A Cognitive Apprenticeship for Science Literacy Based on Journalism

Joseph L. Polman, E. Wendy Saul, Alan Newman, Cathy Farrar, Nancy Singer, Eric Turley, Laura Pearce, Jennifer Hope, and Glenda McCarty
University of Missouri-St. Louis, One University Blvd., St. Louis, MO 63121
Email: polman@umsl.edu, saulw@umsl.edu, newmanalan@umsl.edu, farrarcat@gmail.com, singerna@umsl.edu, turleye@umsl.edu, pearcel@umsl.edu, jmghope@gmail.com, Glenda.McCarty@umsl.edu
Cynthia Graville, 202B Xavier Hall, Saint Louis University, St. Louis, Missouri 63108, cgravill@slu.edu

Abstract: The Science Literacy through Science Journalism (SciJourn) project aims to reframe the discussion of science literacy for citizenship, and explore how science journalism practices can be used to inform a cognitive apprenticeship that increases the science literacy of participants. This symposium features four paper presentations that report on the progress of the SciJourn project. We report on the development of standards for science content literacy based on the expertise exhibited by science journalists, assessment measures for science literacy, and assessment measures for engagement with science and technology. Finally, we describe our efforts aimed at apprenticing high-school aged learners into a science journalism community of practice spanning multiple schools and a community-based organization.

General Introduction

Members of the Learning Sciences community engaged in science education almost universally agree that educated citizens in democracies should develop a strong disciplinary understanding of science. To date, such efforts have focused primarily on practicing expert scientists as the yardstick for what it means to "know science", and in the last twenty years on "coming to know science" through learning environments inspired by apprenticeship. Knowing science has typically been seen as having conceptions consonant with those of expert scientists (e.g., diSessa 2006); "talking science" (Lemke, 1990); using reasoning about models (Lehrer & Schauble, 2006) and spatial representations (Schwartz, 2006) like scientists; and knowing how to carry out the authentic inquiry practices of scientists (e.g., Edelson & Reiser, 2006; Krajcik, et al., 1998; O'Neill & Polman, 2004). Coming to know science has frequently been encouraged by creating communities of practice carrying out science inquiry (e.g., Pea, 1993; Rosebery, Warren, & Conant, 1993; Ruopp, et al., 1993). Learning environments based on a community of practice model have taken inspiration from the research on traditional apprenticeship learning (e.g., Lave & Wenger, 1991), and the related concept of cognitive apprenticeships for learning in schools (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989).

These views of science knowing and learning have had a profoundly positive impact on education through direct reform and by being taken up and elaborated on in influential reports (e.g., Bransford, Brown, & Cocking, 2000; Michaels, Shouse, & Schweingruber, 2008) and standards for science education (e.g., National Research Council, 1996, 2000). The tendency to base science learning goals on analysis of the expertise of practicing scientists is understandable, but it has important limitations relative to a broader view of "science literacy." In the learning sciences and science education literature, "science literacy" is sometimes used synonymously with "practice-based science literacy" (O'Neill & Polman, 2004) focused on being able to carry out the first-hand inquiry practices of expert scientists. When this happens, the literacy in "science literacy" may become lost. But a "science literacy" which includes reading, making sense of, writing, and communicating about contemporary science topics as they relate to everyday life and policymaking is obviously important to life and citizenship.

The Science Literacy through Science Journalism project ("SciJourn"; Polman, Saul, Newman & Farrar, 2008) is a National Science Foundation research effort to better understand science literacy, and how science journalism practices can be used to inform a cognitive apprenticeship that increases the science literacy of participants (see http://www.scijourn.org). The project includes team members with backgrounds in the learning sciences, science education, literacy, science, and journalism; we draw on these diverse backgrounds to inform our understanding of both science literacy and learning. The project began in 2008, and we are in our second of four years of planned development and research. The 2008-09 academic year consisted of our alpha and beta tests of a journalism model for advancing science literacy in two high schools, simultaneous to the development of standards and discourse practices for science literacy, as well as transfer tasks and a survey of engagement. In summer of 2009, we conducted professional development with high school science and English teachers who are implementing various pilot instantiations of a journalism model in their classes during the 2009-2010 school year. At the same time, a group of science news reporters and editors was established at a youth development program at the Saint Louis Science Center (SLSC). The student reporters at schools and SLSC are publishing science news articles in an online and print newspaper we established called *The SciJourner* (http://www.scijourner.org). We are piloting our research instruments in 2009-2010 at school and SLSC sites. The project will conduct further teacher professional development in the summers of 2010 and 2011, and continue implementation studies.

