The White Glove Experience

Understanding the Nature of Science through Primary Sources: Teacher Interpretation and Conversation

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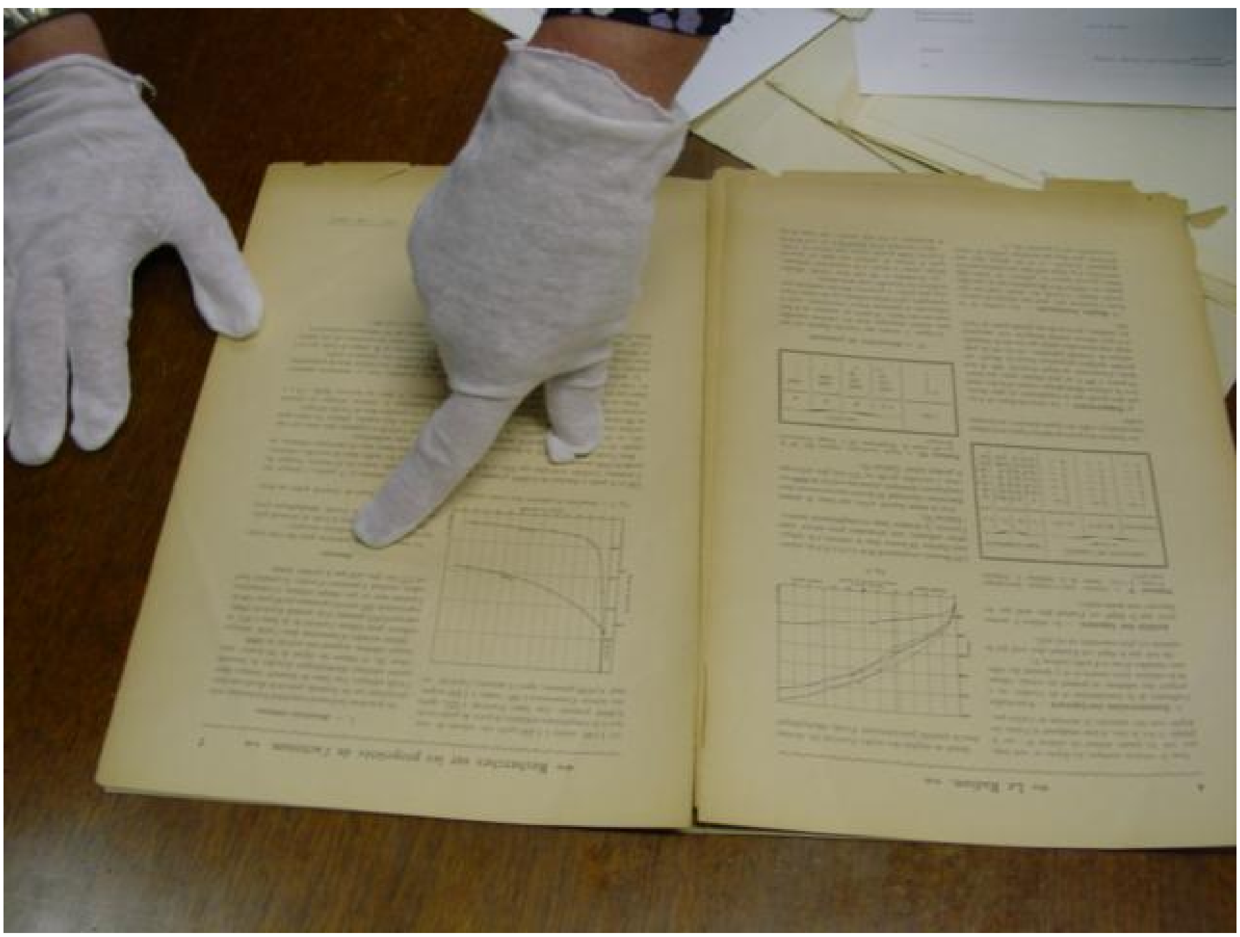

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SUMMARY

How are primary source materials from the history of science useful for the development of teacher understanding of the nature of science?

In an attempt to answer this question, I initiated action research within my professional workplace. Action research is a systematic inquiry with a goal of gaining insight, developing reflective practice, and effecting positive change in practice (Mills, 2000, as cited in Aune, 2002). For my inquiry, I investigated how direct encounters with primary historical science resources can inspire teachers to think about their own role as actors in the social network of science. In general, primary sources from the history of science are two- and three-dimensional artifacts that remain as evidence of some scientific transaction. Typically, science museums are the repositories of these artifacts.

This investigation responds to a national call for students to learn about the nature of science, despite the fact that few teachers are ready themselves to answer that call. Teachers can use primary source materials to develop their personal understanding of the social nature of the scientific process. Only then will they stand ready to answer the call and help turn the tide of student disinterest in science.

My workplace is The Franklin Institute Science Museum in Philadelphia, Pennsylvania. To help me in my research, I invited teachers to participate in direct, hands-on encounters with historical documents contained in a Case File related to the work of Marie Curie. One document in particular—Curie's 1903 published paper entitled Le Radium—became the centerpiece of my inquiry. How could this document inspire teachers to develop their understanding of the nature of science? Throughout the course of three cycles of planning, acting, and reflecting, I discovered that teachers responded positively and enthusiastically to the use of Le Radium as a resource for understanding the nature of science, especially at the Middle School level. I also discovered that interaction with primary source materials becomes most meaningful when accompanied by opportunities for reflection and dialogue. Ultimately, primary source materials from the history of science are most useful for the development of teacher understanding of the nature of science when teachers interpret primary sources for themselves and then share their findings through conversation. In other words, primary sources become most useful when used as tools for teachers to act as scientists do.

