

Scientific literacy as an emergent feature of collective human praxis

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In this article, I propose to view scientific literacy—contrary to the current paradigm—as an emergent feature of (collective) human praxis. I propose an analogy of a thread and its fibres for conceptualising the relationship between science (fibre) and everyday activity (thread). To exemplify the utility of this framework, I draw on data collected during a three-year ethnographic study of environment-related activities in a local community. I provide a detailed analysis of a public meeting in which scientific and technological expertise were implicated in important ways.

Without doubt, new scientific discoveries and technological inventions render the world increasingly complex. Fostering students' scientific literacy has therefore become a primary goal for many science educators (Kolstoe 2000). Yet the concept of scientific literacy is itself not at all clear (DeBoer 2000). In this article, I contest the reigning paradigm, which holds that scientific literacy is an individual property and characteristic of students in science. ('The science class should give students the knowledge and skills that are useful in the world of work...' [DeBoer 2000: 592].) I propose instead that scientific literature should be understood as a recognisable and analysable feature that emerges from the (improvised) choreography of human interaction, which is always a collectively achieved indeterminate process.

What scientific literacy is depends very much on the conception of knowing and learning that is discursively associated with it. Despite differences in the definition of 'scientific literacy', the reform rhetoric describes the individual informed citizen as one who participates in public discourses and uses rather than produces science. Many citizens are said to have 'blanks' in their background knowledge left by formal education and therefore needs to be given 'information' to make up (Hazen and Trefil 1991); others suggest, more strongly, suggest that most people are not only ignorant but also incapable of scientific literacy (e.g.

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Shamos 1995). Like the makers of the film *A Private Universe* (Schneps and Sadler 1987/1992), these authors mocked the answers that Harvard graduates gave to the question, ‘Why is it hotter in summer than in winter?’ Here, scientific literacy is defined in terms of the answers that individuals give to questions in interviews or on questionnaires. The implications of such individualist takes on scientific literacy are—because ‘every citizen should have some level of scientific literacy’ (Hazen and Trefil 1991: xv)—to find ways in which the individual comes to know more of the facts (and sometimes processes) of science.

To rethink scientific literacy in radical 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) that 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 (all proper names are pseudonyms), 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. The public meeting was scheduled to allow a 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; science was but one type of thread yet one that appeared in a variety of colours. The decisions to be made interconnected with science but never only science.

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. [Bisgrove]

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. Bisgrove suggested that this was not the wish of the people who would benefit from the watermain. Rather, these people 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 Bisgrove 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, Bisgrove's contribution followed that made by Carmichael, a member of the 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. [Carmichael]

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 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 Bisgrove 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 Bisgrove 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) Bisgrove and Carmichael, and lack of scientific literacy should not be attributed to those individuals who did not speak up during the public meeting. All those present and not present contributed, in their own way, to the public meeting and scientific literacy. Knowing, as learning, ‘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, a member of the Water Advisory Task Force. 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.¹

- 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 Ed 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.

The overlapping turns show how both Fowler and Bisgrove attempt to control access to the floor. Fowler attempted to get the floor to make the desired comment, whereas Bisgrove tried to prevent Fowler, as anyone else, to engage in critique that might lead to a confrontation (‘let’s try not to bash each other’). 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.

In the analysis of this episode, I show that scientific literacy is not just about knowing science in a traditional sense, or participating in a public meeting from which we have said that 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 also part of the choreography of the public meeting, and an integral part of scientific literacy that can be observed. 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 (of science) and the polis (the untutored public). 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 of collective phenomena.

Activity theory articulates human activity in non-reductionist ways, 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. Thus, 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)

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 phenomenon. Thus, everyone (speakers, listeners, moderator) and everything (reports, spatial arrangements, historical context) in the public meeting was part of the appearance of scientific literacy. Furthermore,

activity theory allows us to rethink the context of 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.

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).² 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. This means that not all individuals have to know a basic stock of scientific facts or concepts—most of us drive without knowing anything about car mechanics and we eat bread without knowing to bake.

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, our views of teaching will change. When learning does no longer ‘belong 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 car-

ried 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.

Struggle over troubled water: the context

The data sources for this article were collected as part of a three-year ethnographic effort to document science in the community, in environmental activist group, and in science classes where children produced knowledge that was made available to the community. The database includes fieldnotes, videotapes, and audiotapes documenting various ways in which the people of Oceanside³ and environmental activists pursued activities relating to the health of the watershed in which they live. (Elsewhere, we provided detailed analyses of fact construction by environmental activists and the democratisation of science in the community [Lee and Roth 2001a, 2001b, 2001c].) Here I focus on the participation of citizens and scientists in one particular audiotaped event, a public meeting concerning the problematic situation of the drinking water in one part of Oceanside. As a public meeting, the events reported here constitute an example of the ways in which ordinary citizens can participate in policy- and decision-making regarding environmental and health issues.