There is an extensive and ongoing discussion in the broad field of science education over what constitutes science literacy and how it applies in schools, various other settings and life situations (e.g.; DeBoer, 2000; Eisenhart, et al., 1996; Hurd, 1998; Shamos, 1995; Turner, 2008). Nearly all definitions include aspects aimed at furthering civic, cultural and personal understanding (AAAS, 1989; Department of Education, n.d.; National Research Council, 1996; Trefil, 1996). For the purposes of the SciJourn project, we embrace the ideas embodied in terms such as "public understanding of science" (Bodmer, 1985); "public engagement with science and technology" (House of Lords, 2000); "scientific awareness" (Devlin, 1998; Shamos, 1995); "science for citizenship" (Fensham, 2004); etc. To whit, our goal is to educate students to:

- Think, talk, and write critically about what they read, hear and see in the media;
- Understand what counts as science;
- Recognize the risks and benefits of scientific discoveries and technologies;
- Become engaged with science and technology;
- Develop the confidence and skills to tackle science/technology issues independently;
- "Use" experts to answer questions and solve problems; and
- Understand the nature of science as an ongoing process of exploration with varying opinions or general consensus on theories, different stakeholders and levels of expertise, and norms for claims and evidence.

In this symposium, we feature four paper presentations that will report on the progress of the SciJourn project in developing standards and measures for science content literacy and engagement, as well as developing a set of practices and norms aimed at apprenticing high-school aged learners into science journalism as means to increase science literacy. Our discussants, who also serve as advisory board members for the project, will provide critical commentary and discuss the project's implications for the learning sciences. Bill Penuel (SRI International) will comment on the science education and measurement issues raised by the papers; Kevin Leander (Vanderbilt University) will comment on the literacy and discourse practices and issues.

Symposium Presentations

Toward an Articulation of Standards for Science Literacy Based on Journalism – Newman, Saul, Singer, Turley, Pearce, and Polman

Authors of the Alliance for Education/Carnegie Foundation (AAE) report entitled "Literacy Instruction in the Content Areas" call upon educators to rethink the ways in which we prepare students for college, work and citizenship. They—and we—are especially concerned with the ability of secondary students to read and write about academic content—specifically science content. To clarify salient features of science literacy we turned to a set of experts who work to communicate scientific content to a public audience—science journalists and editors. Drawing on qualitative data from interviews, read-alouds, and editorial comments experts provided to high school students and teachers writing science news articles, this paper begins to articulate prominent features that characterize scientifically literate individuals. Their comments, perspectives, and priorities are then used to articulate standards we seek to introduce to high school students and teachers. These standards are not an attempt to impose professional journalistic standards on novice student writers, but rather to help articulate practices of reading, writing and thinking that stand to improve students' science literacy. In the SciJourn project, we will be using these standards to inform a writing rubric as well as coding of discourse.

The five standards describe the importance of: 1) using multiple sources; 2) attending to issues of credibility and attribution of sources; 3) contextualizing science information; 4) making the reported science relevant to readers [high school students in our case]; and 5) presenting factually accurate, up-to-date information.

Just as science journalists report comments and ideas from multiple sources as they write and edit, we want students to write articles based on **multiple sources**, and recognize the importance of corroboration of sources when reading. Science journalists determine relevant and reliable sources with respect to a topic or issue and, when appropriate, consult various stakeholders. It is important for students to recognize that not all sources are equally trustworthy and even credible sources have perspectives and biases, which should be taken into account. They also need to understand and assess the limitations of scientific information.