RESEARCH CONTEXT – RESPONDING TO A PROBLEM

"In learning science, **students need to understand that science reflects its history and is an ongoing, changing enterprise**. The standards for the history and nature of science recommend the use of history in school science programs to clarify different aspects of scientific inquiry, the human aspects of science." (National Committee on Science Education Standards, 1996)

The National K-12 Science Education Standards call for students to learn about the nature of science, yet few teachers have developed their own personal understanding of the scientific practice. Primary source documents from the history of science offer evidence of what it means to be a scientist, yet few collections of primary sources are accessible to teachers. Science Museums, like The Franklin Institute, can help teachers resolve this conflict.

The Franklin Institute is a Science Museum located in Philadelphia, Pennsylvania. The Institute's unique collection of primary source documents from the history of science and technology is not accessible to teachers or the general public. By enabling online access to these artifacts for educational use, the Institute can help teachers develop their capacity to meet the challenges of the National Science Education Standards.

In and of itself, the online presentation of primary sources will help teachers meet the challenge of understanding the nature of science. Beyond that, however, lies an investigation of impact. Through this investigative inquiry, the utility and impact of one artifact became evident.

RESEARCH QUESTIONS

How are primary source materials from the history of science useful for the development of teacher understanding of the nature of science?

If I provide hands-on access to primary source documents, how will teachers decide to use them for K-12 classroom learning?

If I provide a structured workshop experience with primary sources, how will teachers decide to use them for K-12 classroom learning?

If I provide online access to primary sources, how will teachers decide to use them for K-12 classroom learning?

LITERATURE REVIEW

Science: A Living Process

The nature of science exists at the crossroads of human curiosity, the physical world, the natural environment, and social interaction. Those who stand at that crossroads are the scientists and inventors—like Edison, Einstein, and Curie—who change the world. Their lives exist, in retrospect, as case studies of what it means to be an individual in service to science. But, those individuals never stand alone. They act as members of social networks that provide the infrastructure and opportunity for innovation. (Latour, 1987) They communicate and collaborate with peers as they think about how to make sense of the world and demonstrate that science is a living process of change.

Students: Losing Interest in Science

Science is a primary exploration of the dynamic interaction of human beings and the natural world, yet K-12 students learn science using secondary sources in isolation from social networks. This contradiction negatively impacts K-12 student interest in science. Students commonly experience scientific phenomena in isolation—from other phenomena and from other investigators—while using derivative sources of information. (Lederman, 2004) To counteract the negative impact of science education, students need an introduction to the dynamic social nature of a professional life in service to science.

The stories of science across the generations illustrate the nature of scientific life, yet science textbooks and resource materials present lifeless, sanitized accounts of dramatic events. (Lederman, 2004; Clough, 2004) The real unfiltered history of science can humanize the scientific process and address common student misconceptions. (Rudge, 2004; Matthews, 1994)

K-12 students can meet the inspirational role models who populate the history of science through examination of historical documents and work with primary source materials. Students can come to understand the challenges and rewards of the scientific and technological enterprise, and of the lives of the people who undertake it. (Schamel, 1998) For example, time spent considering the documentary evidence of Marie Curie's work within the international network of chemists—not to mention within her own household—suggests a vibrant life that was never boring. Through primary sources and prompted reflection upon the scientific achievements of the past, students can develop readiness for the transformative impact of today's research on tomorrow's world.

Documented use of primary sources in K-6 lacks depth. (Otten, 2000) Evidence exists, however, to suggest that the use of primary sources in grades 9-12 is burdened by a need to overcome false notions about the nature of science. (Tao, 2003) Intervention at the middle school level, therefore, is likely to be impactful.

Technology can be a particularly effective tool for achieving this educational goal; (Kelley, 2002; Becker, 2000a, 2000b; Brown, 2000) Museums cannot reasonably allow student examination of the real artifacts. Through the Web, students can work with primary sources without risk. Of course, students need structures to help them understand how to use the primary sources and how to draw conclusions from them. Research suggests that scaffolding models that have been successful in classroom learning can be applied to technology-supported learning environments. (McLoughlin, 1999; Lee, 2004; Bereiter, 1993)

Teachers: Social Actors in Science

The National Science Education Standards call for K-12 students to develop an understanding of the nature of science, so student use of primary sources is appropriate. (National Committee on Science Education Standards, 1996; Olson, 2000) However, few K-12 teachers are ready to answer this call. In many cases, teachers have a naïve understanding of professional science. (McComas, 2004; Abd, 2000) By providing access to the real artifacts of the history of science, teachers can be comfortably challenged to consider what it truly means to "do science." (McKinney, 2004) Only then can they begin to engage their students in meaningful ways with a conceptualization of the nature of science and to develop the intellectual curiosity that leads to deeper investigation of the world around them. (Otten, 1998)

Research has shown that this strategy of direct teacher engagement can lead to important professional growth. For example, the National Writing Project has documented its successful approaches to teacher development that derive from: a distinctive set of social practices that motivate teachers, make learning accessible, and build an ongoing professional community; and networks that organize and sustain relationships among these communities and produce new and revitalizing forms of support, commitment, and leadership. (Liberman, 2002) The Writing Project has shown that teachers become better writing teachers by becoming better writers. A strong parallel exists between the Writing Project's approaches—social practices, accessibility, professional community, and social networks—and the professional nature of science. As Latour (1987) suggests, the nature of science involves many social actors. As teachers become better actors in the scientific process, they become better science teachers.

