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Trading zones and interactional expertise

Harry Collins [a], Robert Evans [a], Mike Gorman [b,1]

[a] Centre for the Study of Knowledge Expertise and Science (KES), Cardiff School of Social Sciences, Cardiff CF10 3WT, UK
[b] Department of Department of Science, Technology, & Society, University of Virginia, Charlottesville, VA 22904-4746, USA

Abstract

The phrase 'trading zone' is often used to denote any kind of interdisciplinary partnership in which two or more perspectives are combined and a new, shared language develops. In this paper we distinguish between different types of trading zone by asking whether the collaboration is co-operative or coerced and whether the end-state is a heterogeneous or homogeneous culture. In so doing, we find that the voluntary development of a new language community—what we call an inter-language trading zone—represents only one of four possible configurations. In developing this argument we show how different modes of collaboration result in different kinds of trading zone, how different kinds of trading zone may be 'nested' inside each other and discuss how a single collaboration might move between different kinds of trading zone over time. One implication of our analysis is that interactional expertise is a central component of at least one class of trading zone.

Keywords: Trading zones; Interactional expertise; Interdisciplinarity; Creole

1. Trading zones as the locus of incommensurability

Peter Galison introduced the term 'trading zone' to the social studies of science.[2] His purpose was to resolve the problem of incommensurability between Kuhnian paradigms: how do scientists communicate if paradigms are incommensurable?[3] Galison's approach has two legs. The first leg denies that scientific paradigms are as monolithic as Kuhn says. The second leg uses the metaphor of the trading zone to explain how communication is managed where there is a degree of incommensurability. Here we concentrate on the second leg.

We concentrate on the second leg because the first leg diverts attention from the interesting philosophical/sociological questions; if paradigms are not monolithic then, wherever they overlap, there is no problem to be resolved. Thus, Galison points out that even if there were theoretical incommensurability between, say, the Newtonian and Einsteinian worlds, experiment went on much as before and those who built instruments went on much as before. But if Kuhn is read as applying the Wittgensteinian notion of 'form of life' to science then there is less continuity, even in the realms of experiment and instruments. The 'actors' in those spheres may not experience the continuity that

E-mail addresses: CollinsHM@cardiff.ac.uk (H. Collins), EvansRJ1@cardiff.ac.uk (R. Evans), meg3c@virginia.edu (M. Gorman).
[1] Author's names in alphabetical order.
[2] The key reference for this is Galison (1997).
[3] Kuhn introduces the term paradigm in his classic *The structure of scientific revolutions* (Kuhn, 1996).

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the analyst sees. For example, even if it seems to the analyst that the same material objects are being built by instrument makers before and after the revolution the instrument makers themselves might see them as having different meanings before and after the revolution, rather as a cowrie shell might be an ornament for one tribe, a unit of currency for another tribe, and your grandmother's soul for another tribe. To think of the cowrie shell as the 'same thing' in each of these cases is to privilege a certain kind of analyst's viewpoint, something which is encouraged by the recent obsession in science and technology studies with the material. The interesting thing is that sometimes different groups manage to trade with material objects which may be 'the same' from our point of view but are not the same from theirs. Galison makes the point, remarking:

> Two groups can agree on rules of exchange even if they ascribe utterly different significance to the objects being exchanged; they may even disagree on the meaning of the exchange process itself. Nonetheless, the trading partners can hammer out a *local* coordination, despite vast *global* differences.[4]

It is how this is done that is the interesting problem for analysis; some analysts take apparent material continuity to be the solution to the problem rather than the problem to be solved. We make no attempt to solve the problem in this paper but it should not be forgotten when we talk, below, of 'boundary objects'.[5]

Not all trade is conducted in trading zones—at least, not according to our definition. We define 'trading zones' as locations in which communities with a deep problem of communication manage to communicate. If there is no problem of communication there is simply 'trade' not a 'trading zone'. Here, however, we consider only those cases where there are difficulties of communication and ask how they are overcome. That is the problem of trading zones as we see it. To repeat, if we do not start with a problem of communication we do not have the problem of trading zones, we simply have 'trade'.

1.1. Inter-language trading zones

To resolve the problem of trading zones as defined here, Galison looks to real economic trade in food and other goods between culturally disparate communities. He claims the problem is solved by the development of 'in-between' vocabularies through which communication can be accomplished. The simplest of these 'inter-languages' is a 'jargon', more complex is a 'pidgin', while a 'creole' is a new language in itself. Galison applies this metaphor to science. Using it he describes the development of technologies such as radar and high-energy physics particle detectors which involve/d communication between physicists and engineers who he treats as culturally dissimilar groups. He also describes the growth of new sciences, such as biochemistry, which arose out of chemistry and biology. In this case the result is a new expertise in biochemistry which involves a full-blown creole which can be taught as a free-standing language/culture to new generations of students.

