Whose Literacy? Discursive constructions of life and objectivity
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Introduction
Science education is not always the same as research science. Literacy studies have had particular and profound effects on ways it is possible to think about science within science education. Considering the importance of written discourse in scientific communities (Atkinson, 1999; Bazerman, 1988; Harris, 1997; Latour & Woolgar, 1979), and consistent with current reform efforts aimed at scientific ‘literacy’ (AAAS, 1993; NRC, 1994), research on writing in science education created an extensive body of research in the last decade (see e.g., Hand, Hohenshell, Prain, 2004; Hand, Prain, Lawrence, Yore, 1999; Holliday, Yore, & Alvermann, 1994; Keys, 1999, 2000; Keys, Hand, Prain, & Collins, 1999; train & Hand, 1999; Rivard, 1994). This research became increasingly integrated with studies of spoken classroom discourse (see e.g. Keys, 1997; Rivard & Straw, 2000; Roth & Duit, 2003; Windschitl, 2004), thus emphasizing the ways communication systems work in social groups. The emerging field of New Literacy Studies (NLS) has affected the trajectory of science education research, and therefore the larger discussion surrounding notions of science literacy. The ways in which science is done—epistemology, method, and pedagogy—have been affected by literacy-oriented research.

There is ample evidence of interplay between the literacy concepts of NLS and those of science education research. Culture and literacy researchers like Bruner, Gee, Lave and Wenger are all prime examples of this trend. Wells’ (2000) description of “progressive discourse” (p.72) – the process by which a group shares, questions and revises the ideas of all members – is just one example of how NLS research draws upon and reinforces the collaboratively heuristic methods of science. Wells suggests a kind of dialogic inquiry for science (and other) learning environments that allow learners to exist as co-inquirers so long as there is a meaningful question. Roth and Duit (2003) is a good example of how science education research is combined with literacy-oriented techniques to examine and understand what it means to be scientifically literate within an inquiry context. Recognizing one methodological hurdle, Roth and Duit surmise that “it is typical for researchers to assume that students build internal mental models independent of familiarity with the language corresponding to the topic” (p.870), thus recommending a more NLS-oriented approach to science literacy.

With regard to science literacy, we argue from the position that language is not separable from science (see, e.g., Bazerman, 1988; Halladay & Martin, 1994; Latour, 1999). We do not take the position that language is an unfortunate but inevitable inconvenience that tends to get in the way of real science. Instead, we regard science as a discursive practice. The view of science as discourse is not new, such studies have been called social studies of science, sociology of science, sociology of scientific knowledge, and science and technology studies. Myers (1990) expresses the position clearly:

Those who believe that scientific discourse is essentially different from other discourse—including some realist philosophers of science, some Marxists, and some practising scientists, at least in their polemical statements—point to a distinctive scientific method involving falsification or replicability, to institutions such as peer evaluation and publication, to the position of the scientists in historical processes, or to some quality of
the subject matter studied. These distinctive characteristics of science are taken to separate science from the realm of rhetoric and of social processes, so that, however much social factors may enter in any particular case, real science always continues, or works best, apart from those factors. But as I shall show, the application of this demarcation is itself a question of rhetoric and social processes; such characteristics as replicability are invoked in order to persuade the audience that some fact or field lies beyond matters of persuasion. (Myers, 1990, p. 4)

Following Myers, we argue that a discursive perspective on science is important for science literacy because it counteracts the tendency in science education to “thingify” scientific ideas and concepts without regard to their historical contingency. Our project is similar to that of Désautels and Larochelle (2003). To summarize their study, they concluded:

We have examined students’ epistemology about scientific knowledge and its production. We have sketched a major feature of this epistemology, namely, the tendency to give knowledge an existential status, which we have termed a tendency to ‘thingify’. We also have tried to show ways in which this epistemology relates to the prevailing type of ‘rapport au savoir’ (relationship to knowledge) often being promoted in the school and which inevitably bears both social and cognitive consequences. (Désautels & Larochelle, 2003, p.124)

In this paper we suggest that an understanding of the historical, discursive production of scientific knowledge affects the meaning of scientific literacy in at least three ways. A discursive study of scientific knowledge has epistemological consequences because such a historically grounded approach avoids the selective perception that occurs when facts are abstracted from the historical conditions of their emergence. A discursive approach to scientific knowledge can also be seen as an example of science-as-exploration. If modern science education seeks certainty, other definitions of scientific literacy may seek more ambiguity. Finally, literacy and discourse studies contribute insights that alter assumptions about pedagogical appropriateness in science education.

