for a European Union (EU) client, she remarked that she had a previous proposal (a saved PDF of a product calculation) that included the pricing in Euros for her firm’s environmental remediation solutions. She combed through her digital files until she found the information she sought. In this case, she accessed her distributed memory, an action that allowed her to locate the previously saved and archived product calculation PDF. When asked about this activity, Beatrice remarked that the EU client was a “standard type of case”—which was not new or unique—so she was able to use the saved PDF calculation without “further tweaking.” The saved EU client PDF was a memory distributed and archived for her future use in creating the new proposal. Her Windows computer filing system is thus integral to accessing her distributed memory during proposal invention. It gives her access to information previously saved and reified in product calculation PDFs. Each PDF file is numbered according to her firm’s system and practice, which includes alphanumeric representations of each client (e.g., EEE-01234) for quick and easy recall and access.

Archiving Distributed Memory

Defined as preparing and storing knowledge for future use, *archiving*, for Beatrice, meant employing conventions that helped her to store and later access information. We observed her archiving when she used the product calculator, applying firm-specific conventions and practices to name files and store and access information for future proposals. Her archiving resembled the "memory practices" Van Ittersum (2009) observed in his study of graduate student writing, which, he noted, "were inextricable from long-term questions about future circumstances and the value of their tools and practices in those situations" (p. 276). That is, Beatrice's archiving behaviors were all intended to help her remember (and save time) when writing future proposals. Specifically, she used filing systems that allowed her to locate legacy content that she could reuse in developing current proposals, and those same systems allowed her to save generated content from current proposals for future use.

Beatrice created and maintained an extensive archive, including the PDFs of product calculation proposals. At Beatrice's fingertips was another important archive, a large stack of business cards. Although Beatrice entered client information from the business cards into a content management database so that others in her firm could access client information, she remarked that entering information was tedious. For this reason, Beatrice said, she relied more on the physical stack of business cards than on the database. Some of these business cards had notes written on the back that included information about the conference or city in which she met the client and the client's particular environmental engineering solution needs. To Beatrice, then, the business card archive represents a system external to her computer that she uses to organize the information she needs to remember: key details about clients and their needs. The product calculator itself is an archive of the knowledge that Beatrice has gained through her experience with writing environmental engineering proposals. Also within her computer is another archive—her digital filing system—that provides her with access to texts that support invention and sustain her work. Saving each calculation as a PDF and with a firm-specific file name provides portability and accessibility, yet it serves another function. The PDFs are a secondary archive that Beatrice uses alongside the product calculator to access her prior knowledge and work. This archive is a digital storehouse for her future use, another collection of her distributed memory housed in her computer. We saw Beatrice use this archive to locate a previously submitted EU proposal in order to assist her in creating a current calculation; she used the file's alphanumeric system to quickly find and open the PDF. This PDF archive, the business-card stack, and the product calculator all contribute to reducing Beatrice's cognitive load by enabling her to reassemble her distributed memory in order to complete proposal-writing tasks.

Coordinating Distributed Cognition

Possession of an astrolabe, as Hutchins (1995) noted, does not make one a navigator of the seas. Experience and the coordination of the cognition distributed across numerous sailors enable modern, technologically driven oceanic navigation. The astrolabe allows for "a distribution of cognitive effort over time" (p. 97). Similarly, Beatrice reduces her cognitive effort over time through her use of tools and objects that hold memories that her mind cannot. She is able to expertly operate the product calculator in order to reduce her cognitive load, reassemble her distributed memory, and coordinate her distributed cognition—an embodied process. The product calculator, then, is Beatrice's astrolabe; as she "manipulat[es] the physical device" (p. 102)—the product calculator—she also coordinates her distributed cognitive efforts.

Distributed cognition allocates cognition and memory across objects. Beatrice, as we observed, distributes her memories across business cards, legacy documents such as product calculations and proposals, and client-supplied textual information such as RFIs, e-mail, and phone calls. The product calculator, through reassembling her distributed memory, provides the object to coordinate her thinking and the calculation for the proposal. It is in this coordination that the cognitive work is observable, yet Beatrice's role in the process is essential. Further, it is in this coordination that the distributed knowledge and memory become reembodied in Beatrice. Just as a violin needs a violinist to play music or an astrolabe needs a learned sailor to navigate celestially, the product calculator needs Beatrice to reassemble her distributed memory to coordinate her cognition.

Without Beatrice, the product calculator can neither serve its purpose nor coordinate distributed cognition. Coordinating distributed cognition requires temporary embodiment. It requires the user, Beatrice, to use her senses in order to reassemble distributed memory. Hutchins (1995) warned against conflating cognitive and sociocultural system properties. Further, Beatrice's cognitive properties and those of the product calculator are distinct. In other words, the product calculator cannot be automated; it requires Beatrice's expertise, like Hutchins's astrolabe, to create proposals. Hutchins illuminated this property further: "When the manipulation of symbols is automated, neither the cognitive processes nor the activity of the person who manipulated the symbols is modeled" (p. 362). The product calculator requires Beatrice's expertise for it to work (in any capacity).