Tested models from the National Writing Project, therefore, can be applied to professional development for science teachers. However, the venues and opportunities for teacher engagement with primary sources in science are limited. Science Museums offer a unique solution to the challenge.

Museums: Science Centers for Change

The research literature highlights the importance of addressing teachers' misconceptions about the nature of science before they can engage students. (Abd, 2000) Professional development of this kind is a very large challenge, one that museums can help accomplish. However, museum education efforts in this realm remain unfocused and undocumented.

Museums around the world hold a vast collection of primary source documents from the history of science and technology. The Franklin Institute Science Museum, for example, holds a collection of thousands of documentary case files related to pioneering individuals. (McMahon, 1977) Only rarely do museums make their documents accessible to the K-12 educational community, although museum digitization efforts are making them more available than ever. However, the purpose of digitization is not primarily educational. In a recent survey, museums ranked their primary goals for digitization. Serving students and teachers ranked third behind preservation and professional access. (IMLS, 2002) Despite the museum community's enthusiastic embrace of Schoen's "reflective practitioner" concept, many museum educators stop short of developing a vision for the use of primary sources in K-12 education. (Silverman, 2004)

As more of these primary source materials are digitized and made accessible online, the need increases for teachers to develop an understanding of their value and use for K-12 science education. Some museums have established models for helping teachers develop strategies for using primary sources in their classroom practice. (Allen, 2005; Bennett, 2000, 2002a, 2002b; Sayre, 2002; Schamel, 1998) However, these initiatives keep the teachers distanced from the real artifacts. A need remains to investigate the efficacy of direct, hands-on teacher use of primary sources. Teachers will develop their own understanding of the nature of science through work with primary sources. By developing online scaffolds for student use of those primary sources, teachers will then bring their students into direct encounters with the history of science.

CYCLE ONE REPORT SUMMARY

Three teachers read Marie Curie's papers and grounded their understanding of primary sources and the nature of science through a "white glove experience."

RESEARCH QUESTION & ACTION

If I provide hands-on access to primary source documents, how will teachers decide to use them for K-12 classroom learning?

I began to answer this question by inviting three in-service teachers to work as adjunct members of the Educational Technology Programs team while we were actively digitizing and presenting historical artifacts from the Museums' collections. I chose to invite teachers who were pre-disposed to working with the team so that there was a baseline of common prior knowledge about the Museum and its educational technology work.

Leigh is a veteran sixth-grade teacher at a public school in Philadelphia. She expresses a preference for teaching math and language arts, although enjoys teaching science and social studies as well. She works collaboratively with her two grade partners to share resources and provide common learning experiences for all of their students. Over the past decade, Leigh has attended numerous professional development workshops at The Franklin Institute on topics ranging from science inquiry to software applications. She had never, however, encountered any of the Institute's primary source materials.

Gail is also a veteran teacher at a public school in Philadelphia, where she teaches seventh grade. Her favorite subject is math and she has a deep expertise in math education. Her science teaching inevitably features a strong integration of math applications. For example, plant growth investigations in her science class are likely to include spreadsheets and graphing activities. Like Leigh, Gail has frequently attended professional development events at the Institute but had never worked with historical collections.

As teachers with the School District of Philadelphia, Leigh and Gail both use prescribed curricular materials. For Science, they use the Holt Short Course materials. The District provides a curricular sequence to accompany the materials, such that all teachers in the District are teaching the same way on the same day. Leigh has one computer in her classroom with a reliable broadband connection to the Internet and an attached data projector. Gail's school keeps a few projectors in the media center; she frequently borrows one to attach to the computer in her classroom so that she can project web-based resources for her students.

The third teacher, Anne, works with early-elementary school students at a private school just outside of the city limits. As the “computer teacher” in the Lower School, Anne works with the classroom teachers to identify opportunities to integrate technology with student learning. In many cases, these integrations occur in Science, perhaps because of Anne’s personal interest in Science. Anne’s school features technology access in the classroom as well as in the computer lab. Teachers select curricular materials for science from an approved list, giving them the flexibility to use materials that are most comfortable for them. Like Leigh and Gail, Anne had not previously worked directly with primary sources but she had attended workshops and seminars at the Institute.

Each teacher came individually to spend time with the primary sources. During the Cycle One timeframe, my team was working with three documentary files related to the work of Marie Curie, Elmer Sperry, and William Burroughs. I had intended to have each teacher work with a different file. When all three teachers independently expressed a strong interest in Curie, I quickly realized that it would be more productive to allow them to select the scientist who interested them most. In retrospect, the decision to have the three teachers work with the same file dramatically enhanced the quality of the Cycle One conversations and outcomes.

Each teacher came to the Institute on a weekday afternoon, after having spent the day teaching. My team and I welcomed her and we spent approximately thirty minutes talking about her existing understanding of primary sources and what we hoped she could add to the interpretation of the material. I gave her minimal instruction and encouraged her to be as creative as possible. We then gave her protective gloves and showed her to the artifact table where the Curie file awaited. We left her alone to spend time reading through the file. After about an hour or so, I re-joined her to talk briefly about the experience. I deliberately kept the individual conversations brief. In all three cases, the main theme of that quick conversation was about how “cool” the experience had been. I asked them to take some time in the days to come to think about potential classroom applications.