To examine the confluence of literacy and science in science education we analyze two issues as represented in highly regarded science education journals: the definition of life and the epistemology of objectivity. We choose these two issues because they have attained the status of “foundations” in science education and because, in both cases, the historical makeup of the issue is not widely recognized. After examining the ways science education literature has constructed each issue, we seek to historicize the ideas in terms of the history of science and in the context of research in science education. We begin by examining various constructions of the boundary between life and non-life.

Creating Life, Non-Life, and Artificial Life

“There are infinite worlds both like and unlike this world of ours ... we must believe that in all worlds there are living creatures and plans and other things we see in this world”

Epicurus (341-270 B.C.) in his Letter to Herodotus
The National Science Education Content Standards create separate categories for life sciences and physical sciences that apply across the k-12 curricula. There is hardly a more explicit and definitive statement of a discrete and fixed boundary between life and non-life. At the same time, one of the larger aims of the science literacy movement is producing skeptical and responsible citizens in a technological and scientific society (AAAS, 1989; NRC, 1996; NSTA, 1995). The issue of the distinction between life and non-life is a feature of science literacy (as expressed in the standards) that reflects a historical context of schooling in a way that makes school science different from research science.

In a world where the modification of objects whose status is not so easily identified within a binary life/non-life distinction, issues of ethics and public policy create greater political fuel for promoting science literacy. Research into artificial intelligence, molecular computers, genetic modification and the use of stem cells demands a kind of literacy that can deal with the shifting border territory between life and not-life. This sentiment is expressed by Bryce (2004) in his study of the challenges that face science teachers as a result of biotechnological “progress.” Bryce suggests that “teachers [will increasingly] find themselves engaged in discussions with pupils on value-laden issues deriving from the social and ethical implications of the ‘new science’” (p.717).

Bryce’s quote implies that the life/non-life debate is new. However, a look at the history of science suggests that the debate was occurring already in the 18th century with the study of the “vital force” in chemistry. In his work, “On the Vital Force” (1796/1992) Johann Christian Reil states that “forces,” such as the vital, animal, and vegetable forces, are innate properties of matter. He theorizes that the “foundation of life lies in matter as a whole, in the composition and form of all that which is visible and invisible” (p.8). This notion of life, often identified with vitalism, lost favor with organic chemists in later years. This is not to say that one, inherently wrong view preceded the discovery of truth. Instead, the line demarking the life/non-life divide shifted within the scientific community and even existed in multiple locations at the same time.

Although scientists no longer use the term “vital force,” the life/non-life question arises when we consider the role of cellular reproduction and genetics. Nevertheless, the life/non-life distinction is still unproblematicized in most sectors of science education. For example, as Snyder and Broadway (2004) discuss the presence of heteronormative constructs within current school biology textbooks, they raise the call for a new, broader lens that takes seriously the “science for all” mantra. Issues of power and marginalization in the content are the focus, yet part of their review instrument does include a representation of genetics. The authors claim to include this as a means for placing their analysis “in the context of the NSES [National Science Education Standards]” (p.625), and they cite the relevant aspects as a rhetorical sounding board upon which the biology textbooks can be evaluated. The standard for genetics upon which they base their critique of textbooks reads as follows:

The fact that the human body is formed from cells that contain two copies of each chromosome—and therefore two copies of each gene—explains many features of human heredity, such as how variations that are hidden in one generation can be expressed in the next. (National Research Council, 1996, p. 185)

The language used as a guideline for textbook evaluation implies a static, extant understanding of genetics within the scientific community. The argument that Snyder and Broadway make decries the normative pressures imposed by the textbooks, however, they choose framing language for their research tool that does not represent larger complexities within current
scientific discourse. In the discussion section, they offer a criticism of the examined texts that includes suggestions for including “historical events, such as eugenics performed by Germany in the World War II” (p.629), yet they fail to recognize this same absence—and that of any contextual notion of the concepts—from the framing standards documents.