To conclude, we briefly return to our initial research question: How does Beatrice use computer-based writing technologies in her writing process in order to create proposals? In examining this question, we discovered that Beatrice's proposal-writing process was remarkable in that she frequently cycled through inventional stages as she wrote, accessing and consulting various distributed memory resources as aides, and at the end of her process, she carefully archived her calculations (i.e., as PDFs) and other reified bits of knowledge for future use. Beatrice used a variety of computer-based writing technologies to perform this work, including word processing software, the spreadsheet product calculator, PDF files for saving written proposals, and Internet search engines to access previously archived pieces of knowledge for reuse. Beatrice frequently called on these resources and used these technologies without an articulated awareness of doing so; these actions were so familiar and unremarkable to her that she seldom recalled employing them as she wrote. Thus, these actions were virtually invisible to her although she frequently engaged in them when writing proposals.

Based on our observation interviews of Beatrice and her proposal-writing process, we arrived at three key conclusions: (a) Beatrice distributes her memory across multiple physical and digital sources, and her distributed memory is visibly reified in the product calculator; (b) in turn, the product calculator provides an opportunity for Beatrice to manage her cognitive load and serves as an archive of her memory for future use; and (c) Beatrice can reassemble her distributed memory and coordinate her cognition by using the product calculator. In other words, to reduce her cognitive load, Beatrice distributed her memory—knowledge she needs to write proposals—across multiple physical and digital resources and visibly reified it in the product calculator. The measurements, complicated chemical tests, and calculations that Beatrice must analyze and complete before offering an environmental engineering remedy create a heavy cognitive load (even for an expert). Not unlike the first responders that Angeli (2015) studied, individuals who must deal with a high cognitive workload will find ways to reduce it in order to complete their complex, dynamic tasks. These first responders create artifacts and distribute memory on any surface they can in order to reduce their heavy cognitive workload while working with patients. Similarly, over time, Beatrice created a visible and reified mnemonic tool to manage her cognitive workload: the product calculator.

To manage the relevant information about the proposal and navigate its complex purposes, Beatrice uses and distributes her memory during her proposal-writing process by reifying, accessing, and archiving; these actions allow her to reduce her cognitive load in order to complete her writing tasks. She depends on distributed memory and the technologies it requires in order to develop her proposals. Such strategies also allowed

Beatrice to draw on resources in order to develop her proposal; that is, she stitched together and archived various texts within the product calculator. Only the client's site specifications and needs made the product unique and newly generated. As Flower and Hayes (1981) suggested, a writer's long-term memory is embodied and "exist[s] in the mind." Although they did not address memory as distributed, they did note that memory exists outside and across resources, such as books (p. 371). But to access the technologically mediated texts necessary for proposal development, Beatrice had to rely on her memory of their content and location. The product calculator, though, served as an archive—a repository—for previously accessed and used information: an expert's tool usable only by an expert.

Finally, by observing Beatrice at work, we discovered that her process was both an embodied and a technologically mediated practice. A reorientation of embodiment in technical communication studies in engineering (Haas & Witte, 2001) and the posthumanist research on knowledge work as the new material turn in technical communication (Mara & Hawk, 2009; McNely, Spinuzzi, & Teston, 2015) have compelled us to consider the interplay between the body (and what it can do) and technology (and what it does). By definition, *embodied actions* are performed by the human body, take place in real time and in particular places, and "entail the usually skillful and often internalized manipulation of an individual's body and of tools that have become second nature, virtual extensions of the human body" (Haas & Witte, 2001, p. 416). We contend that this "second nature"—the use of tools—is often tacit, and we agree with Haas and Witte that "the embodied nature of writing is one appropriate and useful way to pursue research on technical communication and other kinds of literate performances" (p. 417).

In our study, Beatrice reified, accessed, and archived her knowledge using multiple technologies. She depended on being able to call on these technologies to store and restore her knowledge. Recognizing that the memories stored within distributed memory are human memories reembodies the knowledge management process, and the distribution of this knowledge—its movement between digital and embodied spaces—requires the interplay of both the body and technology. Distributed memory is thus a bridge between digital and embodied literate practices. In this way, Beatrice's actions illustrate the "complex interplays" that posthumanism, as Mara and Hawk (2009) defined it, postulated between humans and the technological resources that they use. Furthermore, Beatrice's actions demonstrate how "the human and the technical" are viewed not as competing but as collaborating in "complex ecologies" (Hawk, 2004, p. 372). In this way, our investigation includes an analysis of the interplay of these rhetorical practices as integral elements in her proposal-writing process. This interplay, we argue, characterizes Beatrice's use of her distributed memory—a process that can be observed through her embodied behavior and use of the product calculator.