After all three teachers had worked independently with the Curie file, we set a date to meet as a group. Again, the teachers came to the Institute after conclusion of their school day. Leigh and Gail already knew each other well, but had only met Anne casually at Institute workshops in the past. However, common enthusiasm for the Curie file made them bond immediately as co-learners. Each was effusive, bursting with ideas and excitement about the experience. This was the point at which I realized that I had been wise to adjust the plan and allow them to work with the same file. If each had worked with a separate file, I would have been challenged to sustain the conversation. Since each had worked with Curie, we found ourselves still talking ninety minutes after we had begun. Anne, in particular, had been tremendously inspired by the experience. She had purchased and read a biography of Madame Curie and, as a result, was able to tell the others many interesting details of Curie's life and work. At one point in the conversation, Anne reached for the case file to show us the document—written in French—that included a chart for determining the half-life of a radioactive element. Neither Gail nor Leigh had noticed the chart.

EVIDENCE & ANALYSIS

Throughout Cycle One, I looked closely at how the three teachers responded to the primary sources. I used observational data as evidence of the effect of my intervention.

Observational Impressions of Engagement

	Leigh	Gail	Anne
Length of individual interaction with file	60 mins	55 mins	65 mins
Total Length of optional break(s) during interaction	5 mins	0 mins	0 mins
Perceived enthusiasm during first meeting	3	4	5
Perceived enthusiasm during final meeting	5	5	5
Quality of questions during first meeting	3	3	4
Quality of questions during final meeting	5	5	5
Quality of responses during first meeting	2	2	4
Quality of responses during final meeting	4	4	5

The final dialogue was a source of important data. For example, I asked the teachers to articulate their perceived value for primary sources. The table below charts the use of common terms. As the chart suggests, Anne was the most varied in her articulation about the value of primary sources. She did not, however, monopolize the conversation. All three spoke carefully and at length. Leigh and Gail, however, seemed to focus on a few key ideas while Anne seemed to have thought more broadly about the question. All three had the same direct experience, but Anne had opted to purchase and read a biography of Marie Curie after her first session and before our final meeting. This is a likely influence on the diversity of her expressions.

Commonality of Reflective Descriptors

	Leigh	Gail	Anne
personal / personalization	x	x	
authentic			x
direct interaction			x
brings stories to life			x
kids love it			x
fascination / fascinating		x	x
people	x	x	x
back in time	x		
role models			x
"you" / the second person	x	x	x
inspires	x		
interesting	x	x	x
real / reality / realistic	x	x	x

Collectively, Leigh, Gail, and Anne came to the conclusion that the Curie file (and any primary source like it) is unique in its ability to engage learners. For the reasons expressed in the chart above, the Curie file has numerous entrypoints. Anne came to the task with a longstanding enthusiasm for science; Gail had no such disposition, but did bring a high regard for European history. Leigh is a voracious reader of historical novels. They met in the Curie file and each found her place in the social network that was the science of radium.

After about forty minutes of talking about Curie and primary sources, I steered the conversation toward classroom applications. All three teachers were ready and eager to share their ideas. The chart below summarizes the range of applications.

Classroom Applications of the Curie File

	Leigh	Gail	Anne
Science			
Look at the properties of radioactive elements			x
Explore the concept of half-life			x
Social Studies			
Look at the unintended consequences of scientific discovery	x		
Consider the role of women in science.		x	x
Contextualize the file with the geopolitics of the time.			x
Math			
Use the charts of Curie's data for determining medians, means, modes.		x	
Transfer Curie's half-life data to a spreadsheet and generate graphs.		x	
Language Arts			
Use Curie's letters as models for student letter writing.	x		
Compare and contrast persuasive quality of the nomination letters. Create your own letter to add to the case.		x	
Look at the evolution of style between letters in the file and communication today.		x	

I measured success in Cycle One based upon whether or not I effectively engaged the teachers with the creative process of interpretation of primary source materials. Based upon both the quantity and quality of ideas that Leigh, Gail, and Anne generated, I am confident that it was a successful learning experience that deepened my expertise.

In particular, I reinforced my belief that primary source documents can generate enthusiasm for learning about the nature of science. Neither Leigh, nor Gail, nor Anne had any pre-existing experience with primary sources. All three were inspired to learn more—for themselves—about Marie Curie. All three were excited to introduce the primary sources to their students, via the Web.

For a cross-cycle data comparison, see "Cumulative Data Analysis," below.

For a complete report of Cycle One activity, please see: hale.pepperdine.edu/~kelinich/action_research

CYCLE TWO REPORT SUMMARY

Six teachers had "white glove" encounters with primary source documents. The Curie papers became the centerpiece of conversation.

RESEARCH QUESTION & ACTION

If I provide a structured workshop experience with primary sources, how will teachers decide to use them for K-12 classroom learning?

To answer this question, I planned and conducted a pilot workshop called "The Nature of Science Through Primary Sources." I invited seven teachers to attend. All seven expressed immediate enthusiasm, but one teacher had a scheduling conflict.

The participants have all attended professional development events at The Franklin Institute in the past, but none had ever encountered any of our primary source materials. All six teachers work in suburban, middle-class communities. All are veteran teachers with a wide range of K-8 classroom experience. Debbie and Sara both teach science for eighth graders in a rostered middle school environment. Lisa teaches grade one in a self-contained classroom. Kathy, Terry, and Dot are partners for the third grade.

I began the workshop by introducing the history of the Institute's Case Files and explaining my interest in seeing the primary sources be used to help in-service classroom teachers understand the nature of science. I deliberately provided significantly more context than I had in Cycle One. I wanted to establish a common level of understanding about the nature of primary sources. I introduced the teachers to Latour's concept of science as a network of social engagement. (None of the teachers had every heard of Latour.) I suggested that science teachers are scientists because of their important actions within the social network.

