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From the Bronx to Bengifunda (and other lines of flight): deterritorializing purposes and methods in science education research

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Abstract In this essay I explore a number of questions about purposes and methods in science education research prompted by my reading of Wesley Pitts' ethnographic study of interactions among four students and their teacher in a chemistry classroom in the Bronx, New York City. I commence three 'lines of flight' (small acts of Deleuzo-Guattarian deterritorialization) that depart from the conceptual territory regulated by science education's dominant systems of signification and make new connections within and beyond that territory. I offer neither a comprehensive review nor a thorough critique of Pitts' paper but, rather, suggest some alternative directions for science education research in the genre he exemplifies.

Keywords Deleuze & Guattari · deterritorialization · simulacra · dialectics

From the Bronx to Bengifunda (or anywhere)

Wesley Pitts (2011) begins his account of exploring the confluence of global and local referents of science education in an urban chemistry classroom by stating: 'The Bronx is a dynamic place to live and learn science' (p. 89). My immediate response to his assertion was to jot 'aren't they all?' in the margin. A moment later I realized that I was singing (under my breath) the chorus of 'Rotterdam (or anywhere)' (Heaton & Rotheray, 1996), a UK hit single for The Beautiful South:[1]

> This could be Rotterdam or anywhere
> Liverpool or Rome
> 'Cause Rotterdam is anywhere…

By recalling these lyrics I commenced, in terms of Gilles Deleuze and Félix Guattari's (1987) conceptual creations, a 'line of flight' or 'deterritorialization' (p. 9), which as Kaustuv Roy (2003) writes, is 'a movement by which we *leave the territory*, or move away from spaces regulated by dominant systems of signification that keep us confined to old patterns, in order to make new connections' (p. 21; italics in original). Roy (2003) continues:

> To proceed in this manner of deterritorializing, we make small ruptures in our everyday habits of thought and start minor dissident flows and not grand 'signifying breaks,' for grand gestures start their own totalizing movement, and are easily captured. Instead, small ruptures are often imperceptible, and allow flows that are not easily detected or captured by majoritarian discourses (p. 31).

[1] A music video of this song can be viewed/heard at http://www.youtube.com/watch?v=onKrpUeocUk (accessed 15 August 2010).

Forum response to W. Pitts, Potentialities beyond deficit perspectives: globalization, culture and urban science education in the Bronx. *Cultural Studies of Science Education*.

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I do not doubt that the Bronx is a dynamic place to live and to learn science, and Pitts provides a rich and convincing account of the many specific ways in which this dynamism is evident in its changing demography and ecology, and in the cultural 'matrix of being, becoming and belonging' (p. 90) constituted by its inhabitants. In many ways the Bronx is like no other place, but Pitts also ascribes uniqueness to aspects of life and learning that the Bronx shares with many other places. So I will allow my recollection of 'Rotterdam (or anywhere)' to produce a 'small rupture' – a 'minor dissident flow' – in Pitts' argument by pointing to some ways in which learning science at New York High School (NYHS) in the Bronx is simultaneously similar to and different from learning science at Bengifunda[2] High School, a public school in Durban, South Africa, and several other sites in which I have experienced science education in practice.[3] In so doing, I will also make some 'new connections' among the global and local referents of science education in these different locations that, I suggest, raise some critical questions about the dominant systems of signification that frame Pitts' study.

In his abstract Pitts asserts:

> The pervasive spread of neoliberal ideology of accountability and sanctions both globally and locally, particularly in public high schools in the Bronx… fuel situations for teaching and learning science that are encoded with the referents of top-down control (p. 89).

What is so 'particular' about the Bronx here? The 'neoliberal ideology of accountability and sanctions' is pervasive beyond the Bronx and the USA, and the local manifestations of how this fuels 'situations for teaching and learning science that are encoded with the referents of top-down control', was as evident to me in Bengifunda as it was in my recent observations of public schools in Hong Kong, Shanghai, and Taipei. In Tehran, too, I observed students and teachers in science classrooms that were 'encoded with the referents of top-down control', although these included not only traces of the neoliberal restructuring that began in 1989 as part of Iran's post-war strategy of economic reconstruction, but also traces of the complex interplays between neoliberalism, theocracy, and state-sponsored patriarchy. For example, the extent of gender segregation in Iran's schools and education workforce is not only a consequence of the Iranian state's redefinition of women's roles following the 1979 Islamic Revolution, but is also, as Alihossein Hosseinzadeh, Iman Mombeni, and Abdolreza Navah (2010) argue, because neoliberal restructuring serves to reinforce existing patterns of gender inequality: 'By neglecting existing social hierarchies, neoliberal policies come to reflect and consolidate the unequal relations in the society in which they are embedded' (p. 506).

