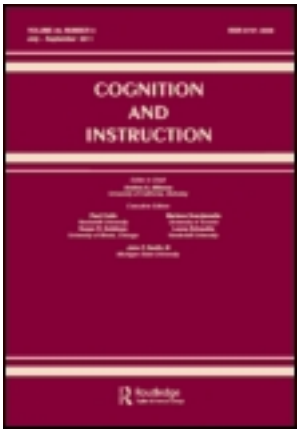

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Managing, Understanding, Applying, and Creating Knowledge in the Information Age: Next-Generation Challenges and Opportunities

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Managing, Understanding, Applying, and Creating Knowledge in the Information Age: Next-Generation Challenges and Opportunities

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New media, new knowledge practices, and concepts point to the need for greater understanding of cognitive processes underlying knowledge acquisition and generation in open informational worlds. The authors of the articles in this special issue address cognitive and instructional challenges surrounding multiple document comprehension—a prerequisite of digital literacy and knowledge work in the information age. In this article, we raise issues of conceptual clarity regarding constructs such as *source* and *document*, and discuss work in disciplinary literacy and knowledge-building communities to clarify uses of information resources to support knowledge creation. The discussion aims to (a) provide insights into the cognitive and social practices needed for students to manage, understand, apply, and create knowledge and (b) suggest research directions to advance these goals.

The articles in this special issue address cognitive and instructional challenges surrounding multiple document comprehension—a prerequisite of digital literacy and knowledge work in the information age. Stadtler, Scharrer, Brummernhenrich, and Bromme (this issue) provide an excellent overview of the field and of the articles in this special issue. The collection as a whole contributes to our understanding of how to prepare students for managing, making sense of, and using the vast sources of information that are literally at their fingertips. In this article we focus on issues and agendas for future research.

The need to keep abreast of advancing knowledge in the information age requires processing large amounts of information quickly. As if that were not challenge enough, governments everywhere are calling for education for knowledge creation. The following G8 summit (2006) statement reflects this need: "new ideas are essential to the development of human capital and

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are key engines of economic growth, drivers of market productivity, and sources of cohesion for all nations." The Organization for Economic Cooperation and Development (2010) refers to "innovation-driven growth" and Homer-Dixon (2000, 2006) argues that new knowledge is needed to deal with urgent and increasingly complex problems (e.g., health, environment, resources, crime). The corresponding cognition and instruction challenge is not simply understanding and integrating vast sources of information but making productive use of those resources to create new knowledge (David & Foray, 2003; Fujimura, 1992; von Krogh, Nonaka, & Nishiguchi, 1999). We return to these issues at the end of this article. First we explore unresolved issues and set the stage for an agenda for future research.

UNDERSTANDING, EVALUATING, AND INTEGRATING INFORMATION SOURCES

The articles in this issue echo the widely acknowledged reality that the information age brings with it the need for citizens to create coherence from multiple sources of information that are as likely to contain conflicting as complementary information (cf. Britt, Rouet, & Braasch, 2013; Goldman, in press; Goldman, Lawless, & Manning, 2013; Goldman et al., 2012c; Leu, Leu, & Coiro, 2004; Leu et al., 2009). Common across the articles is a concern with topics for which there is a scientific knowledge base but about which there is controversy in the public domain, making it highly likely that the lay public will encounter conflicting points of view on these topics. Questions addressed across the set of articles in this special issue include whether conflicts are noticed, what circumstances increase the likelihood of readers noticing those conflicts, and what if anything is done to resolve such conflicts.

Several consistent themes are reflected in the findings: Detecting conflicting information is anything but a certainty (Jucks & Paus, this issue; Maier & Richter, this issue; Stadtler et al., this issue; Strømsø, Bråten, Britt, & Ferguson, this issue). Conflicting information increases readers' attention to metadata about the information (e.g., who, where, when, or why it was created; Strømsø et al., this issue), especially if the conflicts occur across different sources as compared to being found in a single-authored source (Stadtler et al., this issue) or if opposing positions are interleaved versus massed (Maier & Richter, this issue). Also, readers are more likely to accept information attributed to a more knowledgeable spokesperson (Stadtler et al., this issue; Macedo-Rouet, Braasch, Britt, & Rouet, this issue). One of the articles (Jucks & Paus, this issue) reports on "online" efforts to resolve apparent conflicts between information sources through discussion, which is reminiscent of efforts to establish common ground in conversation (e.g., Clark, 1996). There is also some indication that when conflicts in information or differences in expertise are noted, participants exhibit a range of strategies for resolving the conflicts (Strømsø et al., this issue). This is consistent with previous findings on conflicting data and explanations (e.g., Chinn & Brewer, 1998; Goldman, Braasch, Wiley, Graesser, & Brodowinska, 2012b). However, despite choosing spokespersons who could be expected to have some expertise on the topic, 9- and 10-year-olds tended to justify their choices based on the content attributed to the spokesperson rather than on the credentials of the individual per se. This reliance on "information value" of a source document is consistent with previous findings related to judgments about the reliability of websites (Braasch et al., 2009; Goldman et al., 2012b; Wiley et al., 2009).