My introduction lasted fifteen minutes. I then asked the teachers to "pick a partner" and move to one of the three workstations that I had prepared in advance. At each workstation, I had placed two pairs of white gloves and one Case File. I instructed the teachers to wear the gloves while they were exploring the historical materials in order to protect the file. I asked them to skim all of the documents and then focus on a few that most intrigued them.

I had deliberately selected the Marie Curie Case File because of its centrality to my work in Cycle One. However, I wanted to ensure that the first encounter with the primary sources was extensively hands-on. Therefore, I knew that I needed to have no more than two teachers encountering a Case File at once. I placed the Thomas Edison Case File at the second workstation and the Guglielmo Marconi Case File at the third.

I rotated from station to station, listening in on the conversation and making myself available to answer questions. I deliberately avoided lingering too long at any one station. I had decided to allow thirty minutes for this important exploration phase.

At the conclusion of the explorations, I gathered all six teachers around the Curie File and asked the teachers at that workstation to talk about what they had discovered in the file. They immediately mentioned Le Radium and their fascination with its scientific content. Neither of the teachers knew French well enough to attempt a translation, but their knowledge of the universal language of mathematics enabled them to interpret the charts and equations. The teachers who had worked with the Marconi file expressed a similar frustration at the language barrier; some of the Marconi documents are written in Italian. All agreed, however, that there were sufficient English language documents to allow for a meaningful interpretation of the Case File.

Next, I guided the conversation so that the whole group used the Curie File as a case study for talking about classroom applications. Their ideas, detailed below, were thoughtful and creative. As in Cycle One, the teachers seemed to see the Case Files in a cross-curricular context. None of the teachers limited their consideration of the Case File to their science instruction. This view of using a scientist's work across subject areas parallels the idea of a science teacher acting within a larger social network of science.

After a short break, we gathered again at the main table for a discussion about the overall experience. I asked them to discuss the unique characteristics of primary source materials. I asked them to reflect upon the experience they had just had. Each seemed convinced that she had worked with the most interesting Case File. Finally, I asked each teacher to spend a few minutes reflecting and writing about the workshop experience. After ten minutes, I gathered their reflection sheets, concluded the workshop, and thanked them for their participation.

EVIDENCE & ANALYSIS

Throughout the workshop, I looked closely at how the teachers responded to the primary sources. As in Cycle One, I used a simple instrument to record qualitative impressions of the individual reactions. I also subjectively evaluated the quality of each teacher's responses during the meeting using a five-point scale. It was difficult to separate each teacher's enthusiasm and response, since they were working with a partner. I decided, therefore, to represent the observational assessment based upon each two-person team.

Observational Impressions of Engagement

	Debbie & Sara	Kathy & Lisa	Terry & Dot
Length of interaction with file	30 mins	30 mins	30 mins
Perceived enthusiasm during meeting	5	5	5
Quality of responses during meeting	5	4	4

These impressions, combined with the data directly below, suggest that the use of primary sources for science education may be most impactful at the middle school level. While Kathy, Lisa, Terry, and Dot were personally enthusiastic about the experience of working with primary sources, their connections to classroom learning were more metaphorical. Their strongest ideas connected the Case File to language arts, while Debbie and Sara offered more direct connections to science, math, and social studies. I interpret this difference as a practical function of middle school versus early elementary school.

Classroom Applications of the Curie File

	Sara & Debbie	Kathy & Lisa	Terry & Dot
Science			
Look at the applications of x-ray technologies		x	
Test the Case File for radioactivity using a Geiger Counter	x		
How does this science build on the work of other scientists?			x
Implications of Curie's work on medical science.	x		
Investigate the science of paper—the primary source material composition.	x		
Trace today's technology back to origins in primary sources.	x		
Social Studies			
Look at scientific timelines and chart the historical development curves.	x		
Consider the role of women in science.		x	
Contextualize the file with the geopolitics of the time.	x		
International nature of science. Not all inventions are American.			x
Role-play panel discussions with scientific competitors.	x		
Math			
Need to understand the metric system for science.	x		
Use half-life data and other numbers from the file for statistics exercises.	x		
Language Arts			
Use Curie's letters as models for student letter writing.		x	
Create an oral history of scientific events by interviewing grandparents about remembered science.			x
Create a resume for the scientist in today's format.	x		
Write a science fiction story inspired by the primary sources.	x		
Write a skit based on an exchange documented in the file.			x
Write a poem inspired by the primary sources.		x	

I looked across the written reflections and extracted key words. The following table presents the commonality of those words or phrases.

Commonality of Reflective Descriptors

	Debbie	Sara	Kathy	Lisa	Terry	Dot
authentic	x					
important		x		x		
exciting / excitement	x	x	x			x
passion		x		x	x	
awe / awesome	x	x				x
real			x			
connections / connect to life	x	x		x	x	
conversation			x			
humbled / humbling	x	x	x			
imagine / imagining / imagined	x	x		x	x	x
expectations / unexpected			x	x	x	

As in Cycle One, I measured success in Cycle Two based upon whether or not I effectively engaged the teachers with the creative process of interpretation of primary source materials. Based upon both the quantity and quality of ideas that the workshop participants generated, I am confident that this was a successful learning experience that deepened my expertise. In particular, I reinforced my belief that primary source documents can generate enthusiasm for learning about the nature of science.

By comparing the data from Cycles One and Two, I do not believe that there is a significant difference between unstructured and structured encounters with the primary source materials. In Cycle One, three teachers generated thirteen distinct descriptors; in Cycle Two, six teachers generated fourteen distinct descriptors. In Cycle One, three teachers generated ten distinct classroom applications; in Cycle Two, six teachers generated nineteen distinct classroom applications.

In Cycle Two, I did begin to detect a significant difference, however, between teachers of elementary grades and teachers of middle grades. The four elementary grade teachers conceived only eight of the nineteen classroom applications. The two middle school teachers suggested the other eleven. And, the eight applications suggested by the elementary teachers were only metaphorically connected to the science presented in the Case File. The middle school teachers were more ready and able to see a specific use for the primary source materials in science education.

During Cycle Two, I began to consider a phenomenon I am calling "white glove syndrome." I wanted teachers to reinforce my belief that encounters with primary source materials can help them develop their understanding of the nature of science. The unanimity of that reinforcement began to raise doubt. I wondered if the white glove experience was—in and of itself—so novel that objectivity became clouded. In both cycles, every teacher expressed enthusiasm that they could and would use primary source materials in classroom practice. Why were there no skeptics? Certainly, I believed that they all valued the experience, but their universal readiness to use the materials in classrooms seemed unrealistic. I decided to investigate "white glove syndrome" during Cycle Three.

For a cross-cycle data comparison, see "Cumulative Data Analysis," below.

For a complete report of Cycle Two activity, please see: hale.pepperdine.edu/~kelinich/action_research

CYCLE THREE REPORT SUMMARY

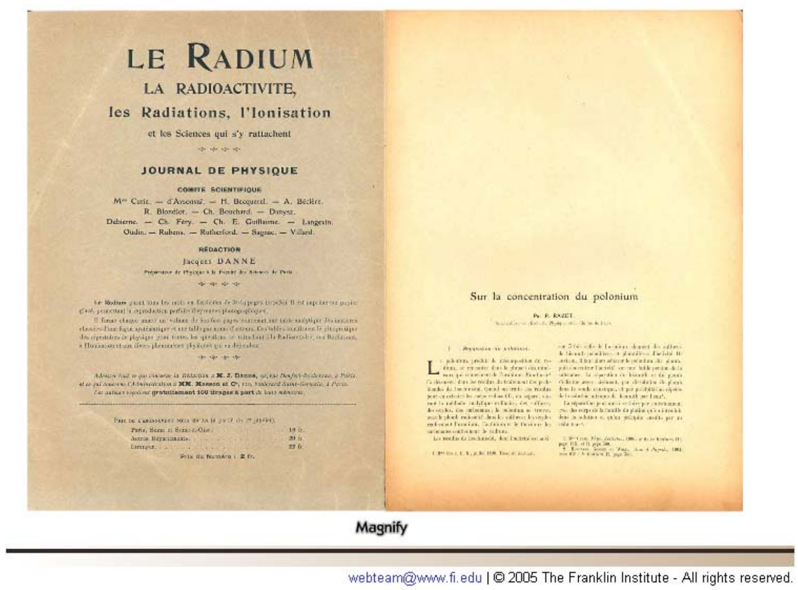
Fifteen teachers accessed the Curie papers through a technological interface and reported their impressions via an online survey.

RESEARCH QUESTION & ACTION

If I provide online access to primary sources, how will teachers decide to use them for K-12 classroom learning?

To answer this question and to extend my work from Cycles One and Two, I created an online presentation of the Marie Curie Case File. I then created a complementary online survey.

In the online presentation of the Case File, I included an interactive, Flash-based interface for access to Le Radium. Through the interface, the user can “turn the pages” of Le Radium by dragging the corner of a page across the screen and dropping it to reveal the next page. The interface mimics the real experience of turning the pages of a book. In this way, the participants in Cycle Three had a similar first encounter with Le Radium as the participants in Cycles One and Two, minus the white gloves. The online presentation was intended to neutralize the “white glove syndrome” that I perceived in Cycle Two. The online presentation also dramatically increases the potential audience for The Franklin Institute’s Case Files as a primary source collection for science education.



In the companion survey, I asked questions that were similar to the discussion topics from Cycles One and Two. I asked participants to reflect upon the experience of interacting with the Curie Case File. I asked for classroom applications. I asked for the likelihood that teachers would actually use the documents in classroom practice.

An underlying question for my research in Cycle Three relates to the phenomenon I am calling "white glove syndrome." As I analyzed my findings in Cycle Two, I began to suspect that the novelty of donning white gloves and paging through documents from a century ago was, in and of itself, so unique that objectivity became compromised. For Cycle Three, therefore, I neutralized the effect by using an online interface for interaction with the primary source materials rather than a physical encounter.

EVIDENCE & ANALYSIS

For Cycle Three, the online survey data provided evidence. Fifteen teachers submitted quality responses to the survey.

Classroom Applications of the Curie File

	Elem	MS	HS
Science			
Look at the related health and medical developments that followed Le Radium.	1		
Connect with the periodic table.		1	
Connect with chemistry classes.		2	
Use as a model for the method and process of scientific research.		1	1
Social Studies			
Consider the historical context of the science of radium.	1		
Consider the role of women in science and/or history.	3	1	1
Construct a timeline of things that were happening in the world at the time.	1		
Language Arts			
Write a biography of the scientist.	1	1	
Write a persuasive letter that could support the case.	1		
In French class, use Le Radium for a translation challenge.	1	1	

Commonality of Reflective Descriptors

	#
interesting	10
fascinating	2
exciting	1
authentic	1
amazing	1
intriguing	1
informative	1

Considering that the fifteen teachers interacted with the Case File in isolation and completed the surveys independently, the commonality of the use of "interesting" as a reflective descriptor is surprising. Ten of the fifteen participants used the word as part of their free-form response. Despite the fact that fifteen teachers responded, the range of descriptors used in the responses is significantly smaller in the online survey than in Cycles One and Two. This reinforces my belief that conversation and dialogue are essential for meaningful interpretation of primary source materials.