Identifying **credible** sources and **attributing** them properly within stories is critical to building a journalist's and a scientifically literate individual's ethos. Science journalists name experts and organizations, qualifying their areas of expertise and noting any biases or potential conflicts of interest. Attribution prevents a science journalist from making blanket or false statements, especially by quoting credible sources. For students, determining whether a source is credible is crucial to science literary. When students name and evaluate their sources, they recognize that information comes from someone and some organization (that may have an agenda). Attribution provides a pathway for the reader to verify and expand on the story, develop new paths of inquiry and creates an historical record of circumstances, opinions and concepts at the moment the story is published.

Science journalists **contextualize** technical and scientific information for a broader audience by: identifying the import of the new scientific information; indicating the status (accepted or preliminary) of those findings, data, or ideas; weighing the importance of the findings; and providing sufficient details. For students, contextualization brings a greater scientific understanding to the story by helping the reader understand the significance of the scientific information, as well as the nature, limits, and risks of the discovery, technology or issue as it relates to science.

In science journalism it is imperative for the journalist to make the scientific information in the article **relevant to the readers**. Most often science journalists accomplish this by "translating" technical language and concepts in easier-to-understand words, analogies or images. We have found that linking scientific findings to local concerns or considering new applications of the discovery/technology helps the student reporter produce stories that are relevant to their reader. Students, then, ought to consider their audience and the audience's questions in writing about a scientific discovery, new technology or pertinent scientific issue.

Finally, a science journalist presents **factually accurate** information showing an understanding of the content and explaining scientific ideas and experimental processes. Precise language is employed and scientific terms are used appropriately. Students learning to think like expert journalists need to pay attention to details, ensuring the science is right and names, figures, and dates are correct. Students should draw on the latest scientific information in their reporting. This encourages students to look at publication/announcement dates as a means to determine timeliness.

Studying the literacy practices of experts in the field of science journalism provides a language and framework for how educators might use science journalism as a means engage students with scientific content. Fusing "science content" and "science journalism" places some traditional practices of science education and general journalism in the background, while foregrounding new ways of engaging students with literacy practices and science content that is current and developing.

Designing Transfer Tasks to Measure Science Literacy–Farrar, Polman, Saul, Newman

This discussion focuses on the development of tasks to measure changes in learners' scientific literacy as defined above. Unlike some other attempts at measuring science literacy, our approach is premised on the notion that science literacy is not limited to an accumulation of facts and concepts, but includes the ability to critically consume and produce science information in order to make decisions personally, socially, and politically. While there are a multitude of assessments designed to assess conceptual understandings in science, a measure that captures such a view of scientific literacy is needed.

Research on scientific literacy stems from three broad interests; social scientists and public opinion researchers, sociologists and science educators (Laugksch, 2000). Although many of these interests agree on a multidimensional nature of scientific literacy (conceptual knowledge, contextualization, and skills) rarely is scientific literacy measured in its entirety (Laugksch & Spargo, 1996). By focusing on smaller components of scientific literacy separately, an incomplete picture of student scientific literacy emerges. Few composite measures of scientific literacy have been published (Laugksch, 2000).

As part of the Science Literacy through Science Journalism project, we have strived to develop a series of tasks that will measure scientific literacy skills that enable them to be critical consumers and producers of science information. These tasks stem from the broader goals of educating students to think, talk, and write critically about what they read, hear and see in the media; understand what counts as science; recognize the risks and benefits of scientific discoveries and technologies; develop the confidence and skills to tackle science/technology issues independently; "use" experts to answer questions and solve problems; and understand the nature of science as an ongoing process of exploration with varying opinions or general consensus on theories, different stakeholders and levels of expertise, and norms for claims and evidence. Korpan, Bisanz, and

Bisanz (1997) posit that one of the hallmarks of scientific literacy is "the ability to make effective requests for information or to ask good questions about scientific research" (p. 518). We contend that in order to do this, a student must be able to do the following: evaluate expertise; identify appropriate questions for experts; select and use multiple credible sources to gain more information; determine coherence between text and image or graphic; employ effective search strategies for more information.