We can call the resolution of communications via jargons, pidgins and creoles an 'inter-language trading zone'. Unfortunately, this model of the trading zone has often been taken to be the only meaning. But there are other ways to resolve problems of communication some of which, we suspect, are much more ubiquitous than the inter-language model. We need to find different terms for the different kinds of resolution and a way of understanding their similarities and differences.

2. A general model of trading zones

A more general model of trading zones can be developed by considering two dimensions along which trading zones can vary. One dimension is the extent to which power is used to enforce trade—this is the collaboration–coercion axis. The other dimension is the extent to which trade leads to a homogenous new culture—this is the homogeneity–heterogeneity axis. The two axes lead, in the familiar way, to four basic types, ideal versions of which can be represented on a two-by-two table.[6] Fig. 1 shows the four basic types of trading zone with one or more examples.

2.1. Enforced trading zones

As can be seen, inter-language trading zones are found in the top left-hand box because, in their ideal form, they involve mutual agreement to trade rather than coercion, and they tend toward homogeneity in a merged culture. A full-blown creole, such as biochemistry, is the ideal-type end point. The opposite quadrant—enforced trading zones—represents the situation with the maximum degree of coercion and the minimum level of homogeneity. The clearest example is slavery. Here, in the ideal-type, the bargain is entirely one-sided and no sharing of culture is

[4] Galison (1997), p. 783.

[5] The standard reference for boundary objects is Star & Griesemer (1989). An alternative way to explore the problem is to analyse interaction across cultures at the level of human actions (Collins & Kusch, 1998, Ch. 4). Collins and Kusch argue that actions cannot be coordinated across cultures unless the actions are 'mimeomorphic', which is to say that repeating the externally describable behaviours associated with an action is sufficient to reproduce the effect of the action irrespective of the intentions. Polimorphic actions, in contrast, need to be understood if their effects are to be reproduced since context is relevant and mere reproduction of behaviour will fail. Thus, it is the mimeomorphic components of 'action trees' associated with the handling of cowrie shells that allow trade.

[6] Gorman and Mehalik earlier proposed three stages in trading zones, the first of which corresponds to coercion, the second to our collaboration categories above, and the third to the kind of shared mental model achieved by the inventors of the ARPANET and by other design and discovery teams on the frontiers, where boundaries and terminologies are fluid. For more details of this typology see Gorman & Mehalik (2002).

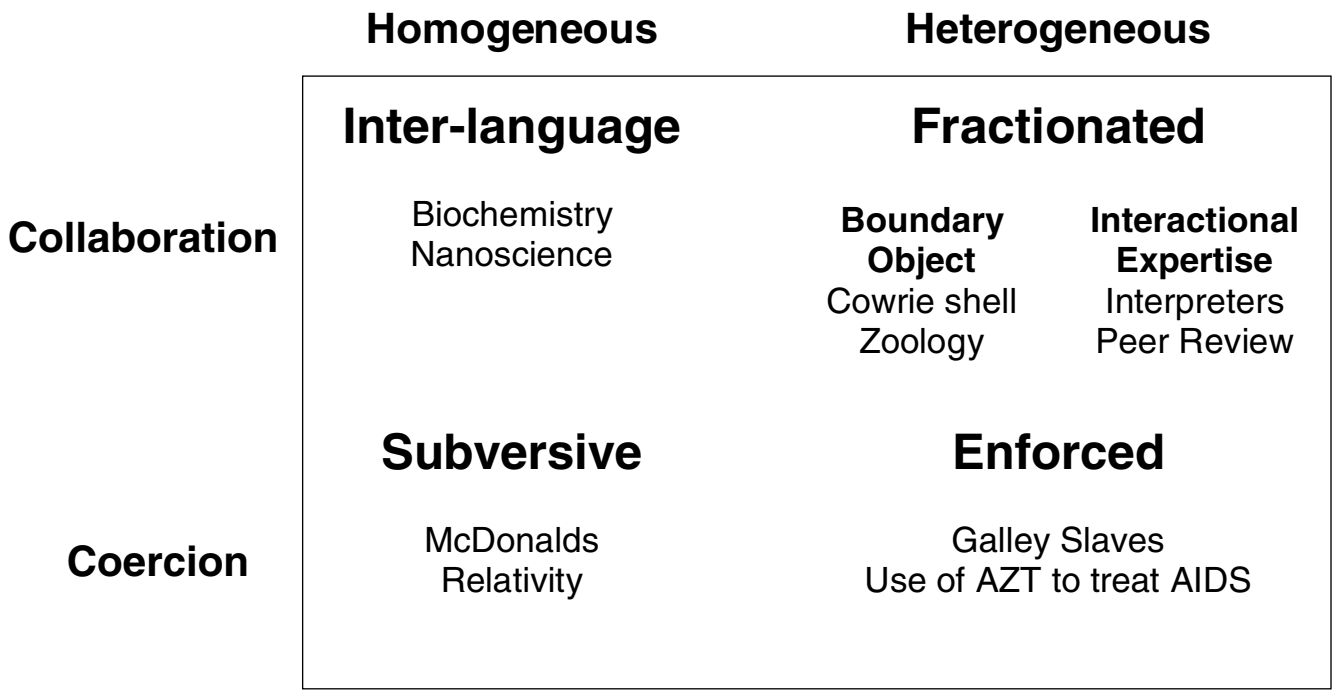

Fig. 1. A general model of trading zones.