My line of flight from the Bronx to Bengifunda produces a new connection between what many Western science educators usually understand by the expression 'high stakes' and the examples Pitts describes of the confluence of global and local referents of science education. Pitts suggests that the school's configuration of the sequence of Regents science courses and examinations 'provided a high stakes atmosphere for participants in the chemistry class' (p. 24). Elsewhere he suggests that the scrubs shirts that NYHS students are required to wear function as 'a mechanism of global affiliation with medical science and services' (p. 101).

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2 Like NYHS, Bengifunda High School is a pseudonym. *Bengifunda* is an isiZulu word that usually translates in English as 'I was studying'; see http://www.cls.yale.edu/zulu/sample/ (accessed 15 August 2010). Although the school has an ethnically diverse student population, the majority are Zulu, with the largest minority being of Asian/Indian descent.

3 These sites include various locations in Australia, Canada, China, Europe, Iran, New Zealand, southern Africa, and the USA. My experiences are both direct (such as teaching or conducting research in these nations/regions) and vicarious (such as supervising or examining research conducted by doctoral students in these sites).

I visited Bengifunda High School in September 2001, accompanied by two doctoral students from the University of Durban-Westville.[4] I quickly realized that the school's 'atmosphere' had a quality that in retrospect clearly warrants the descriptor 'high stakes' (although I would not have used that expression at the time) and that this same atmosphere was inextricably co-implicated with 'referents of medical science and services' rather than simply being co-present, as they are in the case of Regents examinations and scrubs shirts at NYHS. I could barely take a breath in Bengifunda High School without being reminded of the life-or-death struggles that many members of the school's community faced every day. Both doctoral students were researching educational effects of the HIV/AIDS pandemic, which was then accounting for more than 40% of all deaths in KwaZulu-Natal province. One was using life history methods to seek deeper understandings of the educational experiences of the AIDS orphans (children who had lost both parents to HIV/AIDS) that comprised at least 10% of the Bengifunda student population. Most of these students were themselves HIV-positive from birth, as were another 15-20% of students who had lost one parent to the virus. The other doctoral student was investigating how an 'inclusive' curriculum might be conceptualized in circumstances wherein up to 20% of learners were likely to be terminally ill. On one of the days we visited Bengifunda, a biology class I had arranged to observe was cancelled because the students were attending a memorial service for their teacher, who had died as a result of an HIV/AIDS-related illness (teacher attrition in KwaZulu-Natal schools caused by HIV/AIDS was then running at about 13% per year and rising).

I have no quarrel with Pitts' desire to 'move us beyond deficit theories of urban youth towards theories of possibilities and potentialities that extend across difference and create productive ways of being in their lifeworlds' (p. 110). However, when I compare the lifeworlds of the young people in Pitts' study with those of their agemates in Bengifunda, I have some difficulty in determining what these deficit perspectives might be, who holds them, and how they materially affect students' lives. Given the salience of 'deficit perspectives' in the title of Pitts' paper, I was surprised to find so little elaboration of the concept itself and how it was intended to function in shaping his study. One of the very few mentions of deficit perspectives in the body of Pitts' paper appears when he foreshadows that a subsequent section 'outlines a particular entry point into looking beyond deficit perspectives associated with urban (inner city) youth' (p. 93). Pitts hints at what these 'associated' perspectives might be in the previous paragraph, where he states that 'the students who attend public school in the Bronx are inscribed using salient categories of difference, such as urban, Black, Latino, Catholic, tenth grader, English Language Learners' (p. 93). If the deficit perspectives to which Pitts refers are 'associated' with these 'salient categories of difference', then they are clearly 'deficits' of a very different order of magnitude from the categories that inscribe students at Bengifunda High School, such as orphan, HIV-positive, and terminally ill. This raises questions for me about research priorities. I could justify undertaking research at Bengifunda that was directed towards 'looking beyond deficit perspectives' associated with terminal illness, but I could not give it a higher priority than educational research that seeks to reduce the number of students who fall within this 'salient category of difference'.