The survey respondents identified their grade level from a dropdown list of options: elementary, middle, or high school. Nine teachers selected elementary, four selected middle, and two selected high school. As in Cycle Two, I noticed that elementary teachers suggested a more metaphorical use of the Case File, while middle school teachers saw more direct application for science education. Of the six classroom applications for science, only one came from an elementary teacher. Of the twelve social studies and language arts applications, eight came from elementary teachers. While such a small testbed should not be used to make conclusive statements, I do believe that the data is suggesting that the Case Files are most appropriate for use in middle school classrooms. The middle grades are an ideal time to offer students access to primary source materials that offer portraits of the nature of scientific practice. Access, reflection, narrative, and dialogue can combine to provide consequential science learning experiences for middle school students. The result may be a turn in the tide of student science apathy.

The quantity and quality of classroom applications suggested during Cycle Three pales in comparison to Cycles One and Two. Likewise, the variety and creativity of reflective descriptors used by the teachers in Cycle Three also falls short of Cycles One and Two. “White glove syndrome,” therefore does seem to exist, although not in the way I suspected. My original hypothesis was that direct encounters with primary source materials help teachers understand the nature of science and their role in the social network. During Cycle Two, I began to suspect that the novelty of the experience was affecting objectivity. Cycle Three neutralized the syndrome but did not change the essential fact that teachers did see practical classroom application for primary source materials, especially in the middle grades. The passion with which they expressed their opinions was directly related to whether or not they had worn white gloves. “White glove syndrome,” therefore, is a transformative effect on teachers’ understanding of their role within the social network of science and their passion for engaging students with the true nature of scientific practice.

Cycle Three brought me full circle, back to my original premise. During Cycle Two, I began to suspect that I may have been "stacking the deck" in favor of my personal beliefs about the importance of primary source materials in science education through the white glove experience. Cycle Three helped me to understand that there is objectivity in my premise and that technology can both mitigate the novelty and dramatically increase access.

In my original premise, however, I had no foreshadowing of the important role of dialogue in the interpretation of the Case File. My data—while gathered from a small testbed—indicates that the quantity and quality of expression correlates to the amount of conversation and dialogue that occurred during the teachers' engagement with the Case File.

For a cross-cycle data comparison, see "Cumulative Data Analysis," below.

For a complete report of Cycle Three activity, please see: hale.pepperdine.edu/~kelinich/action_research

CUMULATIVE DATA ANALYSIS

Commonality of Reflective Descriptors

	TOTAL
interesting	13
imagine / imagination	5
exciting	5
connect / connections	4
"you" / the second person	3
real / reality / realistic	3
authentic	3
people	3
passion	3
awe / awesome	3
humbled / humbling	3
fascination / fascinating	3
expectations / unexpected	3
personal / personalization	2

Looking across all three cycles at the cumulative data, the most commonly used reflective descriptors are variations on imagination, excitement, and connections. These words express both the novelty of the white glove experience, (i.e. "excitement") and the readiness for practical application (i.e. "imagine the connections"). The frequency of the words awesome and/or humbling also suggests the nature of the hands-on encounter with Marie Curie's papers. Real and authentic are more indicative of professional thought processes.

Classroom Applications of the Curie File

	Elem	MS
Science		
62% of science ideas came from MS teachers.	5	8
Social Studies		
60% of social studies ideas came from Elem teachers.	9	6
Math		
100% of math ideas came from MS teachers.	0	4
Language Arts		
69% of language arts ideas came from Elem teachers.	9	4

Cumulatively, the data supports an interpretation that suggests greater readiness for use of historical primary sources by middle school teachers. While the elementary school teachers expressed comparable enthusiasm and excitement, their interpretations leaned toward metaphorical use of the Curie file as a context for cross-curricular learning, rather than as a tool for meeting the call for students to learn about the nature of science. Any impact at the elementary level, however, is significant. A progression from elementary considerations of the nature of scientific practice to a more literal interpretation in the middle grades will create readiness for scientific pursuit at the secondary and post-secondary levels.

Final Reflection

> "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.” (Weinberger, 2005)

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.

"[I]n order to understand you must predict, and in order to predict there must be **knowledge of how events connect**." (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.

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.

“People remember best what they feel the most.” (Schank, 1997)

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.

REFERENCES

Abd-El-Khalick, F., & Lederman, N.G. (2000). Improving science teachers' conceptions of the nature of science: A critical review of the literature. *International Journal of Science Education, 22:7*, 665-701.

Allen, N. (2005). Collaboration through the Colorado Digitization Project. *Web Wise Conference Proceedings 2005*. Retrieved March 2005 from: http://www.imls.gov/pubs/wwcp5.htm

Aune, B. (2002). Teaching Action Research via Distance [Electronic version]. *Journal of Technology and Teacher Education 10*(4), 461-479.