The public meeting was held in the community of Oceanside, where a variety of water issues are and have been a central and ongoing concern. In this particular case, the local and regional media had repeatedly reported on the situation in a part of the community, Salina Point, not connected to the watermain. All properties of Salina Point supply their own water from locally drilled wells and from cisterns. Because the wells are recharged mainly through precipitation, the water supply depends on weather patterns; very dry summers lead to depletion of the aquifer and a correlated increase in the mineral contents and contamination by biological organisms. Repeatedly in the last several years, local newspapers have carried stories about the fact that the water quality in these wells had been declared unfit for consumption without prior boiling, forcing residents to drive four kilometres to get their water from the next gas station. A total of six reports had been commissioned prior to the public meeting. The Council of Oceanside had called for a public meeting, including the authors of the technical and scientific reports. These authors would first provide a sketch of their work and subsequently avail themselves to questions and comments from the public. Further-

more, the hearing was to provide opportunities for members of the community to ask questions and to make presentations.

Heterogeneity of science: beyond the rigid body language

My research in the community (and particularly in public meetings) shows that ordinary citizens often feel disenfranchised by scientists who talk in decontextualised ways about the issues at hand, which often deeply affect residents life (presence of a high-power radio emitter, access to watermain). Scientists exhibit a very limited ('monoglossic') discourse and a very rigid 'body language', which they consider to be value free. They attempt to impose this discourse and body language wherever they are involved. In this community, as elsewhere, scientists attempt to 'bludgeon publics with "certain facts," often ignoring the public's own culturally embedded understandings: in sum, they practice a rigid body language that quickly alienates and disillusion their lay audiences' (Brown and Michael 2001: 18).

The first part of the public meeting constructed the scientists and engineers present as the 'experts'. Each expert was provided with the opportunity to elaborate key issues in the reports that they had produced, and took the amount of time they deemed necessary. There was no attempt to shorten or curtail any of the presenters—as this would happen in the subsequent parts of the meeting. The experts were constructed as such also by their and the moderators description of positions, titles, or degrees they held. Thus, individuals were variously introduced as 'professional engineer and a professional geologist', 'Public Health Engineer serving the regional district', 'Environmental Health Officer for the Oceanside area... [he] has a Masters of Science degree, and has significant experience with water quality issues and he has been involved extensively in both reports in the sampling episodes' or 'Chief Environmental Health Officer for our Health Region'.

All of these presenters had considerable time to make their presentations—something that is significant when held against the attempt by the moderator to limit questions and contributions of other participants. The independent consultant Lowell, an engineer and hydro-geologist provided a report in which there was no uncertainty left about his methodology of data collection and the facts that resulted from them.

[Lowell] The sampling methodology was, 'sample as close to the well as possible and at an outside tap or right at the wellhead'. We tried to avoid house plumbing and cisterns as much as

possible. So we pumped the wells for as much as 15 minutes and as much as one hour to get a fresh water supply coming straight from the aquifer and not coming from storage. The results of our testing as showed that according to the Guidelines for Canadian Drinking Water Quality, there are no concerns related to health. None were identified in the parameters that we tested. Some aesthetic objectives from the Guidelines for Canadian Drinking Water Quality were exceeded for some of the wells. [...] For all of the bacteriological testing done, no wells were found to be unacceptable. All of the bacterial, bacteriological results were acceptable.

[Magoo] Our suggestion, our conclusions in the final report and recommendations to Council were as follows. Number one, a systematic problem of groundwater supply in the Salina Point area has not been identified instead solutions to problems both quantity and quality can be provided on an individual basis. In this light Council may wish to provide individual homeowners with technical design advice as to the nature of each individually designed solution. Second, it is anticipated this approach will solve the Salina Point water issue in possibly every case. However at the end of a case-by-case household assessment where we actually look at solutions and Council facilitate people to do their own, as Mr. Lowell has said, to solve problems individually...

Magoo, university professor, chairperson of the Water Advisory Task Force, and the representative of its majority, presented a report that was very much built on the facticity of Lowell's report. Repeatedly, Magoo emphasised that Lowell's report was the 'first systematic' and 'unbiased' study of the water problems at Salina Point. Magoo and the report he presented articulated Lowell's science as definitive and all other forms of data as 'mere opinion'.

The presentations by Lowell and Magoo did not pass by uncontested. Another scientist, the representative of the regional health district, presented those present with a very different set of facts. Unlike Lowell, he emphasised the seasonal variations in the concentrations of various contaminants. He also talked about the differences between the concentration measures taken in the field—where Lowell had taken them—and when the water is analysed in the lab—where his engineers had analysed the water. Accordingly, Radford, a public health engineer, had come to the conclusion that there were substantial problems both with biological and physico-chemical pollutants (e.g., chromium), at least during particular times of the year.