The same static definitions of *life* and *living organisms* as unproblematic terms are evident in other recent publications within science education. Stern and Roseman (2004), for example, in their review of life science curricular materials discuss the “core concepts” (p.539) of energy and matter cycling within ecosystems, and treat the concept of “life” with untroubled facility. They discuss the role of energy in carrying out “life functions (e.g., add new cells or convert inputs to outputs)” (p.543) or generalizing about “the transformations of matter and energy in living things” (p.549). Throughout, however, the article fails to question the assumptions surrounding such terminology. The fact that the entire piece is built around the equation of “living organisms” with “plants and animals” leaves little room to wonder whether the life/non-life boundary has ever been mobile, let alone questioned.

Early in Venville’s (2004) article about younger students and their changes in concepts of living vs. nonliving things, the author offers a clear picture of just how unproblematic the distinction between these two categories is: “Many young children, such as 6-year old Anna, cannot distinguish between living and nonliving things in a way that adults would consider scientifically acceptable… [even though] she uses sensible everyday criteria for these decisions” (p.450). The notion that the distinction between living and nonliving is based on “sensible” criteria, let alone that of the “everyday” variety, is problematic when the scientific community regularly debates such things. In discussing children’s development of “appropriate concepts about living things” (p.450), Venville makes an explicit suggestion of some correct conception of life coupled with an implicit indication that this conception is of the ‘absolute truth’ variety—a timeless, unquestionable fact that all students should eventually come to recognize. Given that the phrase “living things” is used extensively in this article (well over 70 times) and that it is continuously treated as a point of tacit consensus, the suppositions of a research community served by such an article come into question. When citing other educational research, Venville discusses certain “facts… such as living things reproduce, grow, and change, have complex internal structures that regulate resources to maintain patterns of homeostasis” (p.454); these apparent truths may not be so obvious to those who are engaging in debates about artificial life.

The definition of science literacy in science education does not line up with debates in the broader scientific community. This mismatch is heightened when the science education researchers classified the children in their study as either “scientific,” “transitional” or “nonscientific,” based on whether they “had understandings that could be considered inconsistent with a scientific view” (p.458). By the end of the article, the authors reify the life/non-life binary. They call for approaches that focus on conceptual change strategies for understanding the concept of living things *rather than strategies that simply result in assimilation of facts and information* (p.476, emphasis added), yet this may be considered ironic.

As the life/non-life example demonstrates, shifting views that have developed in research science have not always found their way into the discourse of scientific literacy. The goals for such literacy may contain rhetorical elements of holism and systems thinking (AAAS, 1989; NRC, 1996; NSTA, 1995), yet larger issues of complexity and contextualization do not appear within the discourse of science education. Since discussions of the historicized concept of life are frequently absent from the larger science education discourse, and that discourse is highly existentialized, what kind of science are students really doing?
Popkewitz (2002) offers some insight into factors that may contribute to this non-alignment. He suggests that as science is absorbed into educational discourse, an alchemy occurs in which the objects of the subject matter take on aspects of psychology, pedagogy and social science. We know from the history of the social sciences that certainty and measurability were critical to their development (Wagner, 1998; Winch, 1958). As disciplinary knowledge becomes part of the science education discourse, the tendency is to ‘thingify.’ In addition, developmentalist theories, such as that of Piaget, reiterate the modernist understanding of concrete-as-easy and historical-as-advanced. The messier questions of history and ethics are not the focus of the alchemized science literacy, and this alchemy may be a reflection of broad tendencies toward modernization that occurs in schools. Yet these messy questions remain central to the work of research scientists.

Since changes in the scientific community’s thinking about life has not been echoed within science literacy, expectations of school science are being crippled by old notions of science in the classroom. At any particular time and place, conceptions of life – what it means to be ‘living’ – both exist and change. Throughout the history of science, questions surrounding such conceptions have been taken up in a variety of ways, and each time the boundary between life and non-life emerges in a different place.

Of course, there are famous debates about when life begins that are associated with oppositional stances on abortion. However, there are other examples that cannot so easily be attributed to religious or political differences. One recent example of the shifting life/non-life boundary is the classification of viruses. In 1840, Jacob Henle theorized disease-causing agents within living systems that were too small to see, yet until 1898 when Martinus Beijerinck referred to this new disease agent as a contagious living liquid–contagium vivum fluid—there was little consideration of such agents being non-living. With discoveries regarding viral dependence on hosts and gene expression, the life/non-life borderline shifted several times within the last century and within different camps.ii Even within the current discourse, the questionable status of viruses is apparent in the language that is used to describe them. The American Society of Microbiologists weighed in on the proposed national drinking water regulations of 2000, raising issues around the monitoring of “viable” virus levels.iii This kind of language, adopted elsewhere in the field, further problematizes the distinction between life and not-life since it allows for a broader discussion of degrees of life. Yet a domain that more recently adopted the term ‘virus’ provides another worthwhile example of shifts in the border between life and not-life.