Implications for Teaching and Future Research

To produce the requisite writing (e.g., RFIs that initiate proposals, PDF proposals), environmental engineers will likely rely heavily on their working memories. Thus, we should reconsider and reemphasize memory in both technical communication and engineering pedagogy, taking further note of these potential pedagogical implications. If environmental engineers typically engage the benefits of technological inventional aides (i.e., spreadsheet templates that make tacit knowledge explicit and help users to manage their cognitive load in a familiar genre), then educators who instruct engineering and environmental engineering students should reinforce the importance of such technologies as an element of the writing process, especially to make students' writing processes transparent. To introduce this concept to engineering students, we might ask them to attend to their inventional practices by consciously noting when they look up words, refer to models, or gather a piece of information from the Internet as they write. Even the common practice of creating and maintaining a collaborative style sheet for an assignment offers opportunities to learn how this kind of distributed memory work occurs. Formalizing this process in technologies, such as databases or wikis, would teach students to archive their knowledge in ways that allow quick access and retrieval and would provide them with an understanding of professional engineering writing practices. As we discovered, to create archives of her reified tacit knowledge, memory played a crucial role in Beatrice's writing process as an environmental engineer; learning from her example, we can offer our students better instruction in how to distribute their memories using these technologies to reify knowledge.

Students might also benefit from focused instruction on how to use the filing features of Windows in order to systematically store knowledge and reduce their cognitive load by temporarily distributing items from their working memory. Specifically, options for file management and file-naming conventions should be taught to technical communication and engineering students. As environmental engineers continue to write proposals and complete remediation projects, they need to be able to keep all of those projects in an easily accessible archive that provides digitally stored knowledge as they progress through their careers.

Beyond these pedagogical implications, this case study calls for future research. Our study provides additional qualitative evidence of memory at work, as described by Leijten et al. (2014). It further supports Van Ittersum's (2009) and Leijten et al.'s findings that writers use multiple physical and digital sources when composing and builds on the foundation that Winsor (1990, 1992, 1998, 1999, 2001) laid in multiple studies. In the future, qualitative writing researchers might further explore the roles of distributed memory and distributed cognition in engineering writing processes. Additionally, we echo Whittemore's (2007) call for future research that continues to address the role of the classical rhetorical canons—specifically, memory as a useful and well-worn theoretical framework for analysis. Van Ittersum (2009) has noted the importance of "sustainable memory practices" (p. 262). We extend his notion to include sustainable distributed memory and distributed cognitive practices.

Appendix

1. Please tell me about the proposal you were writing.
2. Did you find this proposal-writing experience typical? Can you explain?
3. Did you use any resources writing this proposal? Which ones? Why?
4. Do you usually use resources when you write a proposal? If so, which ones? Why?
5. Did you use any Web sites? If so, why?
6. What were you thinking about while you were writing the proposal?

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Notes

1. We obtained the approval for research with a human participant from the institutional review board at Texas Tech University.
2. Although Beatrice has created several product calculators for the bioremediation products that her engineering firm offers, for simplicity's sake, we refer to the product calculator in the singular.

References

Angeli, E. L. (2015). Three types of memory in emergency medical services communication. *Written Communication*, *32*, 3–38.

Bazerman, C., Little, J., & Chavkin, T. (2003). The production of information for genred activity spaces. Informational motives and consequences of the environmental impact statement. *Written Communication*, *20*, 455–477.

Bazerman, C., & Prior, P. (Eds.). (2003). *What writing does and how it does it: An introduction to analyzing texts and textual practices*. London, England: Routledge.

Beaufort, A. (2004). Developmental gains of a history major: A case for building a theory of disciplinary writing expertise. *Research in the Teaching of English*, *39*, 136–185.

Beaufort, A. (2007). *College writing and beyond: A new framework for university writing instruction*. Logan: Utah State Press.

Beyer, H., & Holtzblat, K. (1997). *Contextual design: Defining customer-centered systems*. San Francisco, CA: Morgan Kauffmann.

Bivens, K. M. (2017). Rhetorically listening for microwithdrawals of consent in research practice. In L. Meloncon & J. B. Scott (Eds.), *Methodologies for the rhetoric of health and medicine* (pp. 138–156). London, England: Routledge.

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). Thousand Oaks, CA: Sage.

Chun, W. H. K. (2011). *Programmed visions: Software and memory*. Cambridge, MA: MIT Press.

Dayton, D. (2002). Evaluating environmental impact statements as communicative action. *Journal of Business and Technical Communication*, *16*, 355–405.