My line of flight from the Bronx to Bengifunda also departs from a territory regulated by Western science educators' dominant systems of signification in which global affiliation with medical science and services, domesticated by scrubs shirts, is assumed to be benign. In many parts of the majority world[5] the beneficence of Western medical science cannot be taken for

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4 Now known as the Westville Campus of the University of KwaZulu-Natal.

5 I prefer the term 'majority world' to the largely inaccurate, outdated and/or non-descriptive terms 'developing' nations, 'Third World' and global 'South'. The term has been promoted by the communications cooperative New Internationalist (www.newint.org) since the early 1990s to describe this global community by reference to what it is, rather than what it lacks, and also to draw attention to the

granted, not least as a result of the increasingly complex global linkages between traditional cultural practices (such as the production of herbal medicines by traditional gatherers and healers) and the activities of transnational corporations (especially the large pharmaceutical companies). In South Africa, for example, around 80% of the black population consult a traditional healer, either before, after, or in preference to consulting a Western physician, a statistic that has attracted the interest of large pharmaceutical companies in traditional medicines, and thereby increased the potential for economic exploitation and environmental degradation. As a result, many of the local sources of traditional herbal malaria remedies have been over-harvested to near extinction. Europe's former colonies are still sites for producing knowledge and resources from Other people's labor in which the colonizers perform the experiments and the colonized are the guinea pigs. As Sonia Shah (2002) reports, many non-Western countries have a thriving and largely unregulated industry providing subjects for drug trials to multinational pharmaceutical companies.[6] As I have argued elsewhere (Gough, 2007), Western science educators and researchers have a moral obligation to find the fissures in the knowledge space they inhabit and privilege, and begin to experiment with what Helen Verran (2001) calls 'postcolonial moments':

> Postcolonialism is not a break with colonialism, a history begun when a particular 'us,' who are not 'them,' suddenly coalesces as opposition to colonizer… Postcolonialism is the ambiguous struggling through and with colonial pasts in making different futures. All times and places nurture postcolonial moments. They emerge not only in those places invaded by European (and non-European) traders, soldiers, and administrators. Postcolonial moments grow too in those places from whence the invading hordes set off and to where the sometimes dangerous fruits of colonial enterprise return to roost (p. 38).

How might we cultivate such postcolonial moments in a Bronx chemistry classroom? Pitts claims that his research 'represents an ongoing effort to illustrate the emergent possibilities and potentialities of teaching and learning science… in public high schools in the Bronx' (p. 109). and extends this claim as follows:

> In a context of increasing levels of immigration associated with different streams of immigrant groups into NYC and the Bronx, networks of solidarity with global and local referents are created that interpenetrate fields nested in institutions, particularly institutions of education. For example, the blue scrubs shirts that the tenth grade students wore became a local referent for being a tenth grade student at NYHS and simultaneously a global referent for medical science and services (pp. 109-10).

Pitts provides no compelling evidence or arguments to support his contention that 'networks of solidarity' with 'medical science and services' globally are 'created' by the tenth grade students wearing blue scrubs shirts. He tells us that some students do not like to wear the scrub shirts outside of the school building (p. 100), which seems to indicate that for these students the only 'solidarity' to which the scrubs refer is that of local identity (i.e. membership of grade ten at NYHS). Pitts also tells us that one female student 'liked wearing the scrubs while taking public transportation to school because adult passengers… often asked if she was a nurse or going to nursing school' (p. 29), from which he concludes that 'the student's professional and educational aspirations were associated with global referents to medical service and/or education to individuals who wore scrubs' (p. 100). It is reasonable to

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disproportionate impact that the Group of Eight countries – which represent a relatively small fraction of humankind – have on the majority of the world's peoples.

6 For further accounts of medical scientific imperialism see Sardar (1988) and Fourie (2006).

conclude that the student might aspire to becoming a nurse, but there is no evidence that her 'referents' for the nursing profession extend beyond her locality, such as knowing that the Bronx 'shares in a citywide shortage of nurses' (p. 89).