Research in electronics and computers has contributed to thinking about this issue, most especially in the area of artificial life, a term first coined by Christopher Langton in 1987 (Langton, 1988). This evidenced a large scale interest in issues surrounding life and technology, MIT Press launched a new journal, Artificial Life, in 1993. According to its website, the journal:

- is devoted to a new discipline that investigates the scientific, engineering, philosophical, and social issues involved in our rapidly increasing technological ability to synthesize life-like behaviors from scratch in computers, machines, molecules, and other alternative media. By extending the horizons of empirical research in biology beyond the territory currently circumscribed by life-as-we-know-it, the study of artificial life gives us access to the domain of life-as-it-could-be. Relevant topics span the hierarchy of biological organization, including studies of the origin of life, self-assembly, growth and development, evolutionary and ecological dynamics, animal and robot behavior, social organization, and cultural evolution. (http://mitpress.mit.edu/ALIFE)
A larger discourse with the aim of “extending horizons” suggests both shifts in thought, as well as particular standpoints from which fields of view might intersect. Within scientific communities, these fields of view are often disciplinary in nature.

The interweaving of biological and physical sciences allows for a larger discussion of life on the global scale. The recently released Scientists Debate Gaia: The Next Century addresses the interaction of the biological and physical systems of the planet, suggesting that the Gaia hypothesis first proposed by James Lovelock and Lynn Margulis in the early 1970s “has today been incorporated into mainstream interdisciplinary scientific theory, as seen in its strong influence on the field of Earth System Science.”

Given the highly contentious history of the life/non-life distinction, the definition of science literacy comes into question. In current science education standards, one criterion for science literacy is the ability to distinguish living from non-living organisms. This discrete dichotomy is understandable given the historical tendency (“alchemy”) of modern schooling to reify knowledge into timeless concepts. However, this definition of science literacy is problematic since the distinction between life and non-life has continued to be an issue of research science for centuries.

**Different Perspectives on Objectivity**

The life/non-life distinction is one example that gives science literacy a definition that is peculiar to current science education. According to science education standards, the distinction between life and non-life appears to be ontological and unproblematic. Our second example, objectivity, is somewhat different from the life/non-life example. At times, objectivity in science education has been justified on the basis of realist ontological assumptions—namely, there is a real world out there, and scientists can learn about it by methodical investigations (Novick, 1988); however, this position of naïve realism is not the norm, and it has been challenged extensively in science education literature (see, e.g., Keller, 1996; Cetina, 1999; Haskell, 1998). Unlike the life/non-life distinction, objectivity has been recognized as a problem in science education. There is recognition that contextual factors of history, culture, religion, and technology all contribute to interpretive aspects of science such that pure objectivity is not plausible.

More recently in science education, objectivity is less likely to be defended on grounds of (naïve) realism, and more likely to be defended on grounds of pedagogical appropriateness. Science educators have appealed to notions of developmental psychology to argue that young children and novices can learn science concepts more easily if those concepts are presented as simple, certain, and unambiguous (Taylor & Dana, 2004; Popkewitz, 1987). Derived from Piagetian theories, the developmental assumption has been that learners become increasingly able to handle ambiguity as they grow and learn. Based on this sort of pedagogical reasoning, some science educators have argued that objectivity is a developmentally appropriate approach for introducing new science concepts (see, e.g., NRC). Presumably then, in later stages, more nuanced concepts can be introduced, and strict objectivity can be challenged. A Piagetian developmental sequence proceeds from the concrete to the abstract, and from the simple to the complex. In science education, the analogous developmental sequence proceeds from the simple objective fact to the more nuanced contextual variations.
However, this assumption of developmental appropriateness has been challenged in science education literature from at least two different directions. In the section that follows, we summarize these two challenges. First, we discuss research that has drawn upon post-representational linguistic theories to argue that science education is inextricably related to language. This line of reasoning is related to the situated learning concepts formalized by Lave and Wenger (1991), and it emphasizes the contingencies of social interactions as crucial elements of knowledge production. Basically, the argument is that science concepts (like vocabulary and syntax in language acquisition) are more readily grasped when they are learned in context. Second, we cite researchers in the tradition of science and technology studies who argue that the contextualization of knowledge makes science concepts accessible to more people and therefore less elitist. In both these cases, the acquisition of science literacy is facilitated by the historical contextualization of scientific knowledge, and epistemological objectivity is no longer pedagogically mandated.