Research on critically evaluating articles about science is limited (Mallow, 1991). Korpan et al (1997) created a series of tasks to explore the ways in which students evaluated science information in the form of news articles, where students were presented with a science article and asked a series of questions such as "what additional pieces of information would you like to have about the researcher's report to decide whether the conclusion is correct?" (Korpan et. al., 1994). It is in this vein that we have developed the transfer tasks. These tasks were developed in the fall and spring of 2008-9. In the fall of 2009, several teachers are piloting the tasks in their classrooms. The completed tasks will be used to inform the revision process. Full implementation will begin in the fall of 2010 and continue through June of 2012.

Currently there are seven tasks, each of which provide opportunity to gain insight on multiple aspects of a student's scientific literacy. Examples of the tasks:

- Reading informational text such as a brochure on high blood pressure or the flu; followed by prompts such as "What are your risks associated with this?", "Who else would you consult about this to learn more?"; "Why would you contact that individual?", and "What questions would you want them to answer?".
- Creating interview questions from a news article in conjunction with identifying search terms and additional sources.
- Evaluating text and graphics for factual accuracy; suggesting other experts or sources that could help determine if it is accurate.

At this point in development (Fall 2009), our team is creating the coding scheme based on the standards and frameworks for science literacy described above. In the symposium, we will present our coding scheme, results of our pilot implementation in 2009-2010, and describe any revisions to the instruments and coding intended in our research during the 2011-2012 academic year.

In order to comprehensively assess scientific literacy in students, a measure must assess conceptual knowledge, contextualization of information, and the skills necessary to consume and produce scientific information. With the development of these tasks, we aim to provide a more nuanced picture of student scientific literacy, to inform both educational practice and assessment in science classrooms.

Reframing and Measuring Engagement with Science and Technology – Hope, McCarty, and Polman

This paper focuses on the fourth goal of the Science Literacy through Science Journalism (SciJourn) project: educating students to become engaged with science and technology, not just in school but throughout their lives. We believe that the Science, Technology, Engineering and Mathematics (STEM) fields need to follow a path similar to that blazed by Rosenzweig and Thelen (1998) who reframed the discussion of how educated citizens *understood* history by conducting research on how citizens in the United States were actually *engaged with* the past. We see this as aligned with the framing of science literacy as "public understanding of and engagement with science and technology."

Many recent studies of science education interventions focus mainly on "engagement" as indicated by student achievement in the science classroom (Lichtenstein et. al, 2008; Markowitz, 2004; Martin, 2005). Fewer studies of organized education programs consider science engagement related to students' personal lives. While still focused on the outcome of academic achievement, Lau and Roeser (2002) posited that engagement involves multiple facets, including positive feelings and focused attention during the learning activity as well as amount of time spent on school assignments or other science-related tasks during non-school hours. Barton and colleagues (Basu & Barton, 2007; Furman and Barton, 2006) studied urban minority youth in after-school programs, finding that connecting science experiences with students' own future plans, in a social learning environment that supported student agency, led to what they considered a sustained interest in science and to shifts in identity. Ethnographic research from the Learning in Informal and Formal Environments Center (e.g., Barron, 2006; Zimmerman & Bell (2007), has shown the myriad ways that youth engage with science and technology activities in the out of school hours, including personally meaningful experiences at home that school people seldom know about.

Although research shows the public does engage with science and technology, the public's engagement with free-choice science learning is poorly understood (Falk, et al, 2007) and has not been fully researched (Falk, et.al, 2007; Korpan, et al, 1997). Data gathered about books being read, television programs watched, games played, and Internet searching, could lead to insights of how people learn science and influence practices in schools (Korpan, et al, 1997).