The findings in these special issue articles provide an account of efforts on the part of both undergraduates and young adolescents to understand, evaluate, and integrate information across

multiple documents presented to them. We anticipate that new perspectives will emerge as schools become more engaged with knowledge building, problem-based learning, project-based learning, and a variety of inquiry-based pedagogies. In these instructional contexts the educational challenges surrounding multiple document comprehension become increasingly focused on texts discovered by students through Internet searches, with those searches motivated by an effort to find answers to questions they generated. Analyses of work in knowledge-building communities show that students are capable of generating substantial inquiry threads that include summaries of experiments, interviews with experts, reading of multiple documents, and so forth), along with citations to each other and to authoritative information resources (Scardamalia & Bereiter, 2006; Zhang, Scardamalia, Reeve, & Messina, 2009). The activity is quite different from traditional school reading and extends beyond processes investigated in the articles in this special issue on multiple document comprehension and resolution of inconsistencies in those documents.

The digital literacies required for sustained idea improvement in knowledge building communities additionally involve finding and citing relevant information, dealing with information resources beyond grade level, exploring simulations and models, assessing the adequacy of the information resources—including what information might be missing, and selecting information to enter into the class discourse environment for further analyses and improvement. In these contexts, students are involved in sourcing, contextualization, and corroboration (Wineburg, 1991), in addition to the generation of new ideas (Bereiter & Scardamalia, 2010). Below we return to issues of student capabilities in these open informational worlds. For now we simply highlight the fact that evaluation of student capabilities in such contexts will undoubtedly provide a different picture of student capabilities than found in traditional school contexts that provide little opportunity or incentive for meaningful work with information resources. Before returning to these issues we discuss a need that emerges from our attempts to synthesize and integrate across the articles in this special issue, namely the need for greater conceptual clarity surrounding core constructs in multiple-document processing.

INTEGRATING RESEARCH EFFORTS: THE NEED FOR GREATER CONCEPTUAL CLARITY

In reading through the various articles in this issue, we were struck by the polysemy of central terms such as *source* and *document*. For example, across articles, and sometimes within a single article, the term *source* has multiple referents; indeed, several articles contain sections in which the authors clarify their use of the construct, reflecting their perceived concern regarding multiple and unclear meanings. We call out this issue here because without conceptual clarity on fundamental constructs, integration of research on multiple documents and sources will be problematic. Consider for example, that source sometimes refers to an information resource, as in "The source of this information was an article published in the *New York Times*." But the *New York Times* article may also have a byline indicating the specific reporter who contributed that particular article. In some of the articles in this issue, source refers to the person(s) who created an article or other type of information resource (Stadtler et al., this issue; Strømsø et al., this issue) or to whom a position statement is attributed (Macedo-Rouet et al., this issue).

In addition, sources can be embedded within one another (Britt et al., 2013; Strømsø et al., this issue). This is especially true in the sciences where it is expected that new research is contextualized within existing theories and data (Bazerman, 1985). Whether an information resource is considered a single source or multiple sources (documents) is itself an issue. In Stadtler et al. (this issue), and consistent with prior research (e.g., Wiley & Voss, 1996, 1999), the same content either appeared within a document context that itself had a single author or the content appeared as shorter, stand-alone documents, each with their own authors. However, and as noted by these researchers, it can be argued that the single-authored condition distorted the content and structure of an authentic single-authored article in that the single author did nothing to assist the reader in understanding how to link up the embedded information that was attributed to other sources or authors. In authentically occurring texts, authors indicate why they are including or citing the work of others, at least if they are considerate to their readers (Goldman & Rakestraw, 2000).