I would have found Pitts' deployment of conceptions of globalization more convincing if he had actually followed Lyn Carter's (2005) recommendation (which he quotes) to explicate more precisely how 'science education works… in the spaces between globally influenced nation states policy production, and local sites of [cultural production]' (p. 573). For example, a popular high school biology textbook in Australia has a section on disease-causing organisms in which it tells the familiar story of malaria being caused by protozoan parasites and spread among humans by mosquitoes. How science education 'works' in the spaces to which Carter refers is materially demonstrated by the complete *absence* from this story of the extent to which malaria is not just a 'natural' entity in the world. Rather, outbreaks of malaria in particular places and times, together with their severity and which particular members of a given population are most at risk of serious illness or death, result from numerous complex interactions among parasites, mosquitoes, humans and various social, political (often military), administrative, economic, agricultural, ecological and technological processes. Malaria, as it is presently manifested in many parts of Africa and southeast Asia, is a *geopolitical* disease that results from the dominance of the majority world by the colonial and mercantile interests of Western nations (see also Turnbull, 2000; Gough, 2007). Indeed, the development of tropical medicine as a Western medical science specialization can itself be understood as a response by colonial administrators to the devastating effects of malaria and other tropical diseases on imperial demands for resources and labor. For example, Bruno Latour (1988) quotes a French colonial official who complained in 1908: 'Fever and dysentery are the "generals" that defend hot countries against our incursions and prevent us from replacing the aborigines that we have to make use of' (p. 141).

Obviously this particular example does not belong in a grade ten chemistry class in the Bronx, but I would have liked Pitts to have provided us with an example of 'a global referent for medical science and services' that has a similar degree of specificity, rather than the unconvincing assertion that scrubs shirts exemplify such a referent. Perhaps a more fruitful line of inquiry might have been to consider if the scrubs shirts were (from the point of view of the students, teachers and/or administrators who determined that scrubs shirts would be the NYHS 'uniform') a referent for the global entertainment industry and youth culture via their association with the popular TV series, *Scrubs*.

Do we need 'solidarity' to reinscribe a simulacrum?

My second line of flight is to leave the conceptual space in which what counts as 'success' in teaching and learning chemistry is equated with faithfully following a recipe, getting the expected results, and calling this activity an 'experiment'. Jean Baudrillard's (1983) concept of *simulacra* – simulated representations – provides a useful register for questioning assumptions about the purpose and value of school laboratory work. Baudrillard (1988) outlines four successive historical phases of a sign or image:

1. It is the reflection of a basic reality;
2. It masks and perverts basic reality;
3. It masks the *absence* of a basic reality;
4. It bears no relation to any reality whatever: it is its own pure simulacrum (p. 170).

Let us consider whether the acid-base activity Pitts describes represents any reality other than that of school laboratory work itself. I argue that, in at least three significant ways, this

activity fails to reflect any 'basic reality' but, rather, exemplifies the ways in which school laboratory work 'masks and perverts' the 'reality' of science.[7]

First, most school laboratories are stereotypical gestures towards the diverse sites in which scientists pursue their labors, and Pitts presents no evidence to suggest that Rey's classroom is any exception. The activities that take place in such classrooms – indeed, the activities that *can* take place in them – bear little or no resemblance to contemporary scientific practice. For many years, the physical sciences especially have been characterized by the types of highly industrialized and technologized 'Big Science' that require very different facilities from those on which school laboratories are modeled. Many if not most scientific specializations – mathematical, physical, biological, cosmological, etc. – have moved away from studying the simple systems that have been the object of mainstream science since Newton's day towards studies of complex systems (see, e.g., Cohen & Stewart, 1994). Whether they are furnished with optical or electron microscopes, Bunsen burners or multimillion dollar particle accelerators, most laboratories are equipped for studying the *material* structures of simple systems. But in the study of complex systems – protein folding in cell nuclei, task switching in ant colonies, the nonlinear dynamics of the earth's atmosphere, far-from-equilibrium chemical reactions – the emphasis is on modeling their *informational* structure through computer simulations (see, e.g., Casti, 1997). Little of what now counts as 'progress' among communities of working scientists is accomplished by the sort of individualistic, small-scale, low-tech 'bench work' for which school laboratories are designed.