attempted or even in prospect. Imagine slaves being used to propel a Roman galley. Trade is being conducted in the galley: the Romans get their ship propelled and in exchange the slaves get some food, some water, and relief from beatings or death. The trade is maintained by physical force and involves just enough interchange of meaning to allow the bargain to be understood. This interchange need hardly be cultural at all as the 'terms of trade' can be 'explained' to the human slave in rather the same way as it would be 'explained' to an animal—behaviour being 'shaped' by physical punishment and reward.[7]

Different in practice and moral complexion, but in the same location as far as the two dimensions are concerned, are trading zones where the expertise of an elite group remains 'black boxed' as far as the other participants are concerned. The access of the non-elite to understanding of the elite culture is tightly controlled by those in power. At the same time the elite group will make little or no attempt to gain access to the expertise of the natives. In this model there is no attempt to reduce the cultural heterogeneity and all the control is from the top down. In terms of Collins and Evans's 'Three Wave' metaphor the ideology driving such a situation is that of 'Wave One', with the science and technology being imposed from the top down on the assumption that, since science gives access to universal truths, adjustments for local conditions are otiose and there is no reason to meld the expert culture with the non-expert or even for the elite to try to understand the non-expert view of the world.[8] Such a relationship between scientists and non-scientists was once almost universal.

One example of such an enforced trading zone is the way central planners came to dominate agriculture and architecture in some parts of the world. This was to prove disastrous for agricultural production.[9] An alternative but more complex example would be the use of economic and other incentives to change agricultural or industrial practices in the developing world countries. In these cases, those on the receiving end of the policy are obliged to change their practices, for example by growing different crops using novel methods, but are not required to adopt the cultural viewpoint of the dominant group. In each case, the constitution of the trading zone is enforced, although the mechanisms are institutional, legal and economic rather than brute physical repression.

Finally, it should be said that there are circumstances in which an enforced trading zone is beneficial and even morally desirable. It is hard to think otherwise in the case of, say, the current approach to AIDS in South Africa where the government has pressed the case for a healthy diet as an alternative to drugs and in some townships it is thought that sex with a virgin is a cure.[10] It may also be the case in

[7] No doubt more complex tasks would require a great deal more in the way of cultural interchange if they were to be successfully carried out by slaves but we are describing the case in such a way that fills the bottom right-hand quadrant in the manner of an 'ideal-type'.

[8] For a summary of the 'three waves' of science studies see Collins & Evans (2002).

[9] For discussion of this and other cases see Scott (1998).

[10] For an examination of an earlier example of the South African government's sometimes bizarre approach to the AIDS epidemic in its country see Weinel (2007), this issue.

some emergencies. For example, natural disasters that require outside aid and expertise to alleviate their effects may be better handled without taking time for cultural negotiations even though more benefit would be gained in the long term if there was time to develop a more situated approach.

2.2. Subversive trading zones

Inter-languages take components from both parties to the trade but communication can also be achieved when one party's language overwhelms that of the other. In such trading zones, two languages, or forms of life, are on their way to being replaced by one, which originally belonged to just one of the parties; the other language is on the way to being subverted. A good example is the spread of American-style fast food, with all that it implies about changes in the rest of society, which has largely occurred with the acquiescence of the populations involved. The bottom left hand box contains these 'subversive' trading zones.

Subversion is another way in which top-down authority in science can work. Whereas in the enforced trading zone scientific authority was imposed by institutional means, in a subversive trading zone it gradually supplants the alternatives until it becomes the socially appropriate response. If one prefers to think of the Einsteinian revolution as a discontinuity then one would say that Einsteinian physics language has colonized Newtonian physics language. This remains the case in spite of the many Newtonian-looking sentences that are spoken. Every sentence spoken nowadays that appears Newtonian is really an Einsteinian sentence in disguise and the speakers know this (for example they will say that their sentences refer to special cases of what is in reality an Einsteinian universe). The same is also true of the ways in which scientific explanations for everyday events (for example why the sun rises, where babies come from) come to replace lay and folk theories in most Western societies. We refer to this kind of process as 'cultural subversion'.

In addition to the establishment of cultural hegemony, subversive trading zones can also be created through technological or physical means. For example, for most PC users Microsoft's Windows software is technologically coercive—it is the operating system that is most readily available. Over time it has become the default option and most users use it because they have never thought of using anything else. In this sense, most PC users are similar to the users of video recorders described by Donald Norman who are forced, by the structure and interface of the VCR, to enact the designer's mental model of how the technology should be used. [11] Other possibilities are written out of this script and are thus never realized in practice. On the other hand, Apple enthusiasts, or Linux enthusiasts, generally hate Windows and would prefer to keep the alternative approach alive. Nevertheless, they may find they have no choice but to use some of Windows applications, or at least ensure their own applications are compatible with them. Given that they would prefer not to use Windows, then their 'trading' with Windows is better described as enforced and belongs in the bottom right hand box.