**Rhetoric- and Language-based critiques of objectivity**

Objectivity in linguistics (language-as-representation) has been problematized for at least half a century. Structuralist and sociolinguistic analyses provide that the ability to use language hinges on engagements in complex social interactions. Furthermore, research in second language learning suggests that “communicative” language use is the most effective path toward successful language acquisition (Krashen, 1981; Krashen & Terrell, 1983). Insights from linguistic theory and second language acquisition research have been extended to provide insights about science literacy, in the sense of fluency in scientific discourse. As Bazerman (1988) famously writes, “Reference to objects, experiences, and ideas outside the sign system is only a deceiving appearance; the idea of reference is itself only a semiotic creation” (p. 20).

There are science education researchers who are using post-representational linguistic theories to analyze science education. Roth and Duit (2003), for example, provide an elegant argument suggesting that teacher educators would do well to focus on the discursive production of scientific knowledge. Using concepts from the theory of nonlinear systems, Roth and Duit’s research shows that the learning of physics resembles the learning of language, especially with regard to participation in conversations. Moreover, they suggest that teacher educators can understand science teaching by paying attention to theories of linguistics that reject the notion of language as representation:

> In this study, world (object, events) and language are not taken to have a stable meaning a priori. We take words and world to be interpretively flexible and therefore grant that they may be perceived and understood in different ways (that they have different ontologies for different actors). Interpretive flexibility is a positive phenomenon because it allows variation and therefore new ways of thinking about the world to emerge … and allows negotiation to be a meaningful activity. (Roth & Duit, 2003, p. 875)

Roth and Duit’s research is particularly nuanced because their study concerns the learning of chaos theories in physics classrooms. In their conclusion, they suggest that conversation-based approaches to teaching and learning science are warranted both on the basis of the production of scientific knowledge and on sound pedagogical sensibilities. Their research highlights the historically situated and contextual features of science and science education. In this way Roth
and Duit’s research serves as an example of the ways linguistic theories contribute to the problematization of objectivity in science literacy.

In a second example of linguistic and rhetorical studies of science education, O’Neill and Polman (2004) recognize the discursive production of scientific knowledge and emphasize the “credentialing” aspect of scientific claims. In their study of practice-based scientific literacy, O’Neill and Polman studied the day-to-day routine practices of scientists. They observed that scientists spend a great deal of time reading, writing, and responding to research. O’Neill and Polman argue that the practice of science is based fundamentally in literacy; they make this claim based on the amount of time each day that scientists spend reading and writing. Referring to an example of a volcanologist, they then suggest implications for science teaching:

The acts of persuasion and evaluation that occupy much of this researcher’s time are integral parts of a large, institutionalized process, which Suppe referred to as the ‘credentialing’ of scientific claims—a process through which scientists integrate their claims into a public body of knowledge that is considered tried and true by their peers. Current science education ignores these processes almost completely, although knowledge of them would likely be more useful to the general public than a great breadth of content knowledge that is too quickly forgotten. (O’Neill & Polman, 2004, p. 239)

O’Neil and Polman’s research recognizes the aspect of scientific knowledge that is produced by the discourse of publication conventions. Characterizing this aspect as an “institutionalized process,” O’Neill and Polman articulate a pragmatic stance. They do not assume or assert that the nature of science is objective (or non-objective). They make a pragmatic claim that the discursive production of scientific knowledge is a feature of the mundane practices of scientists. Rhetorical articulation of scientific knowledge is a routine aspect of doing science, and therefore it should be part of the science education curriculum and a central feature of science literacy.

A third example of the ways in which science knowledge is studied as a discursive production is found in Yore, Hand, and Florence (2004). In their study of “scientists’ views of science,” Yore, Hand, and Florence regard the construction of science as their object of study. Rather than assuming or asserting that scientific knowledge is objective or not objective, these researchers characterize scientists’ views as constituting a continuum of beliefs and assumptions that range from traditional to modern and postmodern:

An understanding of scientist’s ontological assumptions and epistemic beliefs about science is essential to better understanding the roles of writing in doing and learning science because these assumptions and beliefs should influence the choice of specific language and their interpretation of the functionality of writing in constructing and reporting science claims. (Yore, Hand, and Florence, 2004, p. 341)

These researchers studied the relationship of teachers’ philosophical assumptions and their beliefs about the role of writing in science:

If science was viewed as a traditional absolute epistemology where science ideas were discovered and extracted from nature, then writing was simply telling about what was discovered. On the other hand, if science was viewed as a contemporary evaluativist or
postmodern relativist epistemology, then writing might be viewed as a knowledge construct process. (Yore, Hand, and Florence, 2004, p. 347)vi

These are three particularly robust examples of challenges to traditional objectivity from the perspective of language and rhetoric. They develop quite different arguments—one that highlights the generative value of multiple interpretations in science (Roth & Duit, 2003), one that is based on a discursive analysis of what scientists do (O’Neil & Polman, 2004), and a third that makes objectivity itself the object of a scientific study (Yore, Hand, & Florence, 2004). Together with the arguments about science in context (below), these studies contribute to an understanding of science literacy that departs from a traditional foundation in objectivity.

Contextual and historical critiques of objectivity

There is research both in science education and in philosophy that suggests three major problems with certain objectivist assumptions: 1) objectivity can be unscientific, 2) objectivity may be a form of over-simplification that makes scientific concepts more difficult to understand rather than easier to understand, and 3) objectivity can operate as an exclusionary mechanism in teaching. In the following section, we summarize each of these arguments briefly.

Objectivism as unscientific. Sandra Harding (1992) makes an argument about objectivity that emphasizes the ways in which objectivism effectively censors data, and is therefore an unscientific approach. Harding distinguishes between “objectivism” and “strong objectivity.” She says that if we do not consider historical and contextual factors as part of the production of scientific knowledge, then we are censoring a large part of the available knowledge. This censorship constitutes “objectivism,” an ideological, and therefore unscientific point of view. In other words, if we understand scientific knowledge about radioactivity to be limited to its laws of physics, and we do not consider the historical factors that made radioactivity important to study in the first place, then we have drawn ideological limitations around scientific knowledge in a reductionist way. If we understand science to consist of knowledge that has been abstracted from the contingencies of its means of production, then we are being reductionist about science. In contrast, Harding argues that “strong objectivity” is an epistemological stand that recognizes scientific knowledge to be laden with particular historical values.

Strong objectivity would specify strategies to detect social assumptions that (a) enter research in the identification and conceptualization of scientific problems and the formation of hypotheses about them (the ‘context of discovery’), (b) tend to be shared by observers designated as legitimate ones, and thus are significantly collective, not individual, values and interests, and (c) tend to structure the institutions and conceptual schemes of disciplines. These systematic procedures would also be capable of (d) distinguishing between those values and interests that block the production of less partial and distorted accounts of nature and social relations (‘less false’ ones) and those—such as fairness, honesty, detachment, and, we should add, advancing democracy—that provide resources for it. (Harding 1992, p. 581)vii

Harding’s analysis of objectivity in science literacy maintains a certain classical notion of science as a systematic and empirical study. However, it points out the ways in which all
observations are selective, and it challenges science educators to examine the bases on which some data are examined and other data are ignored.

Objectivity as over-simplification. A second (and closely related) historical critique of epistemological objectivity comes from the well-known work of Thomas Kuhn. Kuhn (1973/1989) raises the issue of “theory choice” when he explains an aspect of contextualizing objectivity. Tracing a history of paradigm shifts in science, Kuhn cites examples in which scientists chose among several available theories in order to study phenomena, and that these choices were inevitably subjective in some way. For example, he writes:

The oxygen theory… was universally acknowledged to account for observed weight relations in chemical reactions, something the phlogiston theory had previously scarcely attempted to do. But the phlogiston theory, unlike its rival, could account for the metals’ being much more alike than the ores from which they were formed. One theory thus matched experience better in one area, the other in another. (Kuhn, 1973/1989, p. 357)

In this way, Kuhn provides historically grounded examples of the ways in which science involves theory choice. Theory choice is inevitably subjective, and therefore objectivity can be a form of oversimplification in science teaching. Since theory choice is something that scientists must do, it seems important that theory choice be considered an aspect of science literacy.

Kuhn draws on the history of science to explain why contextualizing scientific knowledge is so important. Other research has suggested that scientific objectivity is problematized by the “disunity of science.” In a volume by that title, the editors Peter Galison and David Stump (1996) (along with others like Ian Hacking, Karen Knorr Cetina, and Joseph Rouse) examine assumptions that “science” could be a single, unified thing. Hacking (1996), for example, historically documents different versions of what “unity” of science has meant: metaphysical unity, practical unity, and methodological unity. In this essay, Hacking shows that objectivity can mean different things not only across different scientific fields, but also across different periods of time. In the same volume, Creath (1996) compares different versions of unity as they were debated in the mid-1930s Vienna Circle. He argues that unity is not a fact about current science, and that discussion across scientific fields is a productive endeavor that is consistent with the exploratory spirit of science. Since epistemological objectivity rests on the assumption that an object is the same regardless of perspective or interpretation, these challenges to unity in science constitute a significant challenge to definitions of science literacy that include objectivity as a standard criterion.

We can also look to recent changes in scientific definitions of “observation” to suggest ways in which objectivity may be an act of oversimplification. Heisenberg’s famous principle can be taken to mean that the act of observing perturbs what is being observed thus increasing the uncertainty in precise measurement. While it holds only for what he called ‘canonically conjugate variable pairs’ such as momentum and position, Heisenberg’s work seriously undermines the possibility that scientific knowledge is objective in the sense of being detachable from its particular historical circumstances of production. In a famous quotation: “It is the theory which determines what we can observe” (attributed to Einstein in a letter to Heisenberg).

Finally, research in language teaching provides further evidence that objectification of concepts may not be pedagogically effective. Language acquisition research distinguishes objectification pedagogies from communicative pedagogies. In a communicative pedagogy,
language elements are contextualized rather than objectified (Krashen & Terrell, 1983). For example, the vocabulary terms *wave*, *tidal pool*, and *surf* are more readily assimilated and retained if they are introduced and practiced in the context of a meaningful discussion about oceans (Brumfit, 1984; Lee & Van Patten, 2003). Research on the communicative approach to language acquisition has challenged assumptions about developmental appropriateness in pedagogy. Previously, it had been assumed that languages would be easier to learn if the elements (e.g., vocabulary words, syntactic structures, phonological patterns) were broken down and taught separately as discrete objects. However, two decades of research on communicative pedagogy suggest now that oversimplification and objectification of language does not make it easier to learn. Rather, contextualization—which often entails making a concept or word more ambiguous—actually facilitates the development of literacy.

**Objectivity as a mechanism of exclusion.** Finally, a contextual aspect of objectivity in science is evident in the sociocultural norms that produce and regulate scientific discourse. Feminist philosophers of science have documented the power-laden processes of scientific knowledge production (see, e.g. Harding, 1992; Cetina, 1999; Keller, 1992; 1996). These critiques have been extended beyond feminist scholarship and into other facets of science education:

The studies…share the theme of examining how groups structure opportunities for individual engagement in knowledge production. More important, these studies describe how particular group members are excluded from participation in group activities. In this sense, evident social factors such as status, gender, and leadership position have been described as having a role in the knowledge produced by a group. These evident social factors are not the only influences on social knowledge production. There is a growing body of literature that focuses not on the particulars of how groups (in a local/micro sense) interact, but on the influence of ideological factors on a group’s production of scientific knowledge (in a global/macro sense). (Kittleson & Southerland, 2004), p. 269)

This exclusionary feature of traditional objectivity pertains to both epistemology and pedagogy of science literacy. According to Bazerman (1988):

Scientific formulations embody ideological components from outside the realm of science. From this point of view the work of science is to advance or provide foundation, legitimacy for larger social programs which themselves may simply be the result of class interests…. Scientific language serves to establish and maintain the authority of science, largely through exclusion and intimidation. (p. 294)

Appeals to objectivity are pedagogically problematic because the claim of objectivity is itself a culturally specific notion that privileges some ways of thinking and discredits other ways. Objectivity then cannot be promoted as being pedagogically appropriate. When we examine traditional objectivity from linguistic, historical, and social-justice points of view, it appears to be a culturally narrow and pedagogically ineffective epistemological stance. When objectivity is regarded as a requirement for science literacy, then science educators have cause to be concerned about both the “science” and the “literacy” components.
Thus far we have considered two fundamental tenets of science literacy: the life/non-life division and epistemological objectivity. We have presented contributions about these two ideas from discourse studies of science and suggested ways in which these contributions may challenge current conceptions of scientific literacy.

Conclusions

The recent emphasis on science literacy within science education has generated a complicated mix of effects that are similar to effects in other fields in the shift from modern to postmodern worldviews. In this shift, previously discrete categories and classifications have become blurry and hybridized. When “science” is combined with “literacy”, certain fundamental categories—life versus non-life, objective versus subjective, and scientific versus cultural—become less clearly defined, and the boundaries between them are less distinct. Current debates in science education about what constitutes science literacy have shaken up some conventional beliefs in scientific certainty. Some science educators may view these shake-ups as the beginnings of “new” scientific developments, and, according to differences in dispositions, they may react to the newness of things with either revulsion or delight. However, it is also possible to see these debates as not new at all. These recent disturbances may be regarded as yet more examples in a long history of scientific revolutions (Kuhn, 1962). It has not been our project in this paper to argue that recent definitions of science literacy are better or worse than previous definitions of accomplishment in science education. Rather, we have tried to show some ways in which literacy studies have had particular and profound effects on ways it is possible to think about science within science education.

Even within a focus on science literacy, there may be continuing efforts to try to preserve traditional boundaries around foundational concepts of modern science. These may be efforts to render “science literacy” indistinguishable from science/ business as usual. This is certainly true about the life/non-life distinction as expressed in the National Science Education Content Standards: “The standards for physical science, life science, and earth and space science describe the subject matter of science using three widely accepted divisions of the domain of science” (NSTA, 1995). In these efforts to preserve discrete boundaries around concepts we can see the influences of modern schooling including the formation of an ordered curriculum and the influx of developmental psychology (see, e.g., Popkewitz, 2002; Rose, 1989).

In some cases, the recent definitions of science literacy have extended and reinforced the influences of modern schooling, namely to “thingify” concepts and to engender a rationally ordered curriculum. However, these conservative efforts have both epistemological and pedagogical ramifications that have not always survived the assays of literacy studies. For example, linguistic, historical and discursive scholarship clearly shows that objectivity is a culturally and historically specific invention. The tendency to abstract bits of scientific knowledge from their historical context is a tendency that reflects a particularly modern ideology in which statistical generalizability was regarded as efficient as a means to administer society (see, e.g., Novick, 1988; Foucault, 1972, 1970). Furthermore, objectivity cannot be promoted on grounds of pedagogical effectiveness or developmental appropriateness because Piaget’s developmental sequence (which proceeds from concrete to abstract) is itself a historical product that privileges some culturally specific ways of thinking. Finally, the perpetuation of fixed concepts in science education (like life versus non-life and epistemological objectivity) misrepresents a broader history of science, which consists of many complicated stories that are
full of change and nuance. In his analysis of modernity, Toulmin (1990) refers to preservation efforts as examples of nostalgia. Toulmin suggests that the spirit of nostalgia goes against the scientific spirit of exploration. The inclusion of literacy in science literacy does not necessarily mean that science education is shifting from “hard” science to “soft” science. Rather, the inclusion of science-as-discourse suggests a definition of science literacy that recognizes the historical production of scientific knowledge, and in so doing extends the possibilities for what can be thought, studied and imagined in the name of science education.

References


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i [http://books.nap.edu/html/nses/6a.html](http://books.nap.edu/html/nses/6a.html)

ii The Classical, genomic and Baltimore systems are current methods for the consideration of viruses, yet differ in regards to treatment of the various mechanisms of viral genome replication.


v Classical works in this vein include Whorf, 1956 and Wittgenstein, 1968.

vi Many philosophers would object to these authors’ definitions of postmodernism and relativism. However, these objections do not interfere with the overall thrust of the article’s central claims.

vii According to a citation search in the Web of Science database, of 34 journal articles that cite Harding’s (1992) piece on objectivity, only two of those citations appear in education journals (Stage & Milne, 1996; Stage & Maple, 1996), and neither of those is a science education journal. Harding is cited only twice in the last two volumes, 2003-2004, of the *Journal of Research in Science Teaching*. 

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In practice, most language teaching in public schools still follows these older assumptions, and university foreign language teacher education is engaged in a perpetual struggle to change teaching methods from formalist drills to communicative activities.

There is no agreement in language acquisition research about why this may be the case. Some connectionist research suggests that memory is facilitated when neurological processing can establish multiple associations, such as those provided by contextualizing information (see, e.g. Levy, 1995).