We believe that a coherent concept of engagement, which captures what is meaningful about the term as it is generally used, includes three facets: **Behavior**, or actual involvement with science and technology ideas and tools; **Interest**, or openness to and stance toward the science and technology in the moment; and **Identity**, or ways that the science and technology connects to people's identity affiliations, in the past, present, and future. These facets have been operationalized in a small research study that will result in a written survey intended for broader use.

Following Fowler's (2009) recommendations, the Youth Exploring Science and Technology (YEST) survey was developed based on previous surveys and the literature, utilizing interviews and verbal think-aloud protocols to refine the survey instrument with a subset of the project participant population, and then administered the pilot survey to a broad audience. A select group of seven teen participants in the Saint Louis Science Center's youth development program contributed to the development of the survey in summer 2009; case studies of their engagement with science and technology were constructed based on observations, interviews, and analysis of drafts and final science news articles created by these youth. In addition to this group, several hundred students of 13 teachers from 10 schools participating in the wider research project were administered surveys in Fall 2009 (prior to the introduction of science journalism related activities), and will be administered parallel surveys at the end of the school year.

At this time, the survey consists of five sections: demographics/background (8 questions), science behaviors (10 questions), technology behaviors (20questions), interest in science and technology inside and outside school (12 questions), future (5 questions). Questions relating to identity are interspersed throughout. By June 2010, at the time of the paper presentation, pilot survey results will be collected, analyzed, and available for inclusion in the presentation. The revised survey structure and items will be presented as well.

Preliminary results of case studies from Summer 2009 give a sense of how engagement may shift through youth participation in the sort of science journalism practices taking place in SciJourn. Max (all names are pseudonyms) was in the summer before his 12^{th} grade, and the survey revealed he was highly engaged in reading and consuming technology-oriented media, although he was not otherwise a big reader. He had strong interests in science and technology, and connected his identity in the present and future with potential computer technology or science careers. Although he did not have much initial interest in researching and writing science news stories, and did not see himself as a writer at all, he responded to the challenges put before him, and produced stories on the program, the health risks of tattoos, and electric cars. Thus, he expanded his engagement in communicating with others about science and technology, and appears to have begun to refine his identity. Khadijah was also in the summer before 12^{th} grade, and her identity was tied more to her general interests in reading, writing, and arguing, and her plans for becoming a lawyer and advocate for youth in foster care. Her engagement in science news reporting allowed her to connect her identity as a writer with science, especially social science concerns, such as the school dropout rate for children in foster care, and how social networking affects the life of teens.

In order to understand the means by which for America's youth connect with learning opportunities, science educators should better understand how youth are engaged with science and technology in their daily lives. The Youth Engagement with Science and Technology survey described in this paper stands to provide a more valid measure of engagement than is presently available. With this tool, programs can pay attention to how individuals with different engagement profiles learn, and can measure the impacts of in-school and out-of-school programs on engagement.

Building an Apprenticeship Community of Practice for Science Journalism – Polman, Saul, Newman, Pearce, and Graville

Within the SciJourn project we are in the process of building a distributed community of practice centered on apprenticing students and teachers into the authentic production of a science newspaper we call *The SciJourner* (http://www.scijourner.org), with the support of a diverse university team. Since our goals involve fostering and driving learning through the critical consumption and production of science news rather than maximizing readership or ad sales, the community of practice can be seen as a cognitive apprenticeship (Brown, Collins, & Duguid, 1989; Collins, Brown, & Newman, 1989) for science learning that is a hybrid of traditional journalism.

Wenger's (1998) research revealed the importance of brokering and boundary objects to the transfer and transformation of practices across communities of practice. As described above, the SciJourn project is taking practices from traditional science journalism, and moving them into a distributed learning environment that encompasses teachers' classes in multiple schools as well as a youth program at the Saint Louis Science Center. As a Ph.D. chemist who worked over 20 years as a science journalist and managing editor, Alan Newman has been our primary agent **brokering** journalistic practices to our nascent community. In addition, we have a diverse set of additional science journalism advisors who provide input. Other members of our project team broker practices from literacy education, journalism education, and science education in formal and informal learning environments. Wenger's concept of **boundary objects** refers to artifacts, documents, terms, and concepts around which communities of practice can organize their interactions. In this paper presentation, we will describe the brokering and boundary objects that have emerged thus far in our project.

