Final Reflection
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"Thinking and explaining catalyze learning. People who go through life repeating the same successful behavior, never trying anything new or different…learn precious little." (Schank, 1997)

How can teachers use primary source materials to develop their understanding of the nature of science? I began my investigation of this question with anticipated outcomes already in mind. While expectation creation is not a conscious process (Schank, 1997), I had predictions in mind, based upon prior experiences. Along the way, I encountered alternate outcomes and embraced these expectation failures—both positive and negative—as the essential core of my learning.

When I began, I expected that teachers would affirm my belief that primary sources are valuable for classroom practice. Yet, when six teachers did so vigorously, I began to doubt their objectivity. Upon reflection, I considered the possibility that the experience of working with Marie Curie's Case File was so inherently unique that an unenthusiastic reaction would be impossible. My expectation failed me; I realized that my expectation was flawed because I had not sufficiently considered all of the implications and consequences of the experience. By reflecting upon this expectation failure, I found an exciting new idea—I identified the phenomenon I now call "white glove syndrome."

Armed with my new idea, I attacked Cycle Three with a whole new set of expectations. I believed that if I used technology to neutralize the effect of "white glove syndrome," the teachers would react with less enthusiasm and contradict my original premise. I hypothesized that the teachers would not react enthusiastically to the value in the primary sources since they had only accessed the Marie Curie papers through a technological interface. Once again, I encountered an alternate outcome. Even though their access was only virtual, the teachers responded positively and—ironically—confirmed my original premise.

My research experience cemented the validity of Schank's theories of learning through failure. (Schank, 1997) I now believe that expectation failure is at the core of every real learning experience. As I reflect upon everything that I have forgotten in my life, I detect the absence of failure. In the learning experiences that remain, I discover failure.

Likewise, Schank suggests the educational value of role-playing. (Schank, 1997) In my investigation, I asked the teachers to play as actors in the social network of science as defined by Latour. (Latour, 1987) By thinking about their own role as participants in the larger network that connects their daily practice with the advancement of scientific culture, the teachers were essentially trying on a new personality. For the teachers who encountered the Marie Curie documents while wearing white gloves, the considered action of professional museum interpretation was yet another role to play. In their post-experience reflections, the participants uniformly used the words "memorable" and/or "unforgettable" to characterize their performance.

On a personal level, I too tried on a new personality as I played the role of educational researcher. Certainly, my action research experience lacked characteristics of professional

research, but in some ways I assumed the role of an understudy—a legitimate peripheral participant (Lave, 1991) in the community of professional education research.

"The knowledge is in the conversation." ~ David Weinberger, "The New Shape of Knowledge"

Another expectation failure warrants consideration. While I was following the scent of my idea about "white glove syndrome," I stumbled across a significantly more important concept. In Cycle One, three teachers encountered the Curie papers separately and then joined together for a face-to-face conversation. In Cycle Two, two teachers encountered the Curie papers together and then shared their thoughts immediately with the other four teachers. In Cycle Three, fifteen teachers interacted with the online presentation of the papers in complete isolation. The level of enthusiasm and breadth of creativity was significantly lower in Cycle Three. I had not anticipated this outcome at all. I realized that the power of primary sources is in the conversation.

Oddly enough, I had enthusiastically embraced Schank's ideas about the importance of narrative (Schank, 1990) in learning around the same time that I began Cycle One. Yet, it wasn't until Cycle Three that I realized the full impact of what I had been reading. Schank's theories about story indexing made perfect sense to me in the abstract; the practical implication only became real in the later stages of my investigation. The lesser quality and quantity of teacher-generated ideas in Cycle Three gave me pause. I reflected upon the differences and realized that all nine of the teachers who participated in Cycles One and Two had "swapped stories." All of them expressed some link between their experience with Curie and some prior life experience. Many articulated practical stories from the classroom. As one teacher finished telling a story, another was ready to pick up the conversational thread and weave it through the tapestry of her own narrative index.

Where does knowledge about the nature of science lie? Weinberger suggests that all knowledge is in the conversation. Schank suggests that the knowledge lies in the narrative index. (Schank, 1977, 1990) The teachers who participated in Cycle Three are likely to have already forgotten their experience with the Curie papers—not because of the technological interface, but because of the lack of conversation. The teachers who participated in Cycles One and Two are unlikely to ever forget their encounter—not because of "white glove syndrome," but because of the story indexing that happened as a result. They will forever have a space in their narrative indices that holds the script for working with primary source materials. Another space is now affixed to the story of Marie Curie's work. And, perhaps most importantly, their indices hold the plans for practical classroom use of the Curie papers as a result of their dialogue.

"Understanding, then, is sometimes all plan-based, sometimes all script-based, and sometimes a mix. The main point is that in order to understand you must predict, and in order to predict there must be **knowledge of how events connect**…In some instances, certain people have scripts available while others have only planboxes to help them in understanding." (Schank, 1977)

The teachers from Cycles One and Two certainly have new knowledge of how events connect. Their strengthened narrative index will serve them well during trivial pursuits over cocktails. Is

there a more significant practical impact? I believe that the process of strengthening the narrative index (Schank, 1990) simultaneously nurtures the development of adaptive expertise. (Bereiter, 1993) The more stories that teachers have indexed, the more likely they are to be adaptive experts in their professional practice.

"What we understand about expertise in general would suggest that if there is an explanation of creative expertise it should lie in *what creative experts know that noncreative experts do not know*." (Bereiter, 1993)

I see sythesis between narrative indexing and adaptive expertise. I propose that adaptive experts have more scripts at their disposal. The complexity of one's narrative index—or "knowledge of how events connect"—could potentially be an indicator of adaptive expertise. Childhood is pivotal in the development of this knowledge. Children are script sponges. The scripts and plans absorbed during childhood become the foundation of adaptive expertise. Do humans reach a point at which the sponge becomes less absorbant? Perhaps. It seems more likely, however, that adults are just as capable of absorbing and indexing new scripts. If this is the case, professional developers who work with in-service teachers should provide frequent opportunities for story swapping and for work with primary source materials.

Summary

Latour's ideas about the social nature of the scientific enterprise inspired my thinking about how teachers might importantly act as participants in that social network. Along the way, Schank's ideas inspired me to think about the essential role of conversation. Interestingly, I now hear the two theorists in perfect harmony. While there are isolated examples of true scientific geniuses working entirely alone, the real nature of science is conversational and collaborative. Scientists work with jigsaws all of the time—individual laboratories shape the curves and then the scientific community assembles the pieces until the puzzle is framed by a straight edge. That assembly happens through shared knowledge. Historically, that transfer of knowledge happened slowly because of the pace of print publication, including documents like Marie Curie's Le Radium. Today, the pace of the scientific enterprise has rapidly accelerated because of access to the Internet—the ultimate conversational workspace. Perhaps it is no coincidence that science researchers conceived the Internet because of their need to share data, to "swap stories."

The lines between the modern concept of the nature of science and the actions of the teachers in Cycles One and Two are both parallel and perpendicular. Scientists share knowledge and ideas through various conversation technologies (including human speech); The Teachers shared knowledge and ideas through conversation. These parallels became perpendicular when I realized that teachers are coincidental scientists—and that I had helped them to act accordingly.

Cycles One and Two offered evidence of the value of conversation. Cycle Three offered evidence of the value of an online encounter with primary source materials through a technological interface. Logic suggests that the use of a conversational workspace in tandem with the online presentation of the Curie papers would potentially provide the transformative experience through which limitless numbers of teachers could begin to understand their roles as

actors in the social network of science. That hypothesis, however, will remain untested…for now.