2.3. Fractionated trading zones

Inter-language trading zones operate by developing new cultural tools, subversive trading zones operate by imposing one culture on another, while enforced trading zones operate with almost no cultural interchange. The final type of trading zone, which occupies the top right hand area of the table, involves fractions of cultures as the medium of interchange. There are two kinds of fractionated trading zones: boundary object trading zones, which are mediated by material culture largely in the absence of linguistic interchange, and interactional expertise trading zones, which are mediated by language largely in the absence of the material.

It is, of course, not so easy to divide forms of life into their material and linguistic components. We have already argued that, as with the cowrie shell, what may appear materially 'the same' to an analyst may appear different to the natives occupying different forms of life, so treating each 'fraction' in isolation presents conceptual difficulties. As Galison explains, ideas such as 'boundary object' work because, though the object means different things to the different parties, this does not vitiate their separate projects. One well known example of a boundary-object trading zone is that described by Star and Griesemer, who studied how a diverse group of scientists, trappers, amateur collectors, and university administrators successfully collaborated in providing and cataloguing specimens for the Museum of Vertebrate Zoology at the University of California, Berkeley. According to Star and Griesemer, 'Boundary objects are objects that are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites'.[12] One of the boundary objects in their study was the state of California.

> The maps of California created by the amateur collectors and the conservationists resembled traditional roadmaps familiar to us all, and emphasized campsites, trails and places to collect. The maps created by the professional biologists, however, shared the same outline of the state (with the same geo-political boundaries), but were filled in with a highly abstract, ecologically-based series of shaded areas representing 'life zones', an ecological concept.[13]

[11] For more details of this see Norman (1993).
[12] For a full discussion of this see Star & Griesemer (1989). The quote can be found on p. 393.
[13] Star & Griesemer (1989). The quote is on p. 411.

Both groups could therefore agree that specimens should be collected from California, and location information could be translated between the two kinds of maps if the right data were provided. Standardized procedures for recording information facilitated this translation. In effect, the boundary objects plus the standardized procedures performed the same function as a creole.

The linguistic complement of the boundary object is interactional expertise. This involves internalization of the tacit components of a strange language. While acquisition of interactional expertise does not provide full grasp of the strange form of life—it provides no access to the other parties material culture except in so far as that material culture is represented in discourse—it is surprising how much can be done, is done, and, indeed, must be done, with the language fraction alone.

Interactional expertise is the product of a successful linguistic socialization. Although expressed as language alone, it cannot be too heavily stressed, interactional expertise is tacit knowledge-laden and context specific. It is not the same as the kind of formal representation of the world beloved of artificial intelligence enthusiasts and the like. Language as interactional expertise is just as resistant to representation in computer programs as any other kind of tacit and situated knowledge.

One example of what seems to be a fractionated trading zone based on interactional expertise is water management in Arizona. To make a decision about appropriate technology social scientists were recruited to develop a set of metrics that would allow Bureau of Reclamation engineers, Yavapai Indians, and other stakeholders to communicate about the value, use and need given to water resources. We could say that the social scientists were engaged in two simultaneous projects: trying to become interactional experts in the worlds of the various negotiating parties and trying to build an inter-language—in this case a common language of measurement—that both parties would share. The social scientists failed to build the inter-language; both the Bureau engineers and the Yavapai felt that the metrics developed by the social scientists failed to capture important parts of their separate beliefs and values. The interactional expertise part of the enterprise seems to have worked, however. A compromise was reached that avoided the building of a new dam, preserved Yavapai land, and still permitted water management. Cultures that remained incommensurable from a cultural standpoint seem to have found a way to trade via the intervention of social scientists who acquired interactional expertise in both worlds.[14]

Another example of the use of interactional expertise to create a trading zone is that of the San Francisco AIDS activists described by Steven Epstein.[15] The AIDS activists mastered the language of medical research even though they were not medical researchers or practitioners themselves. Initially, groups of activists demanded changes in the protocols and researchers made some concessions, although this relationship was more adversarial than cooperative. As activists grew in sophistication and attracted allies among statisticians, however, the relationship became more collaborative, although both groups retained the separate identities and cultures.

A third example of a fractionated trading zone is provided by the development of an environmentally intelligent fabric by a team that included an architect, a green chemist, a fashion designer and the manager of a textile mill. The fashion designer recruited a 'high practitioner', an architect who pronounced that the fabric would have to follow the maxim 'waste equals food'. The maxim was based on an analogy with natural systems, claiming that all waste in nature is food for other organisms. 'Waste equals food' became a provocative metaphor for the growing team. The green chemist added a protocol for determining which materials and processes fulfilled this maxim. The mill owner had to create the fabric in alignment with the green chemist's protocols. All core members had to achieve interactional expertise in each other's domains in order to produce a successful commercial product.[16] Thus, for example, the green chemist and the architect had to understand enough of the manufacturing processes to be sure they followed the protocol, whilst the mill owner had to understand the guiding principles and protocol well enough to be able to embody them in the design. Nevertheless, the parties did not become contributors to each other's fields nor was any new vocabulary developed—at least, not in the first instance.