Becker, H.J. (2000a). Findings from the Teaching, Learning, and Computing survey: Is Larry Cuban right? *Education Policy Analysis Archives, 8(51)*. Retrieved November 2004, from http://epaa.asu.edu/epaa/v8n51/

Becker, H.J. (2000b). Pedagogical motivations for student computer use that lead to student engagement. *Educational Technology, September/October*. Retrieved November 2004, from http://www.crito.uci.edu/TLC/FINDINGS/spec_rpt_pedegogical/

Bennett, N.A., Sandore, B., Grunden, A.M., & Miller, P.L. (2000). Integration of Primary Resource Materials into Elementary School Curricula. *Proceedings of Museums and the Web 2000*. Pittsburgh, PA: Archives and Museum Informatics.

Bennett, N.A., Sandore, B., & Pianfetti, E. (2002a). Illinois Digital Cultural Heritage Community - Collaborative Interactions Among Libraries, Museums and Elementary Schools. *D-Lib Magazine, 8:1*. Retrieved November 2004, from http://www.dlib.org/dlib/january02/bennett/01bennett.html

Bennett, N., & Trofanenko, B. (2002b). *Digital Primary Source Materials in the Classroom*. Museums and the Web 2002. Retrieved November 2004, from http://www.archimuse.com/mw2002/papers/bennett/bennett.html

Bereiter, C., & Scardamalia, M. (1993). *Surpassing Ourselves - An Inquiry into the Nature & Implications of Expertise*. Peru, Illinois: Open Court Publishing Company.

Brown, J.S. (2000). Growing Up Digital: How the Web Changes Work, Education, and the Ways People Learn. *Change, April*, 11-20. Retrieved November 2004, from http://www.aahe.org/change/digital.pdf

Clough, M.P., & Olson, J.K. (2004). The Nature of Science - Always Part of the Story. *The Science Teacher, 71:9*, 28-31.

Institute of Museum and Library Services. (2002). *Status of Technology and Digitization in the Nation's Museums and Libraries. 2002 Report*. Washington, DC: IMLS.

Kelley, L., & Ringstaff, C. (2002). *The Learning Return on Our Educational Technology Investment: A Review of Findings from Research*. San Francisco: WestEd. Retrieved November 2004, from https://www.wested.org/cs/we/view/rs/619

Latour, B. (1987). *Science in Action: How to Follow Scientists and Engineers Through Society*. Cambridge, MA: Harvard University Press.

Lave, J., & Wenger, E. (1991) *Situated Learning: Legitimate Peripheral Participation*. Cambridge, UK: Cambridge University Press.

Lederman, N.G., & Lederman, J.S. (2004). Revising Instruction to Teach Nature of Science. *The Science Teacher, 71:9*, 36-39.

Lee, J.K., & Calandra, B. (2004). Can Embedded Annotations Help High-School Students Perform Problem Solving Tasks Using A Web-Based Historical Document? *Journal of Research on Technology in Education, 37:1*, 65-84.

Lieberman, A., & Wood, D. (2002). The National Writing Project. *Educational Leadership, 59:6*, 40-43.

McComas, W.F. (2004). Keys to Teaching the Nature of Science. *The Science Teacher, 71:9*, 24-27.

McKinney, D., & Michalovic, M. (2004). Teaching the Stories of Scientists and Their Discoveries. *The Science Teacher, 71:9,* 46-51.

McLoughlin, C. (1999). Scaffolding: Applications to learning in technology supported environments. *Proceedings of EDMEDIA 1999: World Conference on Educational Multimedia and Hypermedia & World Conference on Educational Telecommunications.*

McMahon, A.M., & Morris, S. (1977). *Technology in Industrial America*. Philadelphia: The Franklin Institute.

National Committee on Science Education Standards. (1996). *National Science Education Standards*. Washington, DC: National Research Council.

Olson, S., & Loucks-Horsley, S. (2000). *Inquiry and the National Science Education Standards: A Guide for Teaching and Learning*. Washington, DC: National Research Council.

Otten, E.H. (1998). *Using Primary Sources in the Primary Grades*. Washington, DC: U.S. Department of Education, Office of Educational Research and Improvement. Retrieved November 2004, from http://www.ericdigests.org/1999-1/primary.html

Rudge, D.W., & Howe, E.M. (2004). Incorporating History into the Science Classroom. *The Science Teacher, 71:9*, 52-57.

Sayre, S., & Wetterlund, K. (2002). *Pyramid Power: A Train-the-Trainer Model to Increase Teacher Usage of the ArtsConnectEd On-line Resource*. Museums and the Web 2002. Retrieved November 2004, from http://www.archimuse.com/mw2002/papers/sayre/sayre.html

Schamel, W.B. (1998). *Teaching with Documents: Using Primary Sources from the National Archives. Volume 2*. Washington, DC: National Archives and Records Administration.

Schank, R. (1990). *Tell Me A Story*. Evanston, IL: Northwestern University Press.

Schank, R. (1997). *Virtual Learning*. New York: McGraw-Hill.

Schank, R., & Abelson, R. (1977). *Scripts Plans Goals and Understanding*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Silverman, L., & O'Neill, M. (2004). Change and Complexity in the 21st-Century Museum. *Museum News, Nov/Dec*, 37-43.

Tao, P.K. (2003). Eliciting and Developing Junior Secondary Students' Understanding of the Nature of Science through a Peer Collaboration Instruction in Science Stories. *International Journal of Science Education, 25:2*, 147-72.

Weinberger, D. (2005). *Keynote Address: The New Shape of Knowledge.* National Educational Computing Conference. Retrieved June 30, 2005, from http://www.kidzonline.org/webcast/webcast.html?id=97

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