A second way in which the activities in classrooms like Rey's 'mask and distort' the 'reality' of scientific work is that they reproduce stereotypical and mythologized versions of science and its methods. During the last three decades, a number of studies of scientists at work (e.g., Charlesworth, Farrall, Stokes & Turnbull, 1989; Haraway, 1989; Latour, 1987; Latour & Woolgar, 1979; Turnbull, 2000) have explored the differences between what is actually done in sites of scientific labor and the image of science constructed from what scientists and school science textbooks say they do and what society at large believes they do. For example, Charlesworth et al. (1989) conclude that: 'What strikes one forcefully as one looks at the way scientists carry on in reality, is the enormous disparity between that reality and the idealized or mythical accounts of it that are given by… scientists themselves' (p. 271). Thus, when Rey and Angel refer to the laboratory exercises they conduct as 'experiments',[8] they are gesturing towards the pervasive myth that scientific work is characterized by a special kind of method. But as Latour (1983) writes:

> Now that field studies of laboratory practices are starting to pour in, we are beginning to have a better picture of what scientists do inside the walls of these strange places called 'laboratories'… The result, to summarise it in one sentence, was that nothing extraordinary and nothing 'scientific' was happening inside the sacred walls of these temples (p. 141).

Charlesworth et al. (1989) reach similar conclusions:

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7 It is beyond the scope of this essay to make the case that this example 'masks the *absence* of' and/or 'bears no relation to any reality whatever', but I believe it would be possible to do so. See Gough (1998) for an example of how such a case can be argued in relation to a physics laboratory exercise.

8 Pitts frequently refers to the serial dilution activity as an 'experiment' and he quotes Angel talking about 'when we do experiments' (p. 108). I infer from this, and from Pitts' references to, for example, 'the acid-base experiment that Rey had planned for the next scheduled laboratory activity' (p. 98), that Rey also calls such activities 'experiments'.

> the neat classical picture of deductions being made from theories and then tested by observation and experiment (the so-called hypothetico-deductive method) scarcely ever corresponds to the reality of the scientific process. Much of scientific investigation relies on a pragmatic 'let's try it and see what happens' approach, and the getting of data is all important (p. 271).

Thus, much science education distorts the interrelationships between theory, method and data by representing data generation as part of an invariable sequence of activities that can be rationalized as 'the scientific method' of producing 'scientific knowledge'.

A third way in which school science typically 'masks and perverts' scientific work is by trivializing the myth of scientific method itself (that is, adding a further layer of distortion to what is already a distortion). To refer to the procedure that Rey instructs his class to follow as an 'experiment' is a ludicrous perversion of even the 'neat classical picture' of experimental method. To call any and every 'practical' activity conducted in a school laboratory an 'experiment' seriously distorts – and therefore impedes learners' understanding of – the history and philosophy of experimental science. Most often they are not experiments at all in the hypothetico-deductive sense, but recipes for physically demonstrating the propositional knowledge that students are expected to reproduce in tests and examinations. Labeling this highly regulated activity an 'experiment' trivializes the role of experimental method in scientific inquiry and diminishes the imagination, skill and ingenuity with which scientists design and conduct the kinds of experiments that do, in fact, advance scientific knowledge. As passages such as the following make clear, there was nothing 'experimental' about the students' activity, which was directed entirely towards following a procedure to obtain expected results:

> Since Angel's group was one of the last to complete this part of the lab, they knew that the liquid in each test tube was going to change color when they added the indicator. They also anticipated observing a range of colors. There was a lot of excitement and positive emotional energy that was building up in the classroom as each group realized the desired results, as indicated by the correct range of color changes. As each group obtained the expected results they shouted out with excitement (p. 103).

> 'Rey: See, if you follow the procedure you get the best results' (p. 108)

One of the stated purposes of Pitts' research is to find ways for classroom participants to 'become aware of productive ways to build solidarity… to create and sustain successful teaching and learning of chemistry' (p. 89). On the evidence presented here, I cannot accept that reinscribing a simulacrum that 'masks and perverts' the meaning of 'experiment' deserves to be called 'successful teaching and learning of chemistry'. From what I have been able to learn of the Regents examinations in chemistry, students are expected to have an understanding of the textbook version of experimental method. For example, the 2009 examination includes two questions requiring students to interpret the results of historic experiments by J. J. Thomson and Ernest Rutherford.[9] Given that the laboratory activity Pitts describes undermines this aspect of the mandated curriculum then, in an important sense, the teaching and learning it entailed was *u*nsuccessful, and building solidarity to achieve such an outcome could be interpreted to be a waste of effort. Pitts writes of 'orienting prosody, emotional energy and synchrony to create solidarity and success' (p. 103), but the only

[9] Accessed 15 August 2010 from http://www.nysedregents.org/Chemistry/20090617exam.pdf The NYC Chemistry site also has a section titled NYS Regents Chemistry & Scientific Method that provides the conventional understanding of experimental method; see http://tiny.cc/4e9dt

'success' that seems apparent is that the students dutifully followed a procedure which, to my mind, is a relatively trivial achievement in 'learning science'. His elaborate and extensive micro-measurements and analyses of prosodic markers, such as measuring 'the production of alignment and misalignment of pauses, overlapping speech, pitch, amplitude changes, and power in the air (energy in the air per unit time)' (p. 102) also strike me as misplaced effort, since the 'fluency, emotional energy, and solidarity' (p. 102) of which these are alleged to be 'signs' are oriented to the achievement of a relatively trivial purpose.

Pitts pays a great deal of attention to what we might call the technical validity of his measurements, that is, he describes very precisely how his techniques of data production measure what he intends to measure, such as elapsed time measured in tenths of a second, sound intensity measured in decibels, pitch measured in Hertz, power in the air measured in units of micro irradiance (Watts/m^2). He gives much less attention to what Gert Biesta (2009) calls the *normative* validity of measurements: 'the question [of] whether we are indeed measuring what we value, or whether we are just measuring what we can easily measure and thus end up valuing what we (can) measure' (p. 35). Unless we connect our research methods and practices to valued purposes of education we leave ourselves vulnerable to what Stephen Ball (2003) calls 'the terrors of performativity' – to becoming compliant and complicit in a culture which treats means as ends in themselves, and in which *measures* of selected qualities of teaching and learning become mistaken for *valued* qualities.

Even if Pitts' micro-measurements and exhaustive analyses of 'physical and verbal displays of synchrony, mutual focus, entrainment, and emotional energy, body gestures, and prosody markers' provide empirical evidence of 'productive ways to build solidarity and interstitial culture across salient social boundaries' (p. 89), he does not tell readers how he expects 'classroom participants [to] become aware' of these and deploy them to resist, subvert or diminish the undesirable effects of the 'pervasive spread of neoliberal ideology of accountability and sanctions… [and] top-down control' (p. 89). I tried to imagine the participants in Pitts' study – Amber, Angel, Diamond, Disaya, and Rey – reading his paper and encountering passages such as the following:

> As the group reached the step to start adding the three drops of indicator solution to each test tube, emotional and mutual focus continued to increase… This was an opportunity to find out how roles were going to be appropriated and negotiated in Angel's group and how mutual focus, solidarity, and entrainment were going to be embodied by the group members in order to complete the laboratory exercise successfully. Disaya positioned herself on one side of the rack to start adding drops while Amber position[ed] herself on the other side. Diamond sat on a tall workbench chair and positioned herself between Disaya and Amber directly in front of the rack. Angel started to lean over on the other side of the workbench facing Amber, Disaya, Diamond, and the test tube rack… Rey also joined the group and started to gaze at the test tube rack… Diamond appropriates Rey's presence (capital as teacher and evaluator) as a resource to reinforce group solidarity by uncovering her head and engages the group again. Rey's entry into the field does not decrease the emotional energy… [and] after Amber indicates that the group is adding the drops to test tube one, Rey gestures with an affirming nod to go ahead. At this point, Rey and the members of the group are all mutually focused on the medicine dropper and the first test tube in the rack. The system of test tubes is imbued with emotional energy. The group encounters, emotional valence, prosody, and speech content are structured by what happens to the test tubes (p. 106).

This passage seems to contain a number of contradictory messages. Did Angel's group really need to appropriate and negotiate roles 'to complete the laboratory exercise successfully' or

did they simply need Rey's 'affirming nod to go ahead'? Was Diamond consciously aware that she 'appropriated Rey's presence… as a resource to reinforce group solidarity' or is this something that Pitts' findings will help her and her classmates to recognize as a 'potentiality' that they can deploy in future? This ascription of agency to the students (according to Pitts, they all actively 'positioned' themselves in various ways) contrasts with his passive voice in the sentence: 'The system of test tubes is imbued with emotional energy'. If the system of test tubes was indeed imbued with emotional energy then somebody (or bodies) did the imbuing.

To conclude this section, I return to a key statement in Pitts' abstract, which I have abridged, paraphrased, and re-assembled in a way that I trust does no violence to his intentions, but expresses a little more succinctly the prime purpose of his study (as I interpret it):

> *In the face of the pervasive spread of neoliberal ideology of accountability, sanctions, and top-down control, classroom participants must become aware of productive ways to build solidarity and interstitial culture to create and sustain successful teaching and learning of chemistry.*

If Pitts' study has succeeded in identifying productive ways to build solidarity and interstitial culture, then his results must be communicated to the classroom participants he studied in a form that is intelligible to them and actually provides them with practical strategies for realizing the 'potentialities beyond deficit perspectives' that he desires. As a follow-up to this study, I would be very interested in reading an account of how Amber, Angel, Diamond, Disaya and Rey respond to Pitts' presentation of his findings.

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Yes, the subheading of this section is '|', the so-called 'Sheffer stroke', a sign that separates a number of terms in Pitts' (2010) paper and, as he explains in a footnote, 'denotes a dialectical relationship between terms and their associated contradictions where each construct presupposes the other' (p. 91). He first uses it to emphasize that 'corresponding conceptualizations of global and local spheres are brought together in a dialectical relationship (global|local) where one component of the dialectic presupposes the other and cannot be thought of analytically without the other' (p. 91).

I was initially intrigued by this gambit because a colleague and I (Sellers & Gough, 2010) have recently used the ~ (tilde) symbol to signal a conjoining of co-implicated notions in what we think of as *complicity*, for example, thinking~writing signifies thinking that is complicit with writing and simultaneously *vice-versa*. Our choice of the tilde is adapted from its use in mathematics to represent equivalence relations and similarity, so I was interested to take a line of flight back into the mathematical history of the Sheffer stroke, beginning with Henry Maurice Sheffer's (1913) paper in which he used the stroke in an axiomatization of Boolean algebras.

Pitts stipulates his denotation of the Sheffer stroke without providing any references to the sources on which he might have drawn in using it in this way. One of the papers he cites for other purposes (Roth & Tobin, 2010) uses the Sheffer stroke without explanation to refer to a 'structure|agency dialectic', but I found a more detailed rationale for its use in similar contexts in Roth and Lee (2007):

> dialectical categories… can aspire to be categorical universals because they assert the mutual presupposition of opposites. To explicitly mark the dialectical nature of such categories, some recent publications have used special notation whereby two mutually

> exclusive but reciprocal terms are combined together…[10] These terms are separated by means of the Sheffer stroke |, which corresponds to the NAND operation in classical Boolean logic that creates statements that are always true when it involves nonidentical terms of the same entity. This approach leads to new categories – for instance, agency|structure – that encompass built-in contradictions (p. 197).

Initially I was puzzled by Roth and Lee's statement that the Sheffer stroke corresponds to the NAND operation (that is, 'not _ and _', also known as *alternative denial*) in Boolean logic, because Sheffer's (1913) original paper quite clearly states that the stroke means 'neither _ nor _' (also known as *joint denial*), which is expressed in computer science as a NOR function: 'p | q may be interpreted as the proposition neither p nor q; in other words, | has the properties of the logical constant neither-nor' (p. 487). According to Michael Morris (2008), the common current use of the Sheffer stroke to express alternative denial (NAND) seems to derive from Jean Nicod (1916), who 'offered both the joint denial (NOR) and alternative denial (NAND) interpretations of "|" as sufficient for his purposes' (pp. 376-7).[11]

This line of flight leads me to ask whether either or both of the operations signified by the Sheffer stroke are sufficient for Pitts' purposes (and indeed for Roth and his various coauthors' purposes). Depending upon how literally (or perhaps I should say how *algebraically*) we understand NAND (alternative denial) and NOR (joint denial) the Sheffer stroke can be taken to denote different types of dialectical relationship between terms such as global|local (Pitts) and agency|structure (Roth and others). Pitts further complicates (or confuses) these different interpretations of dialectical categories by extending his use of the Sheffer stroke from denoting a relationship between 'two mutually exclusive but reciprocal terms… combined together' (as Roth & Lee put it) to three and even four terms, as in the following examples:

> another set of dialectics exist among the global and macro|meso|micro relationships (p. 92).

> these existing frameworks and referents of accountability are often the starting points… that structure science education across micro|meso|macro|global spheres (p. 107).