Yet another example is the field of gravitational wave detection. This is a highly integrated esoteric science, in which everyone is committed to the common goal of building a gravitational wave detector that can detect the waves; there are perhaps 500 gravitational wave scientists. The field is divided up, however, into many sub-specialisms and most scientists have only interactional expertise in the work of a specialism that is not their own and there do not seem to be any new, gravitational wave-specific, inter-languages. Could it be that the growth of inter-languages is the unusual case? It may be that, when examined closely, what appear to be integrated networks of scientists are really conglomerations of small groups bound together by rich interactional expertises.

In these examples trades were managed even though inter-languages were not the key. Goods which had different values in each culture were traded, the exchange being managed either by third parties who had the capacity to talk to both in some approximation to their language or by members of each group gaining interactional expertise in others' worlds. In no case was there full immersion (that

[14] Espeland (1998) describes the case discussed in this paragraph.
[15] For a full account of the research summarised in this paragraph see Epstein (1996).
[16] For more details of this case study see Gorman & Mehalik (2002).

is, practical as well as linguistic socialisation) in the others' forms of life nor the development of new languages or cultures. The interactional expertise trading zone seems so widespread that it might be argued that this, rather than the inter-language model, it is the norm for new interdisciplinary work. Certainly, where inter-languages develop it is likely that interactional expertise is the first step.[17]

3. Trading locations and the fractal approach

One potentially misleading feature of the left hand areas of the table is that once the examples of trading zones that belong there reach their end point—a full-blown creole with a degree of institutional stability such as is exhibited by biochemistry, or a total swamping of one native culture by the other—the problem of communication has been solved and, according to our usage, the 'trading zone' disappears. Thus biochemistry, though it grew up as a trading zone, is now just a new homogeneous cultural location in which trades happen. When they reach their end points, all the examples in the left hand areas slip off the table in a Westerly direction, as it were.

The question remains what these groups consist of once they have achieved the appearance or reality of cultural homogeneity. We have already suggested that a uniform-looking area such as gravitational wave physics is actually made up of many small local groups interacting through interactional expertise. There is also a more 'conceptual' point. It is possible to find discontinuity even in as solidaristic a cultural location as biochemistry by looking closely enough. One can always choose to 'zoom in' on any area of social life and, as the scale increases and ever more detail is exposed, as with a polished metal surface, what appeared smooth turns out to be jagged. Social life, one might say, is like a 'fractal' where the structure is reiterated at every scale and the scale at which one chooses to pitch one's analysis is a matter of choice. Thus, within the mature science of biochemistry there will be small and local regions which still exhibit the characteristics of all the kinds of trading zone represented in Fig. 1.

This fractal model comes naturally to psychology though not by that name. Psychologists talk less in terms of cultural similarity and discontinuity and more in terms of 'shared mental models'. For such psychologists the fractal model is already immanent in the way they look at the world because the sharing may be among greater or smaller numbers of individuals. Thus the idea that a large group of people may share a large scale mental model while not all of them share aspects of its more detailed structure is accepted without special mention. Whether one talks of fractals or different aspects of mental models being shared by more or fewer individuals is a matter of choice of language. In this case, the different languages do not appear to present a problem of communication as it is possible to translate between the two different discourses without loss. Thus, for example, what a sociologist might see as a low degree of inclusion within a technological frame, a psychologist might describe as a partially shared mental model.[18]

On the right hand side of the diagram there is no slipping off. On the right hand side, trading zones remain trading zones without any need for magnification even after long periods of evolution because the separate cultures remain separate. In the case of interactional expertise one party learns the language of the other while retaining their own material form of life and distinct contributory expertises. Indeed, it is precisely the continuing discontinuity between the cultures that enables the individual with interactional expertise, and who thus has a mastery of both languages, to maintain their special role. For example, interpreters can do their job via interactional expertise, going backward and forward between the two groups only so long as the two groups want to communicate but are unable to do so.[19] In the case of boundary objects the two forms of life again remain distinct, each imposing their own meaning on the 'common' material object and working with it in their own way. In the case of slavery, two distinct cultures also remain. In the extreme case of the Roman galley, the slaves are given no opportunity to learn the culture of their masters and the trading zone remains unchanged for as long as the slave masters can exert their will. In more complex settings the continuation of the two cultures may be harder to see, but it is nonetheless still present. For example, where slaves perform more complex tasks they appear to be participating more fully in the dominant culture, so it might appear that the slave's culture is being replaced by that of their masters (that is, the trading zone is becoming a subversive one). In practice, however, a closer inspection often reveals that the original culture continues to survive, albeit in less visible ways and places, so that the trading zone continues to be based on two distinct but different cultures even if, on the surface, it appears as just the one.[20]

Many of the most interesting instances of interactional expertise—such as peer review and the management of scientific projects—can be seen as features of a trading zone only when the magnification is high. Viewed from a distance—from high up the fractal—they look like elements within a coherent scientific culture rather than mechanisms that allow disparate cultures to communicate.