The development of this community thus far has been as follows. In 2008-09, the team of university-based science educators, literacy educators, researchers and journalists began clarifying the links between science journalism and science literacy through literature review and the research with professional journalists described above. At the same time, we implemented what we refer to as "alpha" and "beta" models of a science journalism curriculum and news writing units in two schools, including the classes of one of our PIs (Farrar). We shared results of this with our advisory board, a key journalism advisor, our external evaluator, and our partners at SLSC at two advisory board meetings, to inform our plans for expanding our implementation and research. In the summer of 2009, 14 teachers from 10 high schools participated in the 3-week SciJourn professional development under the direction of Wendy Saul and with the help of Newman and Turley. The teachers also wrote news stories and produced a print edition of *The SciJourner* with Newman as editor, and also co-developed pilot mini-lessons and science journalism units with us. Also during summer 2009, 8 teenage youth from the SLSC participated in the project during their summer 5-week youth development and work program, learning to research and write science news stories, and producing three print editions of *The SciJourner* with Newman acting as managing editor, and the support of three SLSC staff including one professional novelist. During the 2009-2010 school year, the teachers are implementing their own and others' lessons and units and participating in the research. At the same time the development team, which includes Saul, Newman and Pearce, visits classes with the express purpose of refining lessons so they can be used in the summer of 2010 and 2011 as models that can be used for debriefing and discussion. SciJourn curricula is being piloted in biology, environmental science, physics, physical science, English, research, applied biology and chemistry, chemistry, and advanced biology classes. The school districts vary by location and SES (rural, urban, suburban and urban parochial). Although a goal was to implement various aspects of the project during the school year so that teacher efforts culminated in students writing articles for *The SciJourner*, several of the teachers are focusing more heavily on reading than writing. Teachers from the 2009 cohort will meet several times as a group with the SciJourn team during the year. Individual meetings with the teacher group are also held regularly to focus on their activities, concerns and to debrief lessons.

Key boundary objects that have emerged thus far in the project include: 1) the genre of science news articles (beginning with a lede and moving in an "inverted triangle" structure from more important to less important information) vs. the traditional school-based "5-paragraph essay"; 2) story pitches delivered in a "fishbowl" activity; and 3) the related notions of sources, credibility and attribution. So far in schools and in the youth program, teachers and facilitators found that they had to actively work to overcome students' prior experiences with the 5-paragraph essay structure as normative for all non-fiction writing in schools. The SciJourn team and teachers have developed ways of revealing and learning the genre, and it has become a boundary object for moving students out of "writing as usual in school." Journalists traditionally pitch story ideas to editors and groups before being given the go-ahead on assignments, and we have refined a model for pitches that combines this practice from the journalism community with a fishbowl structure borrowed from schooling. In our hybrid, students do some research on story ideas, then one pitches their story to an adult editor as they both sit in the middle of a circle. The editor asks questions, makes suggestions, and helps the student reporter refine their idea, and the people around the edges of the circle also chime in. At the end of the pitch, the editor and group decide whether to move forward on that story. Afterward, the student who made the pitch moves to the editor's chair, and another student pitches. In this way, learners experience modeling and coaching (Collins, Brown, and Newman, 1989) and then begin to appropriate ideas even further as they are asked to model the ways of thinking exhibited by editors. Routinely, students quickly begin asking peers what makes their story interesting to readers (contextualization), what or who their potential sources are, etc. Finally, the journalistic notions of using multiple sources, concern with the credibility or reliability of sources, and attributing sources are all becoming part of the vernacular of science classes in a way that they were not previously. The science teachers in our project have been receptive to these terms and the thinking behind them, and they are implementing them in reading-focused activities in school that take less time than having students write and research new stories.

Several additional instances of people brokering practices and their possible variations within this nascent community of practice are worth noting. The persona and manner that Newman takes on with students both in schools and in the youth program, as a professional editor focused on ideas and concepts in the draft and final products, makes for different feedback norms than most students have previously experienced. In several cases, students have been surprised at the amount of markup provided by Newman in electronic documents returned by him using Microsoft Word's Track Changes. Early on, we began looking for ways to introduce changed attitudes toward extensive feedback as productive rather than merely providing negative judgment, as many traditional school papers with "a lot of red" would signify. We have also pushed the notion that "science and technology can be connected to anything" in order to welcome individual learners' interests and story ideas, but we know that school curricular requirements as well as the knowledge of facilitators will sometimes limit the possibilities for transforming personal topic interests (e.g., tattoos, social networking) into science news stories. Teachers with different backgrounds and in different subject areas (biology, chemistry, environmental science, or English) bring varying assets and vary in what sorts of science news relates to their learning goals. Thus, we will monitor how different classes, contexts, and facilitators deal differentially with welcoming and transforming student ideas into stories.

Conclusion

This symposium will present a reframing of the notion of science literacy, exploring the projects' progress at fostering a scientifically literate citizenry through a focus on the practices and ways of thinking developed by journalists. Implications for research on learning and educational practice will be discussed.

References

American Association for the Advancement of Science. (1989) *Science for all Americans*. Washington, D.C.

Barron, B. (2006). Interest and self-sustained learning as catalysts of development: A learning ecology perspective. *Human Development, 49*, 193-224.

Basu, S. J., and Barton, A. C. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching*, *44*(3), 466-489.

Bodmer, W. (1985). *The public understanding of science*. Royal Society: London.

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated cognition and the culture of learning. *Educational Researcher*(January-February), 32-42.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the craft of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction: Essays in honor of Robert Glaser* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationships to science education reform. *Journal of Research in Science Teaching 37*(6), 582–601.

Department of Education, Institute of Education Sciences. http://nces.ed.gov/programs/coe/glossary/s.asp

Devlin, K. (1998). Rather than scientific literacy, colleges should teach scientific awareness. *American Journal of Physics 66*(7), 559–560.

diSessa, A. A. (2006). A history of conceptual change research: Threads and fault lines. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Edelson, D. C., & Reiser, B. J (2006). Making authentic practices accessible to learners: Design challenges and strategies. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Eisenhart, M., Finkel, E., Marion, S. F. (1996). Creating the conditions for scientific literacy: A Re-Examination. *American Educational Research Journal 33*(2), 261–295.

Falk, J.H., Storksdieck, M., & Dierking, L.D. (2007). Investigating public science interest and understanding: Evidence for the importance of free-choice learning. *Public Understanding of Science, 16*, 455-469.

Fensham, P. J. (2004). Increasing the Relevance of Science and Technology Education for All Students in the 21st Century. *Science Education International 15*(1), 7–26.

Fowler, F.J. (2009). *Survey research methods*. Thousand Oaks, California: SAGE Publications, Inc.

Furman, M., and Barton, A. C. (2006). Capturing urban student voices in the creation of a science mini-documentary. *Journal of Research in Science Teaching, 43*(7), 667-694.

House of Lords (2000). *Science and society*. Her Majesty's Stationary Office: London.

Hurd, P. D. (1998). Scientific literacy: New minds for a changing world. *Science Education 82*(3), 407–416.

Korpan, C. A., Bisanz, G. L., & Bisanz, J. (1997). Assessing literacy in science: Evaluation of scientific news briefs. *Science Education*, *81*(5), 515-532.

Korpan, C.A., Bisanz, G.L., Boehme, C., & Lynch, M.A. (1997). What did you learn outside of school today? Using structured interviews to document home and community activities related to science and technology. *Science Education, 81,* 651-662.

Korpan, C. A., Bisanz, G. L., Dukewich, T., Robinson, K. M., Bisanz, J., Thibodeau, M., Hubbard, K. E., & Leighton, J. P. (1994). *Assessing scientific literacy: A taxonomy for classifying questions and knowledge about scientific research* (Tech. Rep. No. 94-1). Edmonton, AB, Canada: University of Alberta, Center for Research in Child Development.