> the cultural core of what it means to teach and learn science has contingently and contiguously overlapping global and local and historical and current resources that guide the dialectical production, reproduction and transformation (production|reproduction| transformation) of science education (p. 91).

Pitts adds yet another layer of confusion by reducing the three-term relationship 'production|reproduction|transformation' to two in a way that implies yet another type of interplay among them: 'A priority will be to examine ways in which the participants produce (reproduce|transform) interstitial culture' (p. 91).

It seems to me that Pitts is wise to omit any reference to the mathematical uses of the Sheffer stroke, because Roth and Lee's (2007) suggestion that a category such as agency|structure 'corresponds to the NAND operation in classical Boolean logic' does not make mathematical sense. The Sheffer stroke is a function of two variables that is only true when both are *not* true, from which it follows that the stroke implies *everything except the*

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[10] Roth cites three 'recent publications' that have used this 'special notation', all of which he co-authored.

[11] Charles Sanders Peirce (1931-35) noted the functional completeness of NAND or NOR in an 1880 (unpublished) paper titled 'A Boolean algebra with one constant'.

intersection of the two categories (the *denial* of the intersection AND), rather than the dialectical quality of their combination. Three or four variables together do not work mathematically at all. Thus, if the mathematical logic of the Sheffer stroke is applied to agency|structure or global|local, then it suggests that at least one thing is *not* the case or that the intersection is *never* the case. But my impression is that Pitts wants to call attention to interactions rather than distinct categories, that is, some reconceptualization of the boundaries and/or some new way to understand the intersection *per se* rather than everything-except-the-intersection.

My view is that anyone can use a notation to mean anything they want it to mean, provided that they make this clear to their audience. The slash in academic writing is widely understood to mean the equivalent of 'and/or', liminality, blurring boundaries, or collapsing categories. The Sheffer stroke, as Pitts uses it, can be understood as taking the two concepts together as one, and adding the notion of an important dialectical relationship as foreground or background to the destabilization of that relationship. This interpretation makes his extension of it to more than two variables or concepts more comprehensible.[12]

However, we should perhaps be wary of seeing dialectical categories as the only – or the most obvious – alternative to binary categories and dualisms. Consider, for example, Deleuze and Guattari's (1994) critique of dialectical thought in the western tradition:

> The philosophical problem consists of finding... the instance that is able to gauge a truth value of opposable opinions, either by selecting some as more wise than others or by fixing their respective share of the truth. Such was always the meaning of what is called dialectic and that reduces philosophy to interminable discussion (p. 79).

Elsewhere, Deleuze (1991) writes that the dialectical method

> compensates for the inadequacy of a concept that is too broad or too general by invoking the opposite concept, which is no less broad and general… The concrete will never be attained by combining the inadequacy of one concept with the inadequacy of its opposite. The singular will never be attained by correcting a generality with another generality (p. 44).

Deleuze and Guattari (1987) provide an alternative to both dualistic and dialectical thinking through an epistemology of flexible concepts characterized by the conceptual figuration of the rhizome. Rhizomes are 'anomalous becomings produced by the formation of transversal alliances between different and coexisting terms within an open system' (Deleuze & Guattari, 1987, p. 10). Rhizomatic thinking allows the multiple combination and recombination of elements in a creative and flexible fashion because, as Umberto Eco (1984) explains, 'the rhizome is so constructed that every path can be connected with every other one. It has no center, no periphery, no exit, because it is potentially infinite. The space of conjecture is a rhizome space' (p. 57). Thus, it might be more defensible to understand global/local (or global|local) neither dualistically nor dialectically but, rather, as a rhizomatic multiplicity of realities, referents and representations mutually constituting themselves like a tangle of rhizomes (see Gough & Price, 2009).

In pausing (not closing) I wish to emphasize that my deliberations on, and departures from, Pitts' paper are intended neither as a comprehensive review nor a thorough critique of his study. Rather, I have taken his paper as an invitation to explore some alternative directions

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[12] I gratefully acknowledge Peter Appelbaum and William Bricken for their helpful advice in framing the argument I advance in the two preceding paragraphs.

for science education research in the genre his study exemplifies. I try to write in the spirit of Deleuze's (1995) encouragement for 'writing to bring something to life, to free life from where it's trapped, to trace lines of flight' (pp. 140-1) and, whether or not I have succeeded in this instance, I thank Wesley Pitts for provoking me to embark on another attempt to do so.

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