[Radford] There is a very pronounced affect on the aquifer relative to rainwater as evidenced by the pH tested. A pH of 6.8 to 7.2 is similar to the pH of rainwater and if you look at the data you'll see a lot of the pH values in that range. The well data for a log at 617 Salina Point demonstrates that groundwater level fluctuation and that information is from 1996, October to June of 1999. So we do have a couple of years of data in there that shows us what that water table is doing. The total dissolved solids or TDS show the significance of dilution and if you look at the aquifer, you'll find that as the aquifer is drawn down, the chemical constituents increase so there is a fairly significant influence by dilution of the rainwater. [...] We had a

problem and a high level with our chromium levels. Chromium can be a problem when it combines with chlorine and goes to the trivalent state. This is when a carcinogen is formed. Chromium as it generally occurs in the water system is fine. It is a nutrient. But when we have to chlorinate a water system that's where we have the potential for some problems.

The minority report from the Water Advisory Task Force, here presented by citizen Rees, emphasised the problematic nature of a variety of measures and of several technical solutions proposed in the majority report.

[Rees] The report says itself that the analysis is done from the well logs of the area. Well logs, as you probably know, are what the well-drillers report when they hit water. And assumption in the report is made that those water volumes are accurate, they assume that they uh, that the well will run at that capacity all year long and that they will run at that capacity for eternity. Well, all of those assumptions are false. So if you're basing your analysis on false data I think that puts to great speculation the analysis itself. They say that there's no quantity problem and they're quoting, for example, simple math if say, you have 0.2 gallons per minute in a 24-hour period, you'll generate enough water for a household. Well, 0.2 gallons per minute is a very, very small amount and uh there are neighbours around us that have 10 times that flow according to their well logs and they still have uh shortages throughout the year.

In sum, there was no agreement between the scientists and within the Water Advisory Task Force as to the problem and its solutions. Lowell, Magoo, and the community engineer used a very limited discursive (scientific) repertoire; they represented the traditional assumption that there is something like science unfettered from social influences. The present data show that science itself is heterogeneous; science arises as a thread from the interaction of its heterogeneous practitioners and practices. Despite this heterogeneity, the town council took the stand (largely as the consequence of the majority report of the task force presented by Magoo) that the residents of the Salina Drive could not have a watermain. Here, the question was not that every citizen in a community of an industrialised nation *has the right* to sufficient and safe drinking water but that those supplied with the water had to pay for the cost of putting in solutions but excluding the watermain.

The contradictory reports from scientists working for different sides on controversial issues has led to the decreasing credibility of scientists, the infallibility of their knowledge, and their supposedly neutral role in policy (Gonçalves 2000). Fortunately, public meetings provide opportunities for ordinary citizens to participate irrespective of their level of scientific training; or rather, scientific literacy emerges only if public meetings provide spaces for people to talk and be heard. The thread of public meetings then includes citizens and different types of expertise as fibres. Although the initial part of the hearing could be read as a claim to the scientists' and engineers' authority over the water problem at Salina

Point, the participation of the citizens turned out problems in scientific facts and methodology. What are the appropriate facts and appropriate methodology in the public forum and the political process cannot be determined a priori—attributing them to the scientists and engineers—but has to await the outcome of the process.

Science, access, and the politics of voice

In schools, science is (generally) taught as if it and its results were value free and independent of opportunities of access. This, as much research in the sociology of science showed (e.g., Latour 1993), is not the case. Students or citizens cannot be part of scientific literacy if they are prevented from access to the floor of on-going conversations. In reconsidering scientific literacy as an emergent feature of praxis, the question of access and legitimate peripheral participation become crucial. The citizens in this community in general (e.g., in a case of the application for a high-power microwave emitter) and in this public meeting more specifically realised that due process should allow their voices to be heard. As recurrent newspaper features showed, the people in this community did not feel that their voices were heard or that their knowledge, built up through over 30 years of experience, was not valued (e.g., McCulloch 1999, Watts 2001). This is evident in the following episode, which began with a statement about the ripple effect that Lowell's report has had. It first influenced (heavily) the (majority) report by the Water Advisory Task Force, here represented by Magoo, which itself—as other speakers also pointed out—heavily influenced the decision by the town council.

- Naught: Well it seems to me that the report is relying.... Mr. Magoo's report is relying on very heavily on your information, which would suggest that it doesn't matter what the problem is with water, it can be treated. And I would beg to differ on that because I think that when you do something to the water, you affect it regardless of what the treatment is and where the treatment occurs. And that it affects the water in another fashion. So therefore this business of treating water is only a marginal thing with respect to water qualities.
- Bisgrove: We are straying sort of into the area of public opinion and your comments...
- Naught: He's an expert he just told us...
- Magoo: Well, I'd like to make one comment on this...
- Naught: I'm addressing, I'm addressing...
- Magoo: You're looking for technical... This is supposed to be a technical discussion and I think...
- Naught: No I'm talking to Mr. Lowell. I'm not talking to you, I don't think...
- Several: [Clapping] Yeah, we wanna hear.

- Bisgrove: Mr. Naught, I'm sorry but you're really not. If we can keep to a specific question you certainly able to ask questions if we're going somewhere with it but I don't want to get in to a detailed bit by bit tearing something apart.
- Naught: Why? I mean, I'm asking
- Bisgrove: Because, because...
- Naught: This is our only chance to talk to this man who has made a report that influences our lives.
- Bisgrove: Yeah, but it doesn't directly influence your life to the extent that everything is going to hinge on his report. It's merely one bit of information and we've got lots of information back and forth. Other people are presenting as well...
- Naught: Well, I disagree with you.
- Bisgrove: Can I ask... Sorry, can I ask you if there is a specific question that you wish to ask of Dan [Lowell] specifically?
- Naught: Well, I'll ask him another question.

In this episode, Naught attempted to generalise the earlier issue of downstream treatment by claiming that any water treatment constituted an (undesirable) change. This comment was never elaborated because Bisgrove intervened, followed by an exchange that also included Magoo who had spoken in favour of local treatment solutions. Magoo attempted to enter the exchange, insinuating that Naught was inappropriate for this part of the hearing devoted to 'technical discussions' ('This is supposed to be a technical discussion'). However, Naught reclaimed the floor by suggesting that he was talking to Lowell rather than to Magoo, thereby contesting Magoo's claim to the floor. Importantly, several individuals present clapped and loudly voiced the desire to hear more from Naught. The choreography of the hearing then involved Naught and Bisgrove, the former wanting to continue the latter attempting to limit Naught's questioning. Most importantly, Bisgrove who had earlier asked Naught not to ask specific questions now reminded him to ask *more* specific questions. That is, the nature of the specificity of permissible questions is also open for contention. The point here is that scientific literacy is enacted as praxis, involving listeners and applauding audiences as much as speakers and the public demonstration that the expertise of an individual present is more limited than it first appeared. A key point in the struggle, one relevant to our theorising of scientific literacy and science education was made by Naught. *This* meeting was their chance of directly interacting with the person whose report appeared to have most influenced the decision by the community not to pay for the watermain extension. This decision affected the lives of the people living at Salina Point—their participation in the choreography that made the public meeting was motivated by concerns for the quality of their everyday lives. In this case, Naught and other members of the community were

able to gain the floor, making it possible for scientific literacy to emerge as collective praxis in a variety of ways.

Science as fibre in the thread of the controversy

In this public meeting, the choreography changed when citizens were provided with the opportunity to question the experts and to make statements on their own behalf. Here, a more general type of scientific literacy emerged, exhibiting local expertise, historical knowledge of the problems, their emergence, and a variety of (abandoned) solutions. Whereas one might be tempted to attribute scientific literacy to the individual scientists—based on their talks when they did not have to interact—such attributions make no longer sense when one analyses conversations, which are irreducibly social in nature (ten Have 1999). In the present situation, detailed understandings of the trajectories of individual wells became apparent, including a variety of consultant reports, often contradicting the one-time assessments outlined by those present. A different kind of expertise became evident, one that was very pertinent to the highly contingent water problems in the Salina Point area. Although in this meeting, as in other situations reported by sociologists of science, the scientists were discursively marked and set apart by introducing them with their titles and positions, the previous section showed that the (impromptu) choreography did not relegate citizens to mere listeners. The citizens present contributed their part for scientific literacy to emerge in the various forms that we will describe it here. They contributed to raising questions such as ‘What are scientific data representative of?’ ‘What are the limits of scientific expertise?’ and ‘What links fire, water-treatment systems, and other conflicting things?’

What are scientific data representative of?

One of the citizens who ended up getting a longer turn was Tom Naught. I pick up the public meeting after Tom Naught had already been able to raise doubts about Lowell’s (the hydro-geologist) the claim that his measures of biological contamination and dissolved substances represent average values. (Space limitations prohibit more extensive analysis or presentation of entire exchange.) The following excerpt starts when Naught suggested that the tremendous increase in

rain probably let to an increase in the water in the aquifer and therefore to much lower than average concentration (the contaminants).

- Naught: Well, well, it's, okay this is true but the thing is, is that what we've experienced is, rainfall in the order of 522% on average, as far as monthly averages are concerned increase over the summer months. In other words what we've got through the winter period, through the 5 months previously preceding your test results.... If you took that and compared that to an average summer month, a month through that period, it is, there were 522% more. Now, it would seem to me that we're probably not dealing on an average result with your tests. We are probably dealing with the hydrostatic head feeding that aquifer up in the higher, very much higher ends, so that the readings that you are getting are very much diluted.
- Lowell: The hydrograph that we have shows that the water levels are average in late April, early May and I put the average water level on the hydrograph here and the...
- Naught: Could it be an error? Could you be in error here?
- Lowell: Well, I don't take the water level readings but I take the Ministry of Environment...
- Naught: Well, you mean to say that on these particular aquifers out at Salina Point that they are taking the readings? And, and...
- Lowell: The Ministry of Environment produced these readings.
- Naught: And could there be an error? Could they be for example, relevant for some...?
- Bisgrove: I'm not, I'm really, I really don't want to get into.... I hate to cut you off but what I would like to do... Dan's report deals with a specific time that he took the samples. We recognise already through Mr. Radford's comments on their original testing that there are differences in the quality of the water throughout the time. I don't think that you're going to find a smoking gun one way or the other. You may be able to pick apart on specific instances but in general, I don't want to, as I say, get into a slugfest over particular pieces of the report. Dan is not here to defend every little bit of it. I don't, I really would like to move on with it and carry on with the meeting.

Lowell responded that he relied on the hydrograph readings, which at that point in time represented average water levels. A detailed consideration of the issue suggests that even if the water was at an average level this would still be consistent with the water supply to be contaminated for half of the year (Lee and Roth 2001c). Lowell defended his claim by suggesting that he based his claim on the readings from the hydrograph. Naught questioned whether there could be an error (it is unclear what type error this might be) Lowell drew on the readings taken by the Ministry of Environment, presumably an authoritative and accurate source of environmental data. (Authoritative repertoire [register] is one of the discursive resources available when issues of science and scientific knowledge are contested [Roth and Lucas 1997].) The subsequent question relativised the recourse to the authoritative repertoire by raising doubt whether the Ministry of

Environment technicians had actually sampled the particular aquifers at Salina Point, that is, the only aquifer relevant to the people living there.

Although it is crucial for the evaluation of the case to know whether the engineer's data represent the normal or average situation in terms of contaminant concentration, Bisgrove made an attempt to stop the line of questioning. He did, however, point out that the other scientist had established seasonal variation in contaminant concentration. It was also important to know whether the water levels brought into discussions actually represented those at Salina Point or whether they were taken elsewhere and therefore *not* representative. There is then a double methodological issue: What is the extent to which the available data are representative of the specific case that is for discussion. Naught's contributions relativise claims that the concentrations represent an average by questioning the representativeness of water levels and the representativeness of extant readings for the particular location. Here, the legitimacy of the questions is at issue. This part of the evening had been designated as opportunity for technical questions. Although Naught did ask technical questions, Bisgrove attempted to limit the detail with which technical questions could be asked. Being able to maintain the floor and thereby contribute to the choreography of the public meeting under such mediating circumstances is as much part of scientific literacy as knowing the effect of chromium on the human body.

What are the limits of 'scientific expertise'?

In the analogy of thread and fibre, it is less important to know a scientific fact than knowing how to find and use expertise; an important aspect of scientific literacy is therefore the appropriate use of specialist (Fourez 1997). However, even if a scientist involved in a socio-scientific controversy is recognised and used as a specialist, there still remains the question whether s/he is *the* appropriate specialist for *the case at hand*. Appropriate use of specialists therefore means not only to draw on scientists but also to delimit the extent and level of the expertise and evaluate them in the context of the specific problem. In this episode, the geologist is led to admit that his expertise is limited relative to a specific aspect of the water problem. He also emerges as someone who is, at a minimum, not informed about the current state of the field, and at worse, gullible in the face of manufacturers' assurances.

- Naught: Treatment of downstream water, is that your area of familiarity and expertise?
Lowell: I've worked with groundwater and water treatment for over 25 years.
Naught: So, you would consider yourself an expert in that area?

- Lowell: Not in all aspects. An environmental engineer who's an expert in water treatment would know more about it than I do.
- Naught: Do you know, for example whether chromium can be treated successfully?
- Lowell: Yes I do. It can with ion exchange filtrate, a filter. I phoned the manufacturers of certain systems and they assured me that that can be done.
- Naught: And that's good enough for you?
- Lowell: Well, I read it in publications as well.
- Naught: Oh, there's a publication that we have here that says there is no commercial treatment for chromium.
- Bisgrove: Well, again Mr. Naught
- Lowell: Again there wasn't any concern for chromium identified. So I'm not sure what point you're making...

At issue in this exchange is the claim (Lowell) that individualised local solutions better address the problems experienced by the citizens living on Salina Point than a watermain. Not only a particular solution is being questioned but the very expertise Lowell brought to the study ('Is that your familiarity and expertise'). Naught questioned Lowell whether he considered himself a specialist on downstream-treatment of water. After Lowell admitted that an environmental engineer 'would know more about it', Naught asked a specific question about the treatment of water for chromium. Lowell suggested that an ion exchanger would deal with the problem and that he had the assurance of several manufacturers that this could be done. Naught questioned whether such assurance was sufficient and, after Lowell indicated use of publications, Naught described the availability of a publication that suggested the impossibility of chromium removal by means of ion exchange mechanisms. The episode ended with the statement that there was no 'concern for chromium identified' in the study conducted by the engineer and geologist. Although Bisgrove's intervention and the lack of time prevented further elaboration of the chromium issue, other speakers did contest this statement. For example, in his introductory remarks, Radford (from the regional health authority) had already identified chromium as a significant contaminant in some wells. Furthermore, among the reports commissioned by the citizens themselves chromium was also identified as a significant pollutant ('Our water samples, beyond the one that was done by Mr. Lowell, have always tested very high in the negative areas, one in particular is chromium').

Some readers might automatically assume that scientists and engineers are de facto scientifically literate. If the 'efficient use of black boxes' (Fourez 1997) is a criterion of scientific literacy, one could construct Lowell as not being scientifically literate. Here, 'ion exchanger' together with 'manufacturer assurance' constituted an unopened black box. This black box is one of those that scientists have to trust, rightly or wrongly, in their everyday work. It is only when things

go wrong or when knowledge and facts become contested that the problems in this system of trust become evident. However, I prefer to look at the whole situation; here, scientific literacy emerges as an argumentation over the use of a black box. Scientific literacy is embodied in the argumentation rather than attributable to Lowell (on de facto grounds) or Naught (as the one who detected the error).

Scientific literacy is also recognisable when the understanding of technology is contrasted with the understanding of its scientific principle (Fourrez 1997). In the present case, the scientific principle is the exchange of ions. Water softeners working on this principle exchange calcium ions, which are responsible for 'hard' water, with sodium ions. From the technological perspective, the problem of hard water has been alleviated or eliminated by the water softener. However, from a scientific perspective, what happens is an exchange. That is, the ions removed have been replaced by other ions. The most common ion used is sodium. That is, in the process of softening the water, sodium ions, one half of sodium chloride are introduced into the water supply. Whereas these ions are not necessarily dangerous, it is well known that they contribute to health risks—they would constitute hidden sodium for those individuals on strict sodium-reduced diets. Contrasting the understanding of technology with understanding of its underlying scientific principles was also played out in the following episode.

Naught continued his questioning of the recommended methods for treating the water and thereby contributed to the emergence of other aspects of scientific literacy. Scientific literacy arose here from the back and forth between his questions and the engineer's responses. Naught constructed the case that the use of cisterns would make water treatments to work on an intermittent basis, which, according to the information available to him, was not as effective a method as a continuously operating treatment. At first, Lowell suggested that water treatment was in fact continuous and that he did not understand Lowell's point. Then, he admitted again that he had simply recommended extant systems rather than comparing them. At this point, Magoo finally succeeded in taking the speaking floor.

- Naught: Is it a good policy to treat water on an intermittent method? In other words, downstream treating of water after a cistern... Okay, where you are pumping only on occasion, isn't it true that water treatment in that fact is less effective then if you are going to treat something that is moving on a continuous basis at a constant flow?
- Lowell: When the water is being treated and moving through the treatment system, it is coming through at a constant flow. Yeah, I don't know what point you're making.
- Naught: Well, it isn't really, well, it's puzzling...
- Lowell: Most systems are, you know, with a certain flow through them.

- Naught: Yeah, but they start and they stop, they start and they stop. And that kind of a treatment is less than, less than effective then on a treatment system that is working on a constant basis.
- Lowell: Yeah, I didn't compare treatment systems. All I know that the treatment system, any treatment system that I recommended has been tried and proven effective over many years.
- Magoo: I would like to make a comment on that, on his discussion because I think that as Mr. Lowell is being questioned, cross-examined as it were, it should be pointed out that Mr. Lowell's report is the first systematic assessment of the aquifer. And up until the time at which that was requested, the [town] council was being barged with demands to make high levels of public expenditure based upon information from the taps. And the Health Region's testing methodology, which we supplied... we made an assessment of it, if we want to talk about a testing methodology, the testing methodology up until the time that Mr. Lowell came in, was wholly inadequate. And Mr. Lowell's is the first systematic attempt...
- Naught: But his results are greatly affected by the time of year.

In this 'technical question' period, the credibility of Lowell had been undermined not only by Naught but also by the speakers before him, as well as by others yet to come. Given that there was a public perception that Lowell's report had greatly influenced the reports filed by the Water Advisory Task Force and the technical staff of the community, it comes as no surprise that the questioning had focused on Lowell. Magoo described the questioning as a 'cross-examination' and defended the report as the 'first systematic assessment' contrasting the 'wholly inadequate' testing methodology by the officers from the Health Region. Naught reiterated that seasonal variations influenced and biased Lowell's assessment.

What links fire, water-treatment systems, and other conflicting things?

One of the received assumptions is the notion of science or technology as entities that exist independent of other ways of knowing, interests, and human pursuits (Latour 1993). Accordingly, science and technology are, in the dominant educational discourses, thought independently of their everyday real-world involvement with economy, politics, aesthetics, and so forth. Science and technology are thought as pure pursuits happening in science laboratories, which are sullied once they hit the street. Scientists and engineers often appear to be sociologically naïve (Bucciarelli 1994). They promote the facticity of their abstract laboratory-dependent knowledge as wholly unproblematic in the public only to realise that laboratory knowledge cannot be imposed on the world outside the laboratory but has to engage with all the other forms of knowledge and ways of conceptualising

the world. That scientists and engineers might be thinking in this way would not surprise if we had followed their career paths from middle school to the point of leaving formal schooling. Their domains are always presented in pure form.

In everyday life (at least outside the laboratory and outside of school classrooms), science is but a fibre in a more complex thread. The properties of the thread cannot be deduced from the properties of each (much shorter) fibre; and conversely, the properties of each fibre are difficult to discern from the continuity of the thread. This is the image we get of science when we look at the activities in our community where ‘science’ can be identified (Lee and Roth 2001a, 2001b). In the following excerpt, Clay Bolton—a resident who would be affected by the placement of a watermain—wanted to find out about the criteria for the particular size of watermain to be considered.

Bolton: Clay Bolton, 1082 Mount Nemo Crossroad. The report mentions the 6- or an 8-inch pipeline to Salina Point and then a 6-inch pipeline. What capacity are you looking at in terms of population levels that can be met? And obviously agriculture is an issue there too. So what are you dealing with? Why *that* size as opposed to a 2-inch or 4-inch? I’d just like to know what the difference is.

Bisgrove: That’s a good question. The line was sized to provide residential flows and a bare minimum fire flow. Between 500 and 800 gallons a minute sustain flow for a fire anywhere along that line. This would be the bare minimum that we would recommend to be installed under good engineering practice. If, you were to try and provide water for agriculture, you would have to increase the size of the new line. And you would also have to increase the size of the line that runs along Mount Nemo Crossroad from Wendy Drive all the way down past the school where it exists now. It’s only an 8-inch line as well. So the line that is proposed at the moment is simply an extension of that system for residential and fire flow purposes. So, if that watermain were to be approved we, as staff would take it forward a recommendation to Council to at least consider upgrading that for agricultural purposes and to pay the increased cost for it. But yet again that would be a secondary step well after a lot of other things had taken place. Have I answered your question?

Bolton: No you haven’t. My question was, what population would serve...

Bisgrove: I’m sorry, population. The existing population could be served quite readily. Residential flow is really quite small by comparison to fire flow so my concern would be the fire flows. But I can’t give you off the top of my head what would be a residential number but at least probably twice the amount of people that are there now could easily be supported by that from the residential point and still have a fire flow capability. Fire flow capability is always the governing thing in a watermain system design.

In the considerations of a solution to the water quality problem, water quantity also becomes an issue. At the present time, the residents do not have sufficient water for regular fire protection. There are no fire hydrants in their area of

the town, leading to insurance policies that cost much more than those of residents in other parts of the town. From the perspective of the town council (here represented by the engineering staff member Bisgrove), considerations of improving water quality by means of bringing the watermain to Salina Point are irremediably tied to considerations of water quantity. But water quantity is related to the possibility for the expansion of new housing, the realisation of which is imputed by some to the developers who own property in the area that would be served by a new watermain. The size of the watermain also depends on whether its water would be used for agriculture—which at the current price would not be viable in any case from the perspective of the local farmers.

Not building the watermain, in effect, supports current policies for limited expansion of the community. Adding a watermain means opening up the possibility for further expansion of residential housing into this agricultural community, made possible because of the small impact of residential flow compared to required fire flow capacities. Any solution to be considered does not exist on its own but in a context of other possible solutions, each constituting a fibre of its own in the thread of the community and the water problems. In the public meeting, different alternative solutions were also presented and discussed. Each of these solutions was itself tied to other issues such as cost, flow rate, ease of access, and so forth. For example, some residents have already had their water trucked in until the company had to stop operations ‘on sanitary grounds’. Furthermore, within a few years, the cost for the water shipped in this way increased threefold thereby making trucking prohibitive as a long-term solution. Another solution proposed was that of recycling wastewater. Recycling could be tailored to the individual needs of each property. But, as the following excerpt shows, the person who promoted this solution had stakes in the only local company that would deliver such services.

Rees: The last thing that I wanted to say was, I wanted to ask a question directly to Mr. Magoo. In your report, you make some references to recycled wastewater. And that you say that there is a local company that has the technology to recycle wastewater. This company we know is called HydroSystems, and as I said they’re out by the airport. This is a local company. This is great news. But at the end of one of the Water Advisory Task Force meetings, those of us that were there heard Mr. Magoo say that he has an investment interest in this company. He owns stock, a block of shares, however he described it. It seems to me that that might just possibly buy us his assessment of the area and perhaps even put himself into a conflict of interest so I would be interested to know if that is still the case.

Towards pervasive scientific literate praxis

In this article, I present a case study of everyday people involved in the struggle over access to potable drinking water. In the public meeting, they question those scientists whose reports have provided the grounds for Council and mayor to make a decision against a watermain that would provide them with water of a consistent quality and quantity. I articulate the events in terms of activity theory and the associated analogy of thread and its fibres. Using an everyday activity to think about curriculum issues, we avoid the issue of is/ought always related to current educational praxis. The purpose of this article is to rethink scientific literacy through examples from concrete everyday praxis rather than from the perspective of science education and laboratory science, whose practitioners want everyone to think like them.

To date, the controversy over the water supply is not closed; the residents of Salina Drive still pursue their struggle to get access to community water by means of an extension to the watermain. This open nature of the controversy helps us to resist the temptation of putting closure to this issue, or any attempt to provide a master narrative in favour of the ultimate outcome of the debate. We cannot attribute the outcome to more or less scientific knowledge held by one or the other party in the controversy. We do not know how the various fibres contribute to the unfolding events, and which fibres will be constructed as the dominant themes after the fact. However, not arriving at a solution is also a form of action, which contributes to further debates, costs, and impact on the environment, that is, the very shape the controversy will take over its course. As some speakers suggested, the projected costs for a watermain already doubled over the a period of years during which the community and the residents have not come to a solution of the issue, and during which six different and sometimes contradictory reports have been produced.

In everyday life of the community, science is never but one of the many fibres that make a thread. When twisted together with all the other fibres, it is not science that becomes continuous but the thread. I think of the thread as a continuous entity that forces me to think of scientific literacy as something that emerges from the collectivity. It is only when we unravel the thread that we find a fibre. I cannot understand the continuity of thread by thinking as if all fibres were going the entire length; I do not understand each fibre by thinking it from the continuity of the thread. The science (water quality) is connected in deep ways with technological, economic, political, and aesthetic issues. There are different water treatment solutions, each with its own interconnected range of sci-

entific and technological possibilities and constraints, there are costs to the community and individuals, and there are a variety of potential economic benefits.

The analogy of fibre and thread for the relationship between science and other forms of knowledge in controversies about problems forces 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 content that there is simply too much specific for any individual to know the relevant facts even in more constrained contexts. 'We do not have to master all areas of knowledge to live successfully in our society, and awareness of this fact may free us to explore more creatively how to deal with questions of scientific literacy' (DeBoer 2000: 595). Educators may be tempted to teach science so that all students exhibit knowledgeability at the level that arose from the interaction of Naught, the scientists, and many others in this public meeting. But then, we would spend much more time in school even if knowledge transfer from school to workplace and everyday life was less problematic than it already is. 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. Our children would already participate in doing things that benefit the community, and participate in the ongoing discourses and concerns that are relevant to their parents and the community at large. From an activity theory perspective, the children and students would already participate in truly authentic activity, that is activities driven by the motives that are also relevant in the lives of other community members. The notion of 'zone of proximal development' (Vygotsky, 1978) can further help us think through these issues.

In the education literature the 'zone of proximal development' has been used to describe the distance between individual, unaided performance and performance under guidance. Learners are thought to appropriate higher levels of performance into their own repertoires. Here we want to pursue a different avenue for thinking and theorising the notion, an avenue that focuses on collective activity. The zone of proximal development can be thought of as the 'distance between the everyday actions of individuals and the historically new form of the societal activity that can be collectively generated' (Engeström 1987: 174). That is, the zone of proximal development arises from the dialectic relation between social and individual development. In this way, the public meeting is a zone of proximal development. A new form of collectively generated societal activity (in this community).

Collectively, the public meeting has provided an opportunity for scientific literacy to become a recognisable and analysable 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 also emerged because the citizens were involved in an issue where there was something at stake. It has been suggested that scientific literacy as practical activity in the face of problems arising from everyday life include a number of competencies. These include how to use specialists; how to use of black boxes efficiently; how to invent interdisciplinary rationality islands; how to use metaphors; how to use standardised knowledge; how to translate, negotiate, and transfer knowledge; how to use (different types of) knowledge in everyday life to make ethical and political decisions; and how to contrast the understanding of technology with understanding of its scientific principle (Fourez 1997). In the present analyses, these aspects of scientific literacy emerge as aspects of the public meeting, which is an irreducibly collective praxis.

When, how and where do we allow young people to be scientifically literate in these terms? The classical approach is to expose children and older students to the images of scientists' science. This science is a pure subject, often taught in special physically separated rooms, unsullied by common sense, aesthetics, economics, or politics that are characteristics of everyday life. It is also a subject in which each individual, so goes the idealist rhetoric, has to appropriate and exhibit a certain 'basic skill'. Whether students 'have' this knowledge and skill is usually assessed by isolating them from any resource normally available in everyday situations. Conceptualising scientific literacy as a feature of collective praxis changes the situation. Educators now have to think about what to set up situations so that contexts (rather than individuals) exhibit scientific literacy. How can we (teachers) possibly do this? Elsewhere I show (based on my own experiences of teaching science in several seventh-grade classes in Oceanside) 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 propose to create opportunities for participating in this world and to learn science in the process of contributing to the everyday life in their community. Sample contexts are 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.

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Notes

¹ The overlapping square brackets in consecutive lines indicate where the speakers overlap.

² Holzkamp (1993) 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.

³ Although this was a public meeting, recorded and documented by the media, I use pseudonyms to protect the identity of the community and the individuals involved.

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