STRUGGLES AND NEGOTIATIONS TO DEFINE WHAT IS PROBLEMATIC AND WHAT IS NOT

*The Socio-logic of Translation**

MICHEL CALLON
Ecole des Mines de Paris, Centre de Sociologie de l'Innovation

In the space of a few short years the centre of interest in the sociology of sciences has radically shifted. At first timidly, later with increasing boldness, sociologists have penetrated the sanctuary. They no longer confine their interest to a study of how institutions work, or the rules governing competition, or network or community organisation. Increasingly, they are investigating the content of science itself.

Though this change of direction now seems legitimate, and indeed irreversible, it still remains very tentative. Deeply marked by its recent past, the sociology of science still takes for granted the chopped-up, compartmentalised world the scientists are so patiently building up, being ready to distinguish, and even unhesitatingly to place in mutual opposition social factors and technical or cognitive ones (1). Concepts like social contexts of scientific research are still in common use today, proving the continuing vitality of this way of thinking. Within reality territories and domains are divided off, frontiers laid out, a priori factors of different types identified and phases obeying a specific logic enumerated (2).

However, these common distinctions are having increasing difficulty in holding out against sociological ventures. The deeper we delve into content, the more the legitimacy of black boxism seems questionable (3) and the more difficult, hazardous and arbitrary the separation of social from non-social, cognitive from non-cognitive becomes (4). The most solidly-based concepts dissolve, revealing their ambiguity. What does 'reproducing an experiment mean'? (5) What is understood by the expression 'reporting on a research process'? (6) It gradually becomes apparent that social and cognitive are inextricably entwined exactly where unravelling them seemed to present no

Karin D. Knorr, Roger Krohn and Richard Whitley (eds.), The Social Process of Scientific Investigation. Sociology of the Sciences, Volume IV, 1980. 197–219.

problems. The protagonists are involved in a never ending struggle to impose their own definitions and to make sure that their view of how reality should be divided up prevails. Consensuses are reached, lasting for longer or shorter periods of time, concealing balances of power. The dividing line between what is considered social and what is considered technical is constantly re-negotiated.

These struggles bedevil every moment of the research process, though they probably have the most important consequences in the very early stages when problems are being identified and the certain marked off from the uncertain. From this point of view, existing interpretations are not really satisfactory, distinguishing as they do on the one hand, identification or emergence of problems (7) on the other hand, recognition of them and their gradual legitimising until various social groups take charge of them (8). However, analysis of the struggles and negotiations pitting social protagonists against each other as they strive to define what is problematic and what is not reveals that distinctions of this type are unrealistic. During these preliminary skirmishes research problems and the groups which will take charge of them are *simultaneously* determined. Social structures and cognitive structures are defined within the same crucible. Though very different, they are both by-products of the same reaction. The study of problematisation is vital for understanding the rules governing the mysterious chemistry, the constantly renewed fusions, which permanently produce the social and the cognitive.

In this article I aim to show the relevance of this point of view, limiting myself to the study of two issues; (a) Description of the mechanisms through which reality is problematised, that is the work of what I propose to call 'forces of problematisation'; (b) analysis of the relationships between various forces of problematisation and the general mechanisms by which problems impose themselves. I shall attempt to answer these questions by describing French work on fuel cells. This research got underway in the late fifties, occupying, for a decade, a large number of research workers and technicians working within the universities, in CNRS (9) laboratories, and in research centres belonging to large firms. The work was financially and politically supported by DGRST and DRME (10). In reconstructing the development of this research, we have had access to the records of the various laboratories involved and to the complete records of the DGRST. In addition we interviewed the main protagonists.

An Abundance of Problematisations

The DGRST was founded in France in the late fifties, with the aim of preparing, coordinating and implementing French policy with regard to scientific and technical research. One of its first acts was to set up 'concerted actions' in which laboratories, both private and public, within industry or the University, came together for a limited time to work on top priority programmes. Each 'action' is administered by a scientific committee consisting of about fifteen experts (scientists, industrialists and officials) who take part *intuitu personae* in the work of the committee. The committee selects projects from those submitted and distributes the credits allocated to the work. The procedure used was worked out during the final years of the IVth Republic. In this way public and private research can work together and programmes rejected by traditional institutions (CNRS, universities, industrial enterprises) are more readily financed, thus facilitating coordinated and collective work on subjects that have been given top priority.