Flower, L., & Hayes, J. R. (1981). A cognitive process theory of writing. *College Composition and Communication*, *32*, 365–387.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory: Strategies for qualitative research*. Chicago, IL: Aldine.

Goodman, E., Kuniavsky, M., & Moed, A. (2012). *Observing the user experience: Why research is good and how it fits into product development*. Amsterdam, the Netherlands: Morgan Kaufmann.

Haas, C., & Witte, S. (2001). Writing as an embodied practice: The case of engineering standards. *Journal of Business and Technical Communication*, *15*, 413–457.

Hawk, B. (2004). Toward a post-*technê*: Or, inventing pedagogies for professional writing. *Technical Communication Quarterly*, *13*, 371–392.

Hollan, J., Hutchins, E., & Kirsh, D. (2000). Distributed cognition: Toward a new foundation for human–computer interaction research. *ACM Transactions on Computer–Human Interaction (TOCHI)*, *7*, 174–196.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT Press.

Killingsworth, M. J., & Gilbertson, M. K. (1992). *Signs, genres, and communities in technical communication*. Amityville, NY: Baywood.

Koerber, A., & McMichael, L. (2008). Qualitative sampling methods: A primer for technical communicators. *Journal of Business and Technical Communication*, *22*, 454–473.

Kuniavsky, M. (2003). *Observing the user experience: A practitioner's guide to user research*. San Francisco, CA: Morgan Kaufmann.

Lanham, R. A. (1991). *A handlist of rhetorical terms* (2nd ed.). Berkeley, CA: University of California Press.

Leijten, M., Van Waes, L., Schriver, K., & Hayes, J. R. (2014). Writing in the workplace: Constructing documents using multiple digital sources. *Journal of Writing Research*, *5*, 285–337.

Lindlof, T. R., & Taylor, B. C. (2011). *Qualitative communication research methods* (3rd ed.). Thousand Oaks, CA: Sage.

Mara, A., & Hawk, B. (2009). Posthuman rhetorics and technical communication. *Technical Communication Quarterly*, *19*, 1–10.

McNely, B., Spinuzzi, C., & Teston, C. (2015). Contemporary research methodologies in technical communication. *Technical Communication Quarterly*, *24*, 1–13.

Miller, C. R. (1980). *Environmental impact statements and rhetorical genres: An application of rhetorical theory to technical communication* (Unpublished doctoral dissertation). Rensselaer Polytechnic Institution, Troy, NY.

Raven, M. E., & Flanders, A. (1996). Using contextual inquiry to learn about your audiences. *ACM SIGDOC Asterisk Journal of Computer Documentation*, *20*, 1–13.

Rude, C. D. (1997). Environmental policy making and the report genre. *Technical Communication Quarterly*, *6*, 77–90.

Sales, H. E. (2006). *Professional communication in engineering*. New York, NY: Palgrave.

Selzer, J. (1983). The composing process of an engineer. *College Composition and Communication*, *34*, 178–187.

Spinuzzi, C. (2007). Guest editor's introduction: Technical communication in the age of distributed work. *Technical Communication Quarterly*, *16*, 265–277.

Spinuzzi, C. (2013). *Topsight: A guide to studying, diagnosing, and fixing information flow in organizations*. Austin, TX: Amazon CreateSpace.

Van Ittersum, D. (2009). Distributing memory: Rhetorical work in digital environments. *Technical Communication Quarterly*, *18*, 259–280.

Vesilind, P. A., Morgan, S. M., & Heine, L. G. (2010). *Introduction to environmental engineering* (3rd ed.). Stamford, CT: Cengage Learning.

Waddell, C. (1995). Defining sustainable development: A case study in environmental communication. *Technical Communication Quarterly*, *4*, 201–216.

Whittemore, S. (2007). Metadata and memory: Lessons from the canon of memoria for the design of content management systems. *Technical Communication Quarterly*, *17*, 88–109.

Winsor, D. A. (1989). An engineer's writing and the corporate construction of knowledge. *Written Communication*, *6*, 270–285.

Winsor, D. A. (1990). Engineering writing/writing engineering. *College Composition and Communication*, *41*, 58–70.

Winsor, D. A. (1992). What counts as writing? An argument from engineers' practice. *Journal of Advanced Composition*, *12*, 337–347.

Winsor, D. A. (1998). Rhetorical practices in technical work. *Journal of Business and Technical Communication*, *12*, 343–370.

Winsor, D. A. (1999). Genre and activity systems: The role of documentation in maintaining and changing engineering activity systems. *Written Communication*, *16*, 200–224.

Winsor, D. A. (2001). Learning to do knowledge work in systems of distributed cognition. *Journal of Business and Technical Communication*, *15*, 5–28.

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