[17] For more on this see Shrager (2007), this issue.
[18] The concept of a technological frame comes is taken from Bijker (1995).
[19] For more on the work of interpreters see Ribeiro (2007a,b).
[20] The same is true in those cases where slave masters make a deliberate attempt to eliminate the indigenous culture. Where they succeed the trading zone becomes a subversive one, where they fail it remains an enforced one.

4. The evolution of trading zones

If trading zones are dynamic entities then it should be possible to use the typology set out above to describe the different states in which a trading zone might exist over time. Whilst it is possible for new domains to be so innovative that they do not build on any existing cultures, this situation is probably rare. One example may be the ARPANET, the precursor to the internet. Here there was no problem of incommensurability between the partners because the project was so new that the culture had to be invented jointly from a blank slate. Democratic organization and trust appears to have been sufficient for coordination.[21]

By considering the twin dimensions of homogeneity–heterogeneity and collaboration–coercion, the different trajectories and characteristics of trading zones and the way these change as trading zones develop, can be analysed. This possibility is best visualized on a space that admits of in-between positions as well as ideal cases. Fig. 2 represents such a space with degrees of coerciveness and homogeneity now represented on the continuous axes of a graph. It shows the possible trajectory of an imaginary research group coming together around the idea of nanotechnology. The trajectory follows an anti-clockwise movement starting in the bottom right-hand quadrant, each succeeding stage being indicated by a number from 1 to 5. The trajectory is not intended to be prescriptive, it is merely an illustration of the way in which the categories set out above might be applied in a more dynamic context. In this example, step 1 arises when a University 'encourages' the members of their chemistry, physics, engineering, and social science departments to collaborate on a research application to develop 'nanoscience'. At this point disciplinary identities are distinct, so they remain heterogeneous rather than homogeneous, and their coming together has been enforced, albeit gently, so the trading zone is coerced rather than collaborative at this stage. At this point, there are two main ways in which the trading zone might develop. On the one hand, the group may decide to continue to collaborate and develop a research proposal or they may conclude that there is insufficient common ground and the trading zone would then collapse.[22]

Assuming the group decides that working together is viable and desirable, the trading zone would become increasingly voluntary and collaborative. In this scenario, the different departments agree that the nanoscience application is a good idea and, even though they are remain separate disciplines, the initial coercion is replaced by a shared agreement to work together and the collaboration migrates upwards and becomes a fractionated trading zone of one of two types. One outcome—step 2a on the diagram—is that some kind of boundary object (in this case the research application) is produced.[23] Although it is likely, given the continued existence of different departments and disciplines, that the research application will mean different things to different people, these differences are not sufficiently important to undermine the joint project. As work on the application develops and the different parties become increasingly engaged in the ideas then we might expect to see the trading zone drift further up the diagram as the intensity of the collaboration increases.

A shared research proposal is not the only outcome, however. It may be that, despite the initial optimism, no application is produced or, even if it is, that it is not funded. In these circumstances the initial trading zone might disintegrate as the object that united them has now disappeared. On the other hand, it may be that, as a result of the interactions and the sharing of ideas and discourse, some members of the trading zone become sufficiently interested in the others' work to want to understand more about it. If they pursue this ambition it is possible that they will develop interactional expertise in the one of the other disciplines—step 2b on the diagram—and that a fractionated trading zone based around this shared expertise will emerge.

If, however, we assume that the trading zone develops into the boundary object type, united around a successful research application, then the initial collaboration will continue. At this point, as the nanoscience work begins in earnest, the interactions between the different departments and disciplines will intensify still further. Now they may be co-located in the same building, working on joint projects. Researchers will thus have to communicate and co-ordinate their actions with a new and diverse set of colleagues. They might start with interactional expertise as their main communicative resource and then begin to invent jargon terms, which in turn give rise to a pidgin and, perhaps, a creole. As this happens, so the cultural differences between the different disciplinary participants will be reduced and the amount that they share will increase. As cultures become more homogenous, so the trading zone begins to move to the left and the fractionated trading zone becomes an inter-language trading zone—step 3 on the diagram. Over an even longer time period it may even be the case that, as with biochemistry, a distinct new discipline emerges. On the diagram, this would be represented as a further drift to the left to the point where there will be so

[21] For more on the development of ARPANET see Hughes (1998).

[22] Logically there is a third possibility, which is that the university authorities would refuse to accept the decision that a research proposal could not be developed and further insist that the collaboration be made to happen. In this case the trading zone would move south on the diagram as the relative degree of coercion increased.

[23] Anecdotally it seems from presentations at the Arizona Workshop that one of typical stumbling blocks in these kinds of processes is the physical location of the research work. In most cases it seems that a brand new building is better than one that is already seen as 'belonging' to one of the contributing departments.

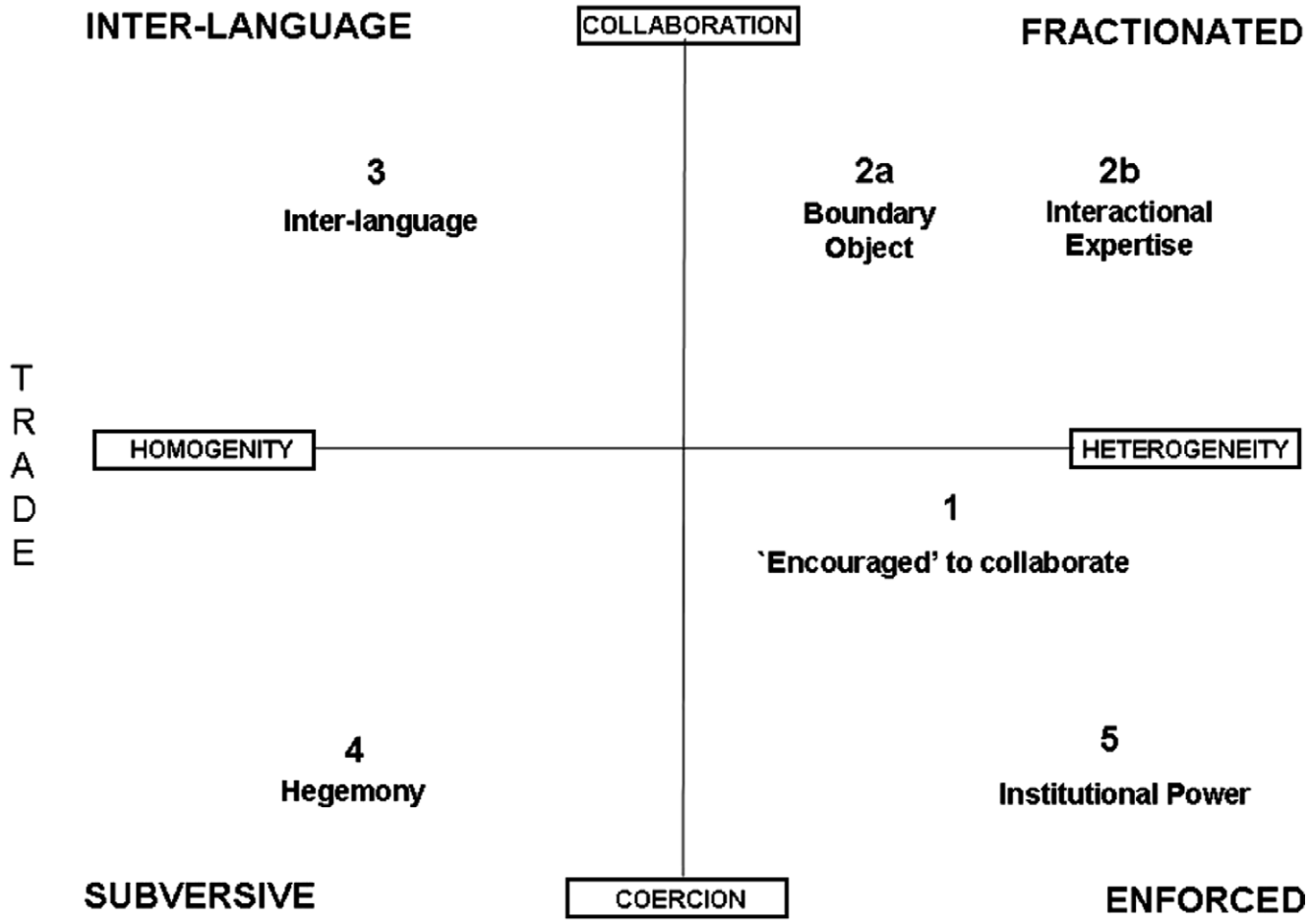

Fig. 2. Evolution of a trading zone.

much in common that the trading zone concept does not apply. There is simply a new science in which trade takes place in the ordinary way.

The creation of a new strong science sets the scene for other changes too. One possibility is that, as the new science develops and becomes more popular then, just as the language of Newtonian physics was eventually subverted by the paradigm shift to Einsteinian relativity, so our current understanding of the boundaries between information science, genetic science and the natural sciences as a whole, will be subverted by the new language. This possibility is realised when departments are set up, textbooks are produced and what was once a radical and innovative experiment becomes a normal science research program. All this takes place over the Western horizon of the diagram. New recruits to the discipline will now find the cultural hegemony so strong that they have no choice but to abandon any ideas they bring with them and accept the dominant culture. Anything strange sucked into its domain will be subverted by the dominant culture of the new science. We represent this with the label 'hegemony' in the bottom left-hand quadrant.