In fact, in the early sixties, the CNRS and industry left the scene vacant, the former undermined by academicism, the latter little concerned with research and innovation. The DGRST filled this vacuum. As a result, the main initial beneficiaries of the operation were those scientists whose disciplines had been misunderstood or looked down upon by both the University and the CNRS, who housed them, but gave them no real means for development. The 'concerted action' procedure fitted them like a glove; they were assured of both industrial and political support; likewise they had scope for action in the form of credits, both of which had previously been refused (11).

The above remarks are fully applicable to the research on fuel cells undertaken within the framework of the "energy conversion" concerted action, whose aim was to develop new forms of energy production. There were no industrialists on the committee responsible for pushing the programme through, the scientists intended to call the tune. They imposed their own analysis of the situation, sketched out the problems to be solved and the links between them. They decided how the work was to be divided up and coordinated. Finally they indicated what was at stake at the social, political and economic levels (12).

In the case of fuel cells, problematisation operated in three phases and reveals a wide range of possible analyses.

(1) The committee's first task was to identify interesting fields of research. The general theme of energy conversion provided an initial territory within which priority sectors had to be identified. The first discussion focussed on the definition of what was interesting and what was not. Two physicists, *X* and *Z*, were set against each other.

When he was asked to sit on the committee, *X* was a scientist well known within his own discipline of solid state physics. He had spent a considerable time working in a well known laboratory in the United States. Since his return he had published several articles that attracted considerable attention. At the committee's very first meeting he put forward an analysis of spheres of research that might be of interest. His argument is summarised in Table 1. At the head of each line and column the various forms of energy are indicated; electrical energy, light energy, mechanical energy, thermal and chemical energy. The columns correspond to the initial energy forms, the rows – the final forms. Each division of the table thus represents one possible method of energy conversion, for example, conversion of chemical energy into electrical energy. Each of these divisions is simultaneously and inextricably linked to various phenomena, various effects and a variety of technical devices. Some divisions are partly empty, either the devices do not yet exist, or else the phenomena have not yet been properly identified. Other divisions refer to spheres so huge that an exhaustive inventory is thought unrealistic. We shall return later to the 'logic' (we would call it 'socio-logic') underlying this table. For the moment we shall content ourselves with pointing out how it functions.

First of all the table establishes a perfectly clear frontier between what is analysed and what escapes analysis. The 'edges' of the table demarcate the reality considered relevant. This is a very general phenomenon, the construction of a black box. *X* has created an inside and an outside, manufacturing a local coherence. He has defined a protected territory, claimed an autonomy.

The table demarcates and defines spheres of research on the basis of categories considered obvious and quite distinct. If the table possesses its own coherence, which enables it to define a distinct universe, closed in upon itself, this is because it provides a strong framework. The energy forms can be located and demarcated. The concept of energy conversion is not called into question. Using his table, *X* divides up the ground, defining territories quite separate from each other. Not only does he mark off the different domains, he also

TABLE 1

Final form \ Initial energy form	Electrical	Light	Mechanical	Thermal	Chemical
Electrical	Converters Rectifiers Transformers Oscillators	Photovoltaic Photogalvanic effects	Electric machines wind tidal power currents	Thermoelectric thermo-ionic effects	Fuel cells Ordinary cells Accumulators
Light	Electroluminescence. Discharge in gases	Luminescence	Triboluminescence	Incandescence	Chemoluminescence
Mechanical	Electric machines	Crookes Radiometer ?	Simple machines; Energy storage	Thermal machines	Artificial muscle Propellant
Thermal	Static heat pumps (Peltier effect). Electric heating by arc. Dielectric heating H. F. Plasmas	Solar energy collection	Heat pumps refrigeration	Refrigerators (adsorption) Exchangers	Combustion
Chemical	Electrochemistry	Photosynthesis Radiochemistry	Chemical grafting laminating	Thermochemistry ?	(too huge) ?

shows what work remains to be done. The squares are more or less easy to fill in, more or less enigmatic. Reams have been written about the conversion of thermal energy into mechanical energy, whilst in the square chemical energy → electrical energy there is little to be said. Darkness reigns. Who at that time would have dared to claim that the functioning of fuel cells had been fully investigated? Thus are contrasted the old and the new, the more and the less problematic; fields already explored (thermal machines, electric machines) and fields that call for new investigations (fuel cells, photovoltaic effects . . .).