When authors are not explicit about reasons for citing particular authors, findings, or information, readers or users tend to operate according to Gricean postulates and assume that inclusion reflects the author's positive evaluation of the material (Britt et al., 2013; Grice, 1975; Strømsø et al., this issue). Readers are free to reject or accept the embedded source information and may base a decision on their evaluation of the embedding article or author. Alternatively, readers may decide to see for themselves and consult the embedded work to confirm the report or form their own evaluations. Thus, in authentic texts, especially in the science domain, there are both explicit and implicit cross-references that reflect knowledge construction in the domain.

Furthermore, we also need to recognize the socially situated definition of a document and what this implies about the assumptions readers will make about the information resource. Britt and Rouet (Britt et al., 2013; Rouet, 2006; Rouet & Britt, 2011) have been extending the original work with Perfetti (Perfetti, Rouet, & Britt, 1999) on the Document Model, as discussed in the Stadtler et al. (this issue) introductory piece for this special issue. In particular, Britt et al. (2013) recently expanded on an assumption of the model, namely that documents are social artifacts. Specifically, Britt et al. (2013) discussed the document-as-entity assumption. They state: "Readers experience more than just the informational content of the text and its semantic association with prior information. Readers also experience texts as social artifacts written by someone, at some point in time, for some purpose, etc." (p. 164). They go on to point out that a reader's experience of document boundaries is fluid and depends on a variety of factors. For example, the same text appearing in print may appear to be bounded differently when it appears on a website. An easy demonstration of this is the difference between experiencing a newspaper article in the hard copy printed form versus accessing it on the newspaper's website. Britt et al. (2013) note the fuzzy boundaries on documents; what readers construct depends on the text and reading environment, readers' goals, and the knowledge they bring to the task. Formation of an integrated mental model of a phenomenon may, or may not, entail the formation of representations for multiple documents even though information in the integrated model was extracted from several different social artifacts. Britt et al. (2013) do note that conflicting information is likely to increase the probability that readers will retain links between specific bits of information and the documents from which they were extracted.

For our purposes here, the important point is that in communicating methods and findings, researchers need to be clear about their operational definitions of source and document, what

they regard as single versus multiple documents, and how they define them for the research participants. This will solve part of the construct clarity problem.

We also suggest that the multiple document community adopt some conventions around usage of the terms *sourcing*, *source*, and *document*. Ground zero for the process of sourcing in the multiple document comprehension community is commonly thought to be Wineburg's (1991) work on the epistemology and inquiry practices of expert historians in contrast to those of novices. In history, documents are the data, the artifacts that historians work with for traces of the past. However, many historical documents contain verbal information, cartoons, maps, film strips, videos, and audio. For historians, these are also considered documents, and the community understands this more encompassing use of the term. Among expert historians, Wineburg found that interpretation of documents very much depended on who produced them, when, for what purpose and audience, and their relationships to other documents and to what else was occurring at the time the document was written. Wineburg thus labeled three processes as essential to historical inquiry: sourcing, contextualization, and corroboration. Sourcing is the process of establishing authorship and understanding the perspectives, goals, intents, and relationship of the author to the event. In particular, is the author a participant observer at the time of the event or an interpreter looking back at artifacts from the event to create a "latter day" explanation or account of a historical event or period? In other disciplines, documents reflect the range of information sources that constitute the data of that discipline and reflect the disciplinary norms and conventions for recording, reporting, and communicating within the discipline (Goldman & Bisanz, 2002; Norris & Phillips, 2003). In science for example, written reports of original research, analogous to primary sources in history, often embed graphs and tables. Journalistic reports of original research—analogous to secondary sources in history—abstract from original reports and frequently summarize findings, deleting graphs and tables.

To clarify some of the usage issues that occur across disciplines and media formats, we propose that *sourcing* be used to refer to the *processes* of identifying and representing metadata, including the author(s) or spokeperson(s) who created the information resource, their purpose in creating it, the intended audience, where and when it appeared initially (i.e., where it was published—YouTube, *NY Times*, etc.), as well as subsequent publication. The more generic term for document would then be *information resource* or *information source*, perhaps shortened to *source*, to characterize the full range of printed or electronic text, static or dynamic visuals, audio-enabled, and so forth. In our own writing, we have used the term *text writ large* to refer to what we here suggest be called information (re)source (Goldman, 2004; Goldman & Bloome, 2005; Goldman et al., 2010).

COGNITION AND INSTRUCTION RESEARCH

The findings reported in this issue are consistent with prior work showing that both content knowledge and knowledge of the epistemology of the content domain are important for detecting and resolving conflicting information. In science (Bazerman, 1985), experts in the domain base decisions on how to read and interpret new articles in their specialization, on the reputation of the researcher, and on publication venue. Wineburg (1991, 1998) discussed differences between expert historians and college and high school students, noting that experts not only paid attention to the author of a historical account but to when it was written and the original purpose for which

it was written. Novices, and even intermediates in a domain recognize that it is important to "consider the source" but often do not really know how to interpret the metadata to which they do pay attention (see Goldman et al., 2012b; Strømsø et al., this issue). Thus from an instructional standpoint we need to seriously consider how we can support acquisition of a knowledge base sufficient to enable those who have little knowledge in a domain to adequately evaluate what they are reading. How can we balance use of authoritative information with blind acceptance of whatever textbooks or websites present so that students do not meekly accept authoritative pronouncements? On the other hand, it is impossible to function in society without taking large amounts of information on authority. Even when it comes to challenging authoritative pronouncements, doing so effectively normally depends on bringing in other authoritative information as evidence.

The answer may lie, in part, in establishing more effective practices. Making sense of existing information and creating new information are processes situated within communities of practice (Lave & Wenger, 1991) that are responsible for defining the norms, criteria, conventions, and "rules of evidence" for what counts as credible knowledge and the acceptable and expected forms of argumentation within specific communities. Analyses of disciplinary communities such as chemists, mathematicians, or historians indicate interesting differences among these communities in how they approach understanding and coherence building processes, as well as in the expectations regarding forms of argumentation (e.g., Goldman & Bisanz, 2002; Moje, 2008; Moje & O'Brien, 2001; Shanahan & Shanahan, 2008).

Each disciplinary community, as well as social and other professional communities, has established norms and conventions for communicating within their discipline and for establishing the credibility of evidence-based claims. In knowledge-building communities—communities where the norm is collective responsibility for knowledge advancement—supports for high-level knowledge processes facilitate a shift from knowledge telling to knowledge transformation processes (Scardamalia, 2002; Scardamalia & Bereiter, 1987, 2006). Students are not simply responsible for their own entries and personal demonstration of accomplishment but for the community's work as a whole.

Collective responsibility requires "constructive uses of authoritative sources," a knowledge-building principle (Scardamalia, 2002; Scardamalia & Bereiter, 2006) that engages teachers and students explicitly in awareness that to know a discipline is to be in touch with the present state and its growing edge, and to try to contribute to it. In addition to finding inconsistencies and creating explanations to bring coherence to collaboratively constructed knowledge spaces, students are encouraged to identify and search for information regarding unsolved problems and the issues at the cutting edge of the discipline. Both teachers and students come to a better understanding of the nature of authoritative sources. While they are encouraged to respect those with more information they also understand that ideas are improvable. They find it surprising that ideas of famous people they admire have been improved throughout history; they come to see idea improvement as the natural order of things. Under such conditions there have been examples, albeit rare, of students finding mistakes in learned sources. Of course, much more frequently the expert resource helps them advance their ideas—not because they are required to learn information from the resource but because the ideas make more sense to them. They often restate the information in forms more accessible to their peers and contribute information to their community space with bibliographic information so others can trace information resources and do their own critical analysis.

As elaborated below, use of information resources as data for continual idea refinement requires both community and technological supports of the sort that support work in knowledge-creating

organizations. Here we stress that three processes—evaluation, integration, and creation—depend on content knowledge and knowledge of knowledge-creation practices within a discipline. These are elevated in importance in the information age and require supportive environments that engage students directly and productively in the forms of work with information resources that characterize advanced knowledge processes in an open informational world (Goldman, 2012a; Goldman et al., 2009; Bereiter & Scardamalia, 2003, 2012, 2013).

In the United States, the Next Generation Science Standards (Achieve, 2013) include both content and practice standards. Science and engineering practices are included in these standards and are directly applicable to the evaluation and integration of science information under the task and document conditions investigated in the work contained in this special issue: (a) engaging in argument from evidence and (b) obtaining, evaluating, and communicating information. The Common Core State Standards for Literacy in Science and Technical Subjects (Council of Chief State School Officers, 2010) indicate that by high school graduation, students should be able to integrate and evaluate multiple sources and types of information (including data, models, and hypotheses), synthesize information, and resolve conflicting information. Research and development of instructional design principles that will support students in developing these kinds of skills is a major challenge for the research and development enterprise. Subject-matter teachers see themselves as responsible for teaching disciplinary content, not reading. They themselves likely have never had the opportunity to explore their own disciplinary literacy and knowledge-building capabilities. Thus they fail to make explicit the complex inquiry and literacy practices in which disciplinary experts engage. At the same time that disciplinary teachers and researchers focus on content rather than disciplinary practices of knowledge generation, reading and literacy researchers tend to focus on more generic reading strategies (Goldman, 2012a). Although a number of innovative methods for engaging in disciplinary reading have been developed and shown to improve student achievement (e.g., Greenleaf et al., 2010), changes needed to sustain such practices have failed to take hold. As often as not, interventions developed by researchers have led to disconnects between the successful short-term interventions and the realities of classroom practices, teachers, and schools.

In an effort to address the disconnect between innovative research and practice, the U.S. Department of Education's Institute for Education Sciences broke the mold in 2010 when it awarded five research and development grants focused on reading for understanding with the requirement that the teams include educational practitioners from the outset. The closer coupling of researchers and educational practitioners during research and development is intended to produce classroom implementable interventions. One of the funded groups, Project READI (Reading, Evidence, and Argumentation in Disciplinary Instruction) is directed by the first author of this article (Goldman et al., 2009). READI defines reading for understanding as engaging in evidence-based argumentation from multiple information resources, situated appropriately in history, science, or literature. Instructional modules are being developed and researched collaboratively with classroom teachers. The modules reflect design principles that specify essential knowledge, skills, and practices of reading for understanding in each discipline as well as instructional strategies for supporting students in acquiring them. The instructional strategies include classroom norms and routines that provide cognitive and social support for student engagement with complex texts to develop evidence-based arguments that address important disciplinary questions. The modules will serve as curriculum materials for students as well as objects of study by teachers so they can implement them in their classrooms. In this way, teachers will have opportunities

to learn the skills and practices they will subsequently teach their students (Davis & Krajcik, 2005).

USES OF INFORMATION RESOURCES TO GENERATE NEW IDEAS

The term *transliteracies* was coined by Alan Liu (2005) to characterize the ability to produce coherent integration of information drawn from diverse sources. Thomas et al. (2007) suggest "transliteracy might provide a unifying perspective on what it means to be literate in the twenty-first century" (para. 1). According to these authors transliteracy is "the ability to read, write and interact across a range of platforms, tools and media from signing and orality through handwriting, print, TV, radio and film, to digital social networks" (Thomas et al., 2007, "What is transliteracy?" para. 1). Transliteracy places a premium on knowledge transformation processes that characterize expertise in written composition: working with complex configurations of diverse ideas, going beyond given information, searching for and reading authoritative source information and finding promising ideas, creating explanatory coherence, and so forth.

As new terms, new media, and new knowledge practices appear, the need increases for greater understanding of cognitive processes associated with the use of informational resources to generate new ideas in open informational worlds. Resolving inconsistencies across multiple resources is embedded in a larger agenda for productive use of these resources for sustained, creative problem solving.

The online environment Knowledge Forum (Scardamalia, 2004) was built to support knowledge transformational processes. The educational issue is whether these processes can be made integral to daily interactions between students, ideas, and information resources. Toward this end each student enters notes; uses scaffolds or discourse markers to characterize entries (e.g., "my theory," "new information + source," "evidence," etc.); and engages in extended discourse during class time with their entries projected on a screen as objects of class discussion. The norm in the community is collective responsibility for idea improvement. These conditions engage students in a transliterate world: They deal with diverse ideas in complex configurations, pose questions and theories that require Internet-based searches for information to refine their ideas, make use of a great variety of media, enter new information into communal spaces, work with others to achieve explanatory coherence, and so forth. The information sources they find are typically beyond their reading level. This, in turn, requires that they discuss the source information, design research, and engage in various knowledge advancing activities to solve problems of understanding.

With most inquiry approaches, responsibility for idea improvement remains with the teacher or curriculum or educational technology designer. Knowledge building requires that students eventually take over such responsibility. To accomplish this, students must not only recognize that their own ideas, like ideas in general, are improvable, but see their work as part of a community process in which their focus in not simply on their own ideas but on the ideas of their community as a whole. Engagement in knowledge advancement as a community enterprise requires that ideas have an out-in-the-world existence to aid community memory and overcome the transitory nature of oral communication. In many contexts this need is addressed to some degree by participant efforts to chart ideas and prepare reports. But a more permanent trace in a community space coextensive with the broader Internet world provides the out-in-the-world existence that supports ongoing development and improvement. In this context students

experience other students building on their ideas and helping to improve them; similarly, they build on and improve ideas of others. Idea improvement becomes part of the social fabric of the community: Students are engaged continuously with multiple information resources, multiple explanations, multiple media formats, and various other drivers of knowledge productions that take them beyond the world of personal beliefs to knowledge work that is more in keeping with the theories and inventions that have a public life in knowledge-based organizations and societies.

Work in such communities provides accounts of what we might expect of junior members of knowledge-creating enterprises. We have often cited a particular child's statement as one of the clearest accounts of a child's perspective on the distinctiveness of a knowledge-building approach (Scardamalia & Bereiter, 2006). This fifth-grader commented on the work of a classmate: "Mendel worked on Karen's problem" (referring to Gregor Mendel, the great nineteenth-century biologist). Note that the student did not claim that her classmate discovered information generated by Mendel or recommend that others read Mendel to find an answer to one of their questions. Rather, the remark treats Karen's work as continuous with that of Gregor Mendel, addressing the same basic problem. Furthermore, the student offered the Mendel reference to others to help advance their collective enterprise, connecting inquiry to that of learned others, past or present. The child is not overawed by authority, nor dismissive, but connected to problems and authoritative sources in the world. Students themselves see their work as more than cultural replication; they are engaged in work that typifies knowledge-creating organizations, as elaborated in other accounts (Bereiter & Scardamalia, 2010).

To this point we have discussed issues surrounding the articles in this special issue and related concepts of transliteracy and knowledge-building communities. This sets the stage for two proposed extensions to current research efforts: (a) use of metadata and metadiscourse and (b) constructive use of authoritative sources.

PRODUCTIVE USE OF METADATA AND METADISCOURSE

We have argued that the concept metadata might bring greater coherence to work in the field and noted the importance of community norms to support productive interactions surrounding metadata. We envision students discussing source information as a normal part of their interchanges: "Where did you get that information?"; "Are you quoting or paraphrasing the author?"; "Did you check the credentials of the writer?"; "You didn't cite sources—please provide a reference"; "Are you citing a primary or secondary source?" In face-to-face collaborative work but especially in online communities such discussions are important for clarifying if a peer's contribution was the peer's own idea or an account created by someone else, and with what authority it was presented. In such contexts it is no longer a matter of an individual trying to locate and work with sources but a community with collective responsibility for providing a historical account, an explanation, or in other ways working with reference material to produce coherence from partial and oftentimes conflicting accounts. Contributions become objects for discourse about their discourse—or metadiscourse.

An investigation conducted in grade 2 (Resendes, Chen, Chuy, & Scardamalia, 2012) illustrates the powerful effect of students discussing their work based on an overview of the discourse markers (e.g., "my theory," "new information + source," "evidence," as mentioned above) that they assigned to their texts when they first entered them into their community space. Students

in grade 2 were shown a bar graph that displayed results based on the discourse markers. A teacher–researcher team reports that these young students found the results fascinating. The bar graph showed, for example, that they had entered many "my theory" notes about how birds fly but not much in the way of authoritative source information (e.g., the "important information + source" scaffold showed low levels of use). And there was very little effort to explain why source information is important (e.g., the scaffold "this information helps explain" was almost never used). The discussion based on these results conveyed an awareness of issues not evident to teachers, students, or researchers from reading the notes in their community space. A higher-level view of their work was required. Interestingly, these grade 2 students, with help from their teacher in reading the graph, came up with plans to remedy problems. For example they refined their information search to find more evidence for their theories. The use of "metatags" to facilitate discourse about discourse illustrates (a) student capabilities that are not evident in short-term experimental conditions may appear in extended problem solving contexts and (b) technological supports built into classroom practices can help foster sustained and creative work with ideas.

Traditional schooling has neither provided realistic contexts for use of information resources nor embedded their use in motivating, authentic, long-term contexts. So data from these traditional contexts may well underestimate student capabilities. At a practical level we recommend greater use of student discussions after experimental data are collected. We also recommend more purposeful efforts to integrate work from research programs that span carefully controlled experimental research and design research aimed at uncovering capabilities under optimal conditions (Fischer & Bidell, 1997). Greater integration requires work at multiple levels of the educational system, including the classroom, content-area department, whole school, and district (Goldman, 2005; Raphael, Au, & Goldman, 2009). Furthermore, the assessment of student achievement will need to reflect the importance of knowledge production as well as knowledge reproduction if we are to see real change in classrooms around understanding, evaluating, and integrating multiple information resources.

CONSTRUCTIVE USE OF AUTHORITATIVE SOURCES

As indicated above, a knowledge-building principle is "constructive use of authoritative sources." The concept has its basis in the work of scientific communities, rather than schoolwork involving information sources. Constructive use of authoritative information comes naturally to a research organization; original work is almost always built upon previous work, and theories are tested against data not only from local work but also from published research and a broad range of information resources (Bazerman, 1985; Wineburg, 1991). In school, however, authoritative information is presented as material *to be learned*. Using it in knowledge building therefore requires a shift—obtaining, recording, and storing information become subsidiary functions in the service of knowledge creation.

Significant advances in knowledge by a research laboratory are obviously emergent; the knowledge didn't preexist in anyone's mind nor was it simply there to be read out of a book. In scientific and scholarly research teams, knowledge building is woven into the social fabric of the group (as we have indicated, could be the case in school communities). This becomes evident if we consider successful research laboratories like those studied by Dunbar (1997) and contrast them with work dominant in school. In the research laboratory, knowledge advancement is the defining purpose. Outputs depend on idea improvement, and discourse is geared to advancing

knowledge-creating goals; in schools, by contrast, the focus is on knowledge acquisition and reproduction of existing ideas. Discourse is typically used to assess adequacy of arguments and ideas in light of authoritative sources.

Attempts to engage students in creative work with ideas has tended to focus on "brainstorming"—rapid generation of individual ideas. By contrast, real-world innovation typically calls for collaborative and sustained creative effort that takes an initial promising idea through to realization of its promise in an invention, theory, or other complex knowledge product. This is very different from integrating information across sources, determining which resource is more valid, elaborating different positions to determine which is more acceptable or which source more credible, and so forth. Such functions characterize "belief mode" work—work to determine which ideas are to be believed. Knowledge-creating organizations operate more in design mode (Bereiter & Scardamalia, 2006; Scardamalia & Bereiter, 1992) where the emphasis is on improving available ideas. Of course, work in both modes is essential. A special difficulty for advancing a knowledge-creation agenda in schools, however, is that schools operate almost exclusively in belief mode. Consider the different sorts of issues that arise with respect to authoritative sources when working in design mode: "Is there any mileage in pursuing this idea?"; "Could something of consequence come from this new direction?"; "What is this idea good for?" Students have little experience reading to find promising ideas. In an effort to address this problem, a team in Toronto has begun to explore the potential of a "promisingness" tool that allows students to clip portions of notes and export them to personal or new community workspaces. Ideas can then be displayed from most to least promising, according to how many community members found it promising. Promisingness research (Chen, Scardamalia, Resendes, Chuy, & Bereiter, 2012) suggests that this tool provides the means for students to rise above long discourses, idea fragments scattered across notes and views, and information overload to focus on a few select ideas. And exporting promising ideas to contexts of use helps students work in design mode, finding ideas that are promising for addressing problems, restarting a conversation that is going nowhere, or in other ways lifting their sights. Chen, Scardamalia, and Resendes (2012) demonstrated that students in a grade 3 class were able to clip promising ideas and in a subsequent whole-class discussion review top hits and select three to be the focus of their new work. This process led to more significant knowledge gains than found in students' notes from the previous year's class—a class without access to the promisingness tool but with same-grade students, same topic, and same teacher.

Research involving both the metadiscourse and promisingness tools demonstrates the power and need for reflection on first-level discourse and potential for knowledge advancement when the whole community is committed to that goal. Through such means we believe it will be possible to extend the framework for research, with students making use of information resources to create new knowledge.

In conclusion, researchers of cognition and instruction need to investigate complex processes demanded by the information age. The work featured in this special issue reports forays into this world. Clearly, there is much to be learned, especially with respect to the design of learning environments that foster knowledge application and creation as well as management and understanding.

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