The creation of a strong science also changes the way in which the science interacts with other groups and becomes part of new trading zones. For example, as the new nanoscience becomes more institutionalised within the broader network of scientific disciplines so the elite of the new science will need to recruit new scientists and police the boundaries of the new field in order to control who should count as an expert in that domain. This institutionalisation, where it happens, is shown as Step 5 on the diagram and returns us to the bottom right hand corner, where the authority of expertise allows the discipline to make knowledge claims that can now be enforced over other knowledge-claims for good or for bad in the manner described in Section 2.1.

We must stress again that this is just one possible model and it is certainly not a prescriptive one. It may be that the trading zone simply ceases to function and disintegrates somewhere along the way. For example, a team, having reached Step 2, might disband when the problem it was created to solve has been dealt with, or it might be that the difficulties of interdisciplinary collaboration become too great as the detailed work begins to be done. Similarly, either of the fractionated trading zone states may prove to be a stable equilibrium so that the development of an inter-language trading zone is neither necessary nor desirable.

The anti-clockwise direction sketched above is also just one possibility. It may be that the power dynamic of the trading zone changes such that one party becomes increasingly able to enforce their views on the others. This would be represented by a drift downwards (as coercion becomes more relevant) and possibly to the left (as the differences are erased). In the case of the nanoscience research project, this outcome might represent the capture of the research agenda by one of the sub-disciplines and an increasing emphasis on a single perspective, to the point where nanoscience becomes a sub-field of chemistry or another existing disciplinary culture. In other words, there is no particular 'right' way of moving through or around the diagram, but the differences between different kinds of trading zones can be made clearer by thinking about how they can be represented in the two dimensional space it defines.

4.1. Funding trading zones

If the diagram were drawn to scale, than (at least for science and technology) the top half of the diagram would be the largest and most important, emphasizing the extent to which interactional expertise and cross-disciplinary working are central to most modern technical collaborations. By considering how these different groups were brought together in the first place (for example by choice or compulsion), and the extent to which they remain distinct, this model provides a framework for understanding the problems that might arise. For example, in the case of enforced trading zones, motivation and compliance are likely to be problematic. Given the emphasis on collaboration, this is less likely to be a problem in the top half of the diagram. Moreover, to the extent that genuinely novel ideas come from 'left field' or from those with a relatively low degree of inclusion, then the top-right hand quadrant seems to be the best location for developing new interdisciplinary partnerships.

There is also a risk with this activity, however. The fractionated trading zone identifies a kind of research activity that funding bodies need to support but to support charitably. Given the heterogeneity of the cultures and the difficulty of learning new languages, then the realistic expectation must be that only a small number of such trading zones will succeed, either as stable fractionated trading zones or as the more institutional homogenous inter-language variety. In funding nascent fractionated trading zones a good allowance must be made for the sheer time it takes to acquire interactional expertise and/or develop boundary objects that are both malleable and robust enough to bridge between the different communities. Yet longer time frames must be used if the aspiration is the emergence of pidgins and creoles needed for new inter-languages to develop.[24]

5. Conclusion

The idea of a trading zone as a place where problems of communication and co-ordination are resolved can help us understand a wide range of styles of social and scientific collaboration and the ways in which they may evolve into one another.

In this paper we have argued that the different possibilities can be captured in a two by two matrix based around the axes of coercion and homogeneity. These ideal-types provide exemplars of the different ways in which trading zones can be made to work. They are:

- Inter-language trading zone (high collaboration, high homogeneity)
- Subversive trading zone (high coercion, high homogeneity)
- Enforced trading zone (high coercion, high heterogeneity)
- Fractionated trading zone (high collaboration, high heterogeneity)

We have also argued that, using the same axes, it is possible to describe how a trading zone may develop over time by moving between different states. This last point is particularly important in the case of interdisciplinary science. Firstly it shows that there is not just one best way of organizing inter-disciplinary collaborations and that, even within the same collaboration, different relationships will develop at different times. Secondly, and perhaps even more importantly, thinking about trading zones as places where cultures meet, languages are learned and tacit knowledge shared, emphasizes the difficult and time-consuming nature of the work. This is not to say that such work should not be funded, but it does serve as an important reminder that such work is different to normal science and needs to be managed and assessed in different ways. In particular, to the extent that fractionated trading zones depend on the development of interactional expertise, then they require a considerable work on the part of at least some participants if their potential is to be realized.

Acknowledgements

The overall approach offered here is inspired by Gorman (2002) where a classification of trading zones based on the idea of interactional expertise is developed. We also draw heavily on a paper by Ribeiro (2007a) who provides a model of communication with many of the components discussed here. The writing of the paper was inspired by a workshop on trading zones and interactional expertise organised by Gorman at the University of Arizona, 21–24 May 2006 and supported by the National Science Foundation (SES-0526096), the Boston Consulting Group and the Center for Nanotechnology and Society.

[24] For a discussion of interdisciplinary research in the context of sustainable cities research, see Evans & Marvin (2006).

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