Krajcik, J., et al. (1998). Inquiry in project-based science classrooms: Initial attempts by middle school students. *The Journal of the Learning Sciences, 7*(3 & 4), 313-350.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge: Cambridge University Press.

Lau, S., & Roeser, R. W. (2002). Cognitive abilities and motivational processes in high school students' situational engagement and achievement in science. *Educational Assessment*, *8*(2), 139-162.

Laugksch, R. (2000). Scientific literacy: A conceptual overview. *Science Education*, *84*(*1*), 71-94.

Laugksch, R. & Spargo, P. (1996). Development of a pool of scientific literacy test-items based on selected AAAS literacy goals. *Science Education, 80*(2), 121-143

Lehrer, R., & Schauble, L. (2006). Cultivating model-based reasoning in science education. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Lemke, J. L. (1990). *Talking science: Language, learning, and values*. Norwood, NJ: Ablex.

Lichtenstein, M. J., Owen, S. V., Blalock, C. L., Liu, Y., Ramirez, K. A., Pruski, L. A., et al. (2008). Psychometric reevaluation of the scientific attitude inventory-revised (SAI-II). *Journal of Research in Science Teaching*, *45*(5), 600-616.

Mallow, J. V. (1991). Reading science. *Journal of Reading, 34*, 324-338.

Markowitz, D. G. (2004). Evaluation of the long-term impact of a university high school summer science program on students' interest and perceived abilities in science. *Journal of Science Education and Technology*, *13*(3).

Martin, A. J. (2005). Exploring the effects of a youth enrichment program on academic motivation and engagement. *Social Psychology of Education*, *8*(2), 179-206.

Micheals, S., Shouse, A. W., & Schweingruber, H. A. (2008). *Ready, set, science! Putting research to work in K-8 science classrooms*. Washington, DC: National Academies Press.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

National Research Council. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. Washington, DC: National Academy Press.

Norris, S. P. (1995). Learning to live with scientific expertise: Towards a theory of intellectual communalism for guiding science teaching. *Science Education*, *79*, 201-217.

O'Neill, D. K., & Polman, J. L. (2004). Why educate "little scientists?" Examining the potential of practice-based scientific literacy. *Journal of Research in Science Teaching, 41*(3), 234-266.

Pea, R. D. (1993). The collaborative visualization project. *Communications of the ACM, 36*(5), 60-63.

Polman, J. L., Saul, E. W., Newman, A., and Farrar, C. (2008). Science literacy through science journalism. Proposal to the National Science Foundation Discovery Research K12 program. Unpublished report.

Rosebery, A. S., Warren, B., & Conant, F. R. (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences, 2*(1), 61-94.

Rosenzweig, R., and Thelen, D. (1998). *The presence of the past: Popular uses of history in American life*. New York: Columbia University Press.

Ruopp, R., Gal, S., Drayton, B., & Pfister, M. (Ed.). (1993). *LabNet: Toward a community of practice*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schwartz, D. L., & Heiser, J (2006). Spatial representations and imagery in learning. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences*. Cambridge, UK: Cambridge University Press.

Shamos, M. (1995). *The myth of scientific literacy*. Rutgers University Press: New Brunswick, N.J.

Trefil, J. (1996). *Scientific literacy*. Annals of the New York Academy of Sciences 775, 543–550.

Turner, S. (2008). School science and its controversies: or whatever happened to science literacy? *Public Understanding of Science 17*, 55–72.

Zimmerman, H. T. & Bell, P. (2007, April). Seeing, doing, and describing everyday science: Mapping images of science across school, community, and home boundaries. Paper presented at National Association of Research in Science Teaching (NARST), New Orleans, LA.

Acknowledgments

We are grateful for the support of the National Science Foundation, under Grant No. DRL-0822354, which has made this research possible. The opinions expressed are solely the responsibility of the authors.