However, *X*'s is not the only possible problematisation; at the same time another physicist, *Z*, put forward another one. *Z* is a product of one of the most renowned French scientific institutions: the *Ecole Normale Supérieure*. Though he is only just starting out on his scientific career, he already has considerable support behind him. He is not yet well known enough to belong to the energy conversion committee, but his reputation is sufficient for him to be allowed to explain his point of view to the scientists and industrialists concerned with fuel cells. A large scale meeting is arranged. In his speech *Z* lambasts *X*. His line of argument leads him to radically different conclusions.

Z does not even refer to the general question of energy conversion. At no point does he distinguish different forms of energy. All this is outside his field of analysis. His point of departure is electrocatalysis, that is catalysis of reactions which liberate electrons (oxidoreduction reactions). In this way he defines the sphere within which research should take place. The concept of electrocatalysis cuts short discussion just as effectively as the table proposed by *X*. Demarcation of this problematic field is based on a set of concepts, theories and elements which are taken for granted. *Z* makes specific reference to the latest developments in solid state physics, and the tools these provide for the study of electrocatalysis.

Z's problematisation is very much less structured than that of *X*, but it follows the same logic; a problematic field closed in upon itself, then statement of elements taken for granted and considered certain, which give the field its rigid, autonomous framework. Though *Z*'s presentation of his problematisation remains somewhat vague with regard to details, he is able to show quite clearly how it differs from *X*'s analysis. He considers that electrochemistry will remain in a very weak position until it has managed to extricate itself from the technological approach that is stifling it. For him the

theoretical unity of the fuel cell is a myth. Though admitted and consolidated by *X*'s problematisation, this object must be 'de-constructed'. The alternative is clear. The problem is not that of improving catalysis in fuel cells, but rather of working out the laws governing electro-catalysis in general.

(2) The committee accepted *X*'s proposed problematisation. Fuel cells are one of the three themes given top priority. The committee instructs *Y* to work out a research programme on fuel cells. *Y* is an electrochemist by training, director of the 'Electrolysis laboratory', which is dependent on the CNRS. After a few weeks work he presents the committee with a document explaining his own problematisation. His analysis is synthesised in a table (Table 2) giving details of the lines research should follow and indicating research centres to be mobilised. How is this table organised?

TABLE 2

Themes	Interests	Research centers	Credits (F)
1. General study of kinetics of reactions to electrodes	. scientific . technical: increasing cell power	CNRS Electrolysis Lab IFP (for hydrocarbons	2 300 000 400 000
2. Study of catalysis of depolarization reactions	technical	CNRS Catalysis center IFP (hydrocarbons) CNRS electrolysis Lab	1 000 000/year
3. Research on electrodes	technical	doubtless industrialists	200 000/year
4. Research on molten electrolytes		Grenoble school	500 000/year
5. Research on internal cell resistance	technical (cell output improvement)	electrolysis Lab	500 000
6. Research on diffusion	Molten, aqueous electrolytes	– ? – CNRS Electrolysis Lab	200 000 100 000
7. Research on special electrolytes	. Semipermeable membranes . solid or immobile electrolytes	?	450 000
8. Technological research	HT cells LT cells	?	1 000 000 500 000

Firstly, the table demarcates a territory for analysis within the area of reality. This territory is firmly delineated by the outlines of a specific object, the fuel cell, and by the theoretical assumptions made about it. *Y*'s problematisation fits perfectly within that of *X*. The latter had already provided a system of partitions which *Y* took over as it stood. The fuel cell represents a privileged object in electrochemistry, as viewed by *Y*. No-one and nothing could undermine this relationship. The cell is contained as a whole within electrochemistry, and vice versa. There is no overlap on either side. The wall around is a perfect fit, it is totally self-sufficient and may not be disturbed in any way.

The table defines themes for research by formulating problems (these are explained at more length in the accompanying notes). *Y* draws up his balance sheet, using his own organisation and formulation of problems. He draws a demarcation line between what, in his view, is known of how a cell works, and what is not known. What strikes the observer forcibly is how the fuel cell's architecture, the different elements that make it up, and the phenomena within it, all correspond closely to the aims and themes for study. There are the electrodes, the electrolyte, the catalyst. There is reference to knowledge that was widely accepted and used at that time in France by those calling themselves electrochemists (diffusion, internal resistance, depolarisation, kinetics . . .). A whole set of concepts, proposals, ways of thinking, methods of giving proof are called into play to isolate and define the darker corners of how a cell works. The areas of ignorance appear against a background of certainty, admitted knowledge and systems of interpretation (13).

We might note in passing, since this helps to explain the nature of the opposition between *X* and *Z*, that one of the most important results of this type of problematisation is the place given to catalysis. *Y* states that catalysis is merely a technical problem, therefore of secondary importance (*Y* is a fundamentalist). This is in strong contrast with *Z*'s position. For *Y* the problem of catalysis will be solved as soon as the problems of kinetics, transport of reagents and optimal structure of electrodes have been elucidated. *Z* states precisely the opposite.

(3) The research programme proposed by *Y* was adopted exactly as it stood. Since a concerted action was involved he divided up the work between the various research centres, both private and public, which he thought were likely to be interested. Thus he proposed to entrust to his own laboratory

(Electrolysis laboratory) several themes of research, in particular the study of catalysis of depolarisation reactions. When the committee accepted his proposal *Y* recruited two researchers, *A* and *B*, whom he incorporated into his laboratory, entrusting the research to them. Thus *A* and *B* in their turn launched into problematisation.

Let us now leave aside what happened in the other research centres and concentrate on *Y*'s laboratory, particularly on his two researchers.

A, who is a metallurgist by training, follows straight on from *X* and *Y*'s problematisations. The technical structure of the cell is for him the furthest limit of all investigation; this is a reified object which researchers must accept. Problems must be formulated and solved within the space occupied by the electrodes, a double layer and the electrolytes, a space organised around intangible elements, whether the material components of the cell, or the concepts, laws and experimental devices which serve to decipher its workings (Tafel's law, Nernst's law, adsorption, kinetics of reactions . . .)

The problematisation *A* puts forward concerns the texture of the electrode (the reference to metallurgy is obvious), that is, the spatial distribution of pores, the distribution and forms of crystallisation of the catalysts, the path followed by the electrolyte moving towards the fuel. *A* is only interested in the electrode and the double layer surrounding it. His problematisation shows the same features as those of *X* and *Y*: (a) It gives an exact definition of the relevant field (here the electrode), and rejects the rest, to remain unexplored. As one moves away from the double layer – the fringe of electrons which surround the electrode and feed it – the shadows gradually darken and finally become impenetrable. (b) The electrode itself is seen as a system for linking up elements which are not problematised (fuel, catalyst, electrons snatched from the electrolyte . . .) During a first phase, all that is open to variation, is the spatial organisation of these elements, that is, the relationships between them.

B, on the other hand, gradually turns against *Y*'s system of division and finally arrives at a radically different problematisation from that of *A*. Taking his inspiration from *Z*, he works towards a problematisation that emphasises the problem of catalysis within an electric field (electrocatalysis). He favours recourse to concepts and methods from solid state physics. The fuel cell is no longer the inevitable point of reference. The aim is no longer to solve the problem of catalysis as defined and delineated by *Y*. *B* builds up the enquiry

in another way. There is no question of electrodes and their texture, nor of diffusion of reagents. The problem posed by *B* is the behaviour of a hydrogen atom on a metallic surface. Under what conditions and by what mechanisms are the electrons liberated? At one stroke another world appears, other frontiers are carved out. *B* