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Scientific literacy as an emergent feature of collective human praxis

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> *Hamlet:* The time is out of joint; O cursed spite
> That ever I was born to set it right!
> Nay, come; let's go together.
> —Act I, scene v, lines 189–191

The time is out of joint. I cannot avoid remembering September 11, 2001—I was in Barcelona, Spain, attending an international science education conference where I was to give a plenary talk about science education as praxis for making a better world. Ironically, on that day I was forced to experience the negative results that the work of science educators can bring forth. I watched (through technology enabled by science, enabled by science education) an act of horror (enacted through technology, enabled by science, enabled by science education) as the Twin Towers of the World Trade Center were destroyed and thousands working there were killed. Back at home, I had to experience the response. Again live, I saw more acts of horror as B-52 bombers (developed by engineers and built by technicians, trained by science educators) destroyed Afghan villages and maimed more innocent people, mostly women and children. There were, of course, other responses in the wake of these events, the redirecting of funding from humanistic programs, increased efforts in the areas of science that feed the technologies of 'star wars', of 'exoatmospheric kill vehicles' and other 'hit to kill' technologies, and of bomblets of the type that littered Afghanistan and functioned as antipersonnel landmines.[1] Colm O'Cuanachain, Chair of Amnesty International speaking at the Centennial Nobel Peace Prize Symposium on December 6, 2001 suggested that 'in response to the horrific human rights abuses of September 11, governments are moving to restrict civil liberties and human rights, ostensibly to promote security'. The means of restricting civil liberties and human rights were again linked to technologies that automatically record and recognise ordinary citizens' faces as they pass airport security, which, once implemented broadly, is a means of tracking frequent travellers in every move they make. Again, scientists and scientifically trained engineers and technicians are involved in designing and developing these technologies. Further development of weapons and 'security systems' that destroy human lives and restrict human freedoms are in the making, if we believe the US Secretary of Energy Spencer Adams speaking on homeland security:

> Our world-class scientific and engineering facilities and creative researchers have helped make our nation more secure for over 50 years. These same resources have been trained on the threats posed by terrorism for some time, and because of this foresight, technologies such as these are in deployment today.[2]

And again, scientists were at the forefront of the development as the Lawrence Berkeley National Laboratory offered its expertise and program experience to the US leaders charged with 'strengthening homeland security' and 'countering terrorist activities'. That is, the causes, results, perceptions of, and

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[1] On the way that I am writing this introduction, even my usually non-interventionist nation Canada is earmarking $7.7 billion to increase its security on land, in the air and on the seas.

[2] See, for example, the web site of the Office of Science of the U.S. Department of Energy, which has 'Science for America's Future' as its motto (http://www.er.doe.gov/feature_articles_2001/December/Homeland_Security/Homeland Security.htm).

responses to the horrors of terrorism, war, and resistance are deeply about science and technology as well as people, culture, mores and ethics. Science is deeply enmeshed with all aspects of our world—in both good and bad ways—and events like the attack on the World Trade Center, the subsequent Anthrax scare in the US, the mass killings of livestock in Britain, the fears concerning GMOs and economic globalisation make this apparent. They make imperative an articulation of scientific literacy that is deeper and more critical than that espoused in current science education initiatives.

The time is out of joint. Every night, science- and scientist-related images flash across the television screen. A drug is pulled off the shelves after 30 years on the market because it has now proven to be cancerous. Geneticists manufacture plants whose seeds are infertile and cannot be used to plant for a crop during subsequent years. Few other than those in the anti-GMO and anti-globalisation efforts seem to be concerned and challenge scientists to account for their actions. Time and again, industry, which often uses scientists as their mouthpieces, tell television audiences to leave them with all decisions because, so they say, they know best. But, having been trained as a research scientist myself and having tried to shed the shackles of the indoctrination, I very much doubt that scientists on their own 'know best'.[3] As a citizen and science educator I ask myself before, during, and after the nightly news, 'How and where do we provide opportunities for this and future generations to engage scientists in a dialogue about what they do and what they produce?' 'How and where do we currently allow scientific literacy to emerge?' The traditional answer to the question about scientific literacy is to expose children and older students to a faint and distorted image of scientists' science. This science is claimed to be a pure subject, often taught in special, physically separated rooms, 'unsullied' by common sense, aesthetics, economics, or politics that are characteristics of everyday life. Science education is, as I have argued in the past, a form of indoctrination to a particular worldview so that young people do not question the very presuppositions that underlie science (Roth 2001). Scientific literacy currently means to question nature in ways such that do not, reflexively, also question science and scientists. The worst is the other part of the current rhetoric about scientific literacy—it is to be for *all*. All individuals (e.g., Americans), so goes the idealist rhetoric, have to learn and exhibit certain 'basic' facts and skills. Just imagine, every individual taking the same ('scientific') perspective on GMOs, genetic manipulation of the human genome, or use of drugs (such as those used to dope certain kinds of children, labelled 'ADHD' to make them compliant). I believe that the classical approaches to scientific literacy, knowing and learning, are based on an untenable, individualistic (neo-liberal) ideology that does not account for the fundamental relationship between

> DERRIDA: To live otherwise, and better. No, no better, but more justly. But *with them*. No being-*with* the other, no *socius* without this *with* that makes *being-with* in general more enigmatic than ever for us. (1994, xviii, emphases in the original)

individual and society. There is a need to rethink some of our educational goals in terms of society, in terms of 'with them', 'socius' and 'being-with'. There is a need to rethink our duty to partake in collective responsibility and to develop a social consciousness with respect to the issues that threaten our planet. I therefore suggest (O cursed spite / that ever I was born to set it right!) that we treat scientific literacy as a recognisable and analysable feature that emerges from the (improvised) choreography of human interaction, which is always a collectively achieved, indeterminate process. Upon reflection, I know it cannot be upon myself to set the times right. I therefore say, 'Nay come; let's go together'.

The time is out of joint…

Without doubt, new scientific discoveries and technological inventions render the world increasingly complex and the sense that things are advancing, getting better, seems to be increasingly ambiguous. My

[3] When I suggested to my physics professors that they were only teaching physics like a tool to make and find out things but that they were never teaching or providing opportunities to talk about its philosophical and ethical implications, they responded that exactly that was their job.

feelings about my role as science educator are highly ambivalent—do I advocate science or advocate its critique, do I search for ways to effectively pass along the canon or enable its deconstruction? Is the better world created through science and science education or through its subversion? In all of this fostering students' scientific literacy has become a primary goal for science educators (Kolstoe 2000). Yet the concept of scientific literacy is itself not at all clear (DeBoer 2000). The reigning ideology expressed in recent science education reform documents portrays scientific literacy as an individual property and characteristic of students in science (AAAS 1993, NRC 1996). Thus, a particular version of science, its knowledge, skills, and attitudes is to be appropriated by all Americans (AAAS 1989) independent of their interests, predilections, needs, or values. 'Everyone', the authors of *Science for All Americans* argue, 'should acquire the ability to handle common materials and tools for dealing with household and other everyday technologies, for making careful observations, and for handling information'. 'By the end of grade 12', so goes the rhetoric, 'all students should develop understanding of the cell, molecular basis of heredity, biological evolution, interdependence of organisms; matter, energy, and organization in living systems; and behavior of organisms' (AAAS 1993). But why should everyone know about meiosis and meitosis (i.e., the molecular basis of heredity)? And why should the public debate about inherited diseases and the use of genetic manipulation be approached from the same ideological position?

The other aspect of the rhetoric concerns the actual state of knowledge each individual 'has'. Currently many citizens are said to have 'blanks' in their background knowledge left by formal education and therefore need to be given 'information' to make these up. Thus,

> a fundamental mismatch exists between the kinds of knowledge educational institutions are equipped to impart and the kind of knowledge the citizen needs.… So *scientists* must define what parts of our craft are essential for the scientifically literate citizen and then put that knowledge in a coherent package. (Hazen and Trefil, 1990, p. xvii, italics added)

Here it is assumed that it's the scientist's place to define what should be known in the field—why should this be when at other times and places scientists claim a lack of interest in how science is used and taught? Others suggest, more strongly, that most people are not only ignorant but also incapable of scientific literacy (e.g. Shamos 1995). Like the makers of the film *A Private Universe* (Schneps and Sadler 1987/1992), many have mocked the Harvard graduates who, answering the question 'Why is it hotter in summer than in winter?' suggested that it was because the Earth was closer to the sun. Isn't it reasonable to assume that the closer you are to a source of heat, the warmer it feels? Why is it so bad not to know that the effect of the tilt by far outweighs the effect of the distance? Surely, we can think of cases where the distance would play a more important role than the tilt. Here, then, scientific literacy is defined in terms of right answers (not reasoning) that individuals give to questions in interviews or on questionnaires.

Despite the rhetoric of scientific literacy for *all*, it is becoming increasingly clear to some science educators that time is out of joint. The spectres of individualistic formulations of educational goals are haunting us. Many students do not continue with science beyond the required courses. Some students drop out (in North America about 20%, but with large regional and local disparities) and therefore do not even have the opportunity to be exposed to whatever the rhetoric espouses for the junior and senior grades. In fact, the very way grades and scores on tests for college admissions purposes are constructed and used contributes to the elimination of many students from scientific career tracks (Roth and McGinn 1998). The very focus on individual achievement shakes many individuals out of contributing to the society in science and science-related fields. Surely, time is out of joint. It behoves us now to question our presuppositions and ideologies and seek for different ways of thinking about science education.

O cursed spite / that ever I was born to set it right

In rethinking scientific literacy in new and radically different ways, I take my cues for thinking knowing and learning from everyday community-based activities in which science, scientific facts, and scientific methods are contested. I challenge reigning assumptions about knowing and learning, which, according to Lave (1993: 15) depend 'implicitly on a homogeneity of community, culture, participants, their motives, and the meaning of events'. Rather than attempting to reason about scientific literacy, collective human practice, and my analogy of thread and fibre in the abstract, I begin with a brief episode from a public meeting in which conflicting voices in the struggle over access to water came to be presented. Taking cues from 'citizen science' may be a much more fruitful curriculum theorising endeavour than taking them from scientists (Jenkins 1999, Fensham in press).

Scientists and citizens: an episode

In the community of Oceanside, the residents of Salina Drive all have their individual wells, which are recurrently contaminated biologically and chemically during the dry summer months. A water advisory is put into effect and these residents have to get their drinking water by driving about four kilometres to the next gas stations. The community refuses to extend the watermain that supplies all other citizens with safe drinking water; this refusal was in part based on the fear that the residents would attempt to develop Salina Drive and therefore change its rural character. A public meeting was scheduled to allow a public discussion of the various reports that had been filed and discussed by the town council. In the meeting, a range of issues from different perspectives was introduced. In these issues, 'science' was identifiable but never standing on its own; the scientists' science was but one type of thread yet one that appeared in a variety of colours. The decisions to be made interconnected with scientists' science but never only with it; a new form of science and scientific literacy emerged from the collective effort, one that is actually sustainable in the community and has the potential to involve all citizens. Such connections can be seen in the following contribution made by Frank Fowler, President of the local voters' association and spokesperson for the residents of Salina Drive during the third, public-comment part of the meeting.

> The people in the area where the watermain would go, I believe, they are all very environmentally conscious and wish to maintain the environment as it is today. We are not interested in development. It is my understanding that the Henderson Creek water is supplied from, a great deal of it is supplied from the aquifer, and that during the summer months 50% of the water that flows into Henderson Creek comes from the aquifer. If we take people off the aquifer and put them on a watermain we will be supporting more water in that creek. [Frank Fowler, President of the local voters' association and spokesperson for the residents of Salina Drive]

One of the (conversational) threads that had been developed in the community was suburban development: If there was a watermain being built this would open the possibility for new housing and more people in the area. Fowler suggested that this was not the wish of the people who would benefit from the watermain. Rather, these citizens are environmentally concerned, a concern that is further underscored by the fact that the watermain would decrease the pressure on the aquifer thereby making more water available to the creek. Their concern for the environment is double—no new housing, which would entail more impervious surfaces, more cutting of trees, and the like, and more water into the creek.

Here, too, in his comment on an earlier contribution by a research scientist serving on the community's Water Advisory Task Force, environment, the politics of development, and geological science emerges. Some readers may be tempted to argue that it was Fowler who made this statement and who should be attributed a certain level of scientific literacy. However, rather than looking at the words as if they emanated from a disembodied and disconnected individual we need to consider the historical context of the unfolding event. Thus, Fowler's contribution followed that made by

Carmichael, a member of the local Water Advisory Task Force, who defended the position that they had taken against a new watermain in the valley.

> You look at a curve like that and you wonder why 1998, which was the hottest record in the millennium, and this past year, which was a very one of our wettest years, only filled the aquifer to the same point. It is because of what we've done within the aquifer. We've paved it and we've turned it into a fast track for storm drainage so water never gets a chance to get back into the aquifer. I would like to see that no matter what the solution of the Salina Point problem is, we take a hard look at protecting the aquifer. The aquifer feeds the creek; without the aquifer there is no flow through Henderson Creek, without it, there will be no fish. [Ted Carmichael, member of the Water Advisory Task Force]

Again, readers may be tempted to attribute this comment to the individual, a resident of the area who is also a scientist in a nearby government research institute. Yet again, Ted Carmichael had spoken up after he heard the previous speaker make 'allegations that the four of us [majority on Water Advisory Task Force] are some eco-warriors' to which he wanted to take exception. After Fowler had spoken, many listeners applauded and laughed, clearly indicating their agreement and support with the statements made. This applause and the laughter, like the struggle for the speaking turn, were as much a recognisable and analysable feature of 'scientific literacy' as the contributions by Fowler and Carmichael that addressed ecological and geological issues related to the lack of water and its quality at Salina Point. Scientific literacy should not be sought in (the heads of) Fowler and Carmichael, and lack of scientific literacy should not be attributed to those individuals who did not speak up during the public meeting. Rather, these contributions take their place in and are part of a much larger conversation. But conversations are irreducibly collective phenomena, they cannot be understood as the sum of individual contributions (Edwards and Potter 1992). All those present contributed, in their own way, to the public meeting and scientific literacy. Knowing, as learning, therefore 'does not belong to individual persons but to the various conversations of which they are part' (McDermott 1993: 292).

A second important point that is seldom addressed in the context of scientific literacy pertains to access. If the access to ongoing conversations is not enabled, particular citizens cannot become part of the choreography of scientific literacy. In the following situation, the citizen Fowler wanted to make a comment to elaborate on an issue raised by the previous speaker, Ted Carmichael. However, the moderator of the session, Bisgrove, wanted to prevent Fowler from making a comment, stating that 'everyone has a bias or concern about' the issues raised. (The overlapping square brackets in consecutive lines indicate where the speakers overlap.)

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Fowler:    I too would like to make a comment about the previous speaker's comments. I
           believe we all [have a
Bisgrove:                 [Frank?!
Fowler:    Frank Fowler.
Bisgrove:  Yeah, I know but everybody has a bias or a concern about it.
Fowler:    No [I could
Bisgrove:     [I don't know if Ted said anything in particular. All he was doing was
           presenting his [side-
Fowler:                   [This is, this is just a [comment-
Bisgrove:                                          [his side of the Water Advisory Task
           Force. Well, okay. Let's try [and-
Fowler:                                 [It's very brief.
Bisgrove:  Well, let's try not to bash each other, please.
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Fowler attempted to take the floor to make the desired comment, whereas Bisgrove tried to prevent him, as anyone else, to engage in critique that might lead to a confrontation ('let's try not to bash each other'). As we saw earlier, Fowler did get his say. But had Bisgrove achieved to prevent Fowler from speaking, a different kind of conversation would have emerged. That is, the choreography of scientific literacy has to include not only what is said but also the ways in which it is said and the struggles to get something said in the first place. Scientific literacy also is about access to conversations about contentious issue, and its opposite is about patronisation by scientists that dwell in hubris.

In this episode, scientific literacy is not just about knowing science in a traditional sense, or participating in a public meeting from which scientific literacy emerges as a recognisable feature. Rather, scientific literacy also means participating in the choreography of the public meeting, enacting access to participation and thereby contributing in different and changing ways as the event unfolds. Preventing people's access to the speaking floor is an integral part of the choreography of the public meeting, and an integral part of scientific literacy that can be observed. (Preventing anti-GMO and anti-globalisation protesters to voice their dismay in appropriate public places is also an attempt to curtail their contribution to the collective praxis of scientific literacy.) During the second part of the hearing, Bisgrove repeatedly asked 'Are there any other questions of a technical nature?' That is, this 'second part' itself was recognisable as such because of the type of questions that Bisgrove, a gatekeeper and 'obligatory point of passage' (Latour 1987), attempted to allow. It is not that other types of questions could not arise. As we have seen, Fowler was able to make a contribution where Bisgrove did not foresee one. Rather, 'second part' characterised by 'technical questions only' are descriptors whose usefulness in this context can be established only after the fact. Negotiating access and preventing it, involving different people with different social positions, is part of the choreography of 'scientific literacy'.

Of threads and fibres: scientific literacy as a collective phenomenon

In the past, science and society have been thought as two entities, two categories that are opposed like the citadel, science, and the polis, the untutored public with all its deficits of misconceptions, alternative frameworks, naïve theories, and so forth. Recent work in the anthropology of science suggests that the citadel is porous, 'science' and 'society' cannot be thought separately but, as categories, are produced inside a more general, heterogeneous matrix of culture (Latour 1993). Culture itself, 'meaning fundamental understandings and practices involving such terms as the person, action, time, space, work, value, agency, and so on, is produced by a far wider range of processes than those deployed by experts producing science' (Martin 1998: 30). Scientists claim that science is pure and that truth will come out whenever there is an instance of a rarely occurring mitigating social influence (Gilbert and Mulkay 1984). Frequently, through their extensive and laborious boundary work (Gieryn 1996), scientists attempt to encapsulate themselves and maintain the image of the citadel standing in opposition to the sullied polis, with its economic, ethico-moral, and political dimensions. But, in fact, science and scientists are just part of discontinuous, fractured and non-linear network of relationships from which 'science' and '[the rest of] society' are made to emerge as constructs. When science and its role in society are studied as everyday activity, their collective nature begins to appear; activity theory is an appropriate framework to conceptualise science, knowing, and learning in and as collective phenomena.

Activity theory articulates human activity in a non-reductionist manner, accounting for the many different ways in which the relationship between individuals and objects of their activities are mediated by tools, community, rules, and division of labour available in the situation. In activity theory, differences in the social location of individuals are inherent in societal structures and arise from specific practices that both produce and re/produce these differences. Differences in interest, motivations, power, and action possibilities are ubiquitous.

The currently dominant (psychological) view takes knowledge to be a collection of entities (representations, concepts, or structures) in heads and of learning as a process of internalising or constructing them. In this view, 'learning' is problematic because teachers and curriculum designers are concerned with the ways in which the external environment has to be configured to allow, depending on the theoretical commitments, knowledge appropriation, transfer, or (internal) construction to occur. A minority view takes knowing and learning to be 'engagement in changing processes of human activity' (Lave 1993: 12). In this approach, 'knowledge' as we have come to know it changes, becoming itself a complex and problematic category. What constitutes 'knowledge' at a given moment or across a range of situations are matters of analysis, which has to take account of the motivations, interests, relations of power, goals and contingencies that shape the activity. It has been proposed to focus on the production of knowledgeability, a flexible process of from which individuals and their lifeworlds emerge. This knowledgeability

> is routinely in a state of change rather than stasis, in the medium of socially, culturally, and historically ongoing systems of activity, involving people who are related in multiple and heterogeneous ways, whose social locations, interests, reasons, and subjective possibilities are different, and who improvise struggles in situated ways with each other over the value of particular definitions of the situation, in both immediate and comprehensive terms, and for whom the production of failure is as much a part of routine collective activity as the production of average, ordinary knowledgeability. (Lave 1993: 17)

I want to conceive scientific literacy in the same way (O cursed spite / that ever I was born to set it right!) When theorised from the viewpoint of praxis, 'scientific literacy' is not something that is owned by (or characterises) certain individuals. Rather, 'scientific literacy' is an emergent, collective phenomenon. Such scientific literacy may, for example, emerge when ordinary citizens question a scientist about the methodology he used, which turns out to fall short considering the problem at hand. Recognising this falling short as a collective achievement is the kind of scientific literacy that I am advocating here. This scientific literacy, then, emerges when scientists, science-related professionals, and people from other walks of life and with different backgrounds engage each other over contentious and personally relevant issues. Thus, everyone (speakers, listeners, moderator) and everything (reports, spatial arrangements, historical context) in the public meeting was part of the appearance of scientific literacy. Activity theory allows us to rethink the context of scientific literacy, human activity, and the relation between individual and context. Thus, contexts are not containers filled with people nor are contexts situationally and individually created experiential spaces (Engeström 1993). Rather, contexts are activity systems, heterogeneous and historically constituted entities composed of many, often dissimilar and contradictory elements, lives, experiences, and voices and discontinuous, fractured and non-linear relationships between these elements, lives, experiences, and voices. 'Context is not so much something into which someone is put, but an order of behaviour of which one is part' (McDermott 1993: 290). Context therefore gives rise to interactional possibilities, which are the source of 'individuals', 'scientific literacy', and so forth.

To return to my story of the Water Advisory Task Force in the community of Oceanside, science is tied up in the thread of life as a fibre among fibres. Individuals, as some activity theorists (Holzkamp 1983) have described (though in different words), participate in and are part of the collective life as the fibres that make the thread (of life).[4] Thinking the relationship between individual and collective life in terms of fibre and thread allows us a new approach to theorising 'scientific literacy'. It is no longer a property of a single fibre or a small number of fibres (scientific community) but it is a property that becomes recognisable and analysable at the level of the thread. Thinking of science as a fibre among fibres helps us to understand it as an entity and as context in a more general endeavour (thread). From the perspective of the thread, science plays a role as all the other forms of knowledge and practices; any attempt to privilege it abstracts from the fact that it itself exists only because of all the other threads. Science education would then be the endeavour to make scientific literacy possible as a collective rather than individual characteristic. It would amount to creating opportunities for individuals (fibres) to participate, each in their own ways, to contribute to the emergence of the phenomenon at a collective level. We are then interested not only in what scientists have to say at the meeting, but also in what all the others have to say who participate (speak, listen, applaud), and specifically the residents whose access to proper drinking water is being denied. This means that not all individuals have to know a basic stock of scientific facts or concepts—we do drive without knowing anything about car mechanics and we do eat bread without knowing how to bake. If we take scientific literacy to be a characteristic of emergent collective practice, then it does not matter which piece each

[4] Holzkamp (1983) provides a categorical analysis of society and human subjectivity. Accordingly, different forms of human life are made possible because of the division of labour (a key concept in activity theory); it is therefore only through the analysis of collective systems that we can understand individual subjectivity.

and everyone contributes but that in the end, decisions are made that take account of a variety of relevant (local) knowledge, values, and beliefs.

Rethinking knowing and learning, science and scientific literacy, and collective public meetings and individual contributions from the perspective of fibres and thread, leads us to radically different conclusions about what and how curriculum should be designed and enacted. When learning is no longer identified with grey matter between the ears but with the relations between people and with doing things together, our views of teaching will change. When learning no longer 'belong[s] to individual persons, but to the various conversations of which they are part' (McDermott 1993: 292), we need to rethink what science curriculum ought to look like. Scientific literacy is then no longer something that is acquired by the child and carried into other settings within and outside of schools. Rather, scientific literacy is something that emerges as a recognisable and analysable feature of (collective) human action and interaction in which the child is but one part.

Nay, come; let's go together

The public meeting, at Oceanside and elsewhere, has provided an opportunity for scientific literacy to become a recognisable and analysable, collective phenomenon. A new form of collectively generated societal activity was made possible in the organisation of the public meeting and in the provision of the questioning and comment periods. Scientific literacy emerged because the citizens were involved in an issue where there was something at stake. A problem in the scientific methodology employed, which had surfaced during the meeting, was not articulated by the engineer who had conducted water tests; the weakness was an outcome of the conversation between the engineer and concerned citizens. In the same way, the omission of important historical knowledge in previous decisions and deliberations was an articulation in the public conversation at the meeting. Thus, the analogy of fibre and thread for the relationship between science and other forms of knowledge in controversies about problems allows me to rethink what knowledge means in the curriculum. Does everyone have to know the same things? Does every student have to be competent on the same issues? We all know that there simply exists too much specific knowledge for any individual to know the relevant facts even in more constrained contexts. What is important is that as collectives we produce the substantive knowledges relevant to the problems at hand. Yet few children and students are prepared to participate in public debates over *real* issues and concerns. Educators may be tempted to teach all the facts that were mentioned during the public meeting. But then, we would spend much more time in school even if knowledge transfer from school to workplace and everyday life were less problematic then it already is. We would also end up producing future generations that all have the same set of blinders, think in the same way about GMOs, genetic manipulation, and designing new weapons. If we think of scientific literacy in different terms, as choreography of a particular kind in which we learn to participate by participating from the beginning, we take radically different approaches to teaching science in schools. For example, our children and students might already participate in activity systems that benefit the community, and participate in the ongoing discourses and concerns that are relevant to their parents and the community at large.

If we abandon the ideology that *all* students should demonstrate scientific competencies and accept that scientific literacy means the collective production of certain competencies and free access to all the mediating resources students require, then what might we do? We might begin by providing opportunities for the collective production of scientific literacy to be brought forth. 'Surely,' some readers might be tempted to say, 'this is a dream. Literacy for all does not emerge unless we *make* everyone learn the right stuff'. 'It is possible', I would respond, 'and has been done'. All you need to do is to ask Bernard, the elementary school teacher in Moussac, France (Roth 1998). Bernard does not 'teach'. He does note tell students what to study ('they do well without me'). He does not follow a prescribed curriculum. What he does is provide the opportunities for the collective to engage in activities. It is in the context of the community that all children come to know, but not necessarily the same things; it is in the context of collective activity that each child finds its place and always becomes literate. Children, when they come to school (they decide themselves what time) write on the board what they will be doing that day, like writing a pen pal, inventing some music, building something in the shop, or writing poetry while sitting near the pond behind the school. Throughout the day, children interact with each other and the adults who come as resource persons for playing chess or tending the garden. In the course of pursuing activities of their interest, all children learn to read, write, and do arithmetic. They also learn everyday things by doing them, like how to post a letter, how to garden, how to write poetry, how to compose music, and how to dream. But Bernard does not have to 'teach' these things. Rather, all Bernard does is make the community work.

> For slowly I learned that when the children are part of a group that really exists as a community, when there is a real setting, when the interactions with this setting, with other children and adults, when this context really exists, at that point, all children without exception learn to read. (p. xiv)

It is out of the existence of this community that literacy emerges. The children produce it together, for example, while the older ones read to the younger ones until the latter take the place of the former with a new generation of younger ones.

Time is out of joint—conceptualising scientific literacy as a feature of collective praxis changes the problems we are facing today. Science educators now can think about how to set up situations so that contexts (rather than individuals) exhibit scientific literacy. How can this possibly be done? The task appears so huge. It is likely that teachers cannot do it alone. It is certain that ivory tower reformers cannot do it alone (I don't think 'that ever I was born to set it right'). Certainly, we do not bring about change by thinking about reform theoretically first and by implementing the results of our thinking after. Let me take my cue from Shakespeare once more. 'Nay come', he makes Hamlet say, 'let's go together'. I join him there and thus. I view educational reform in the way I view scientific literacy: as a collective phenomenon. Science education reform must become a collective effort where teachers and researchers join their hands to change current conditions in and through daily praxis (Roth and Tobin 2002). Based on my own experiences of teaching science alongside other teachers in several seventh-grade classes in Oceanside I know that such a view of scientific literacy provides new opportunities for conceiving of science curriculum (Roth in press). Rather than preparing students for life in a technological world, I work with teachers to create opportunities for participating in this world and for learning science in the process of contributing to the everyday life of the community. Children and older students can (and in some cases already do) participate in environmental activism, salmon enhancement, farming, or traditional food gathering ceremonies among aboriginal peoples. Early participation in community-relevant practices provides for continuous (legitimate peripheral) participation and a greater relevance of schooling to the everyday life of its main constituents. These new opportunities also include the (dangerous?) possibility of a politicisation. Thus, one of the grade 8 students I worked with decided to investigate the frequency of coliform bacteria at different locations in a local creek. Drawing on a university scientist to learn how to do the analyses, he found, that just below two farms in particular the counts were way up. He negotiated access to an open-house event organised by environmental activists where he not only reported these results but also noted that he had not been allowed to conduct further tests just above the two farms.

As a citizen and critical science educator, I am pleased to see such events because they show that there are indeed ways to bring up citizens in a new form of scientific literacy, citizens for whom scientific literacy is a form of collective human praxis. The student contributed to the emergence of scientific literacy in the community, leading to awareness in the community about the water pollution from farms. At the moment though, neither scientists (who feel they 'know best') nor politicians (who exclude alternative voices) are ready to allow scientific literacy to emerge in the way I advocate it here. Just as the eighth-grade boy was prevented in his investigations, global corporations (often by manipulating and using governments and scientists) attempt to exclude the critical voices in our society from the conversation about issues such as genetic modification, use of hormones in the raising of animals, use of pesticides in food production, and so forth. They attempt to use their economic power and that of the American nation to make other nations accept their GMO products, their cigarettes, and their hormone-infested meat. There is more than one reason to rethink scientific literacy and to see it as an emergent collective praxis. The time is out of joint. I ask, 'come; let's go together'. But let's go!

> Exeunt, bearing off the bodies;
> After which a peal of ordnance is shot off.
> —Act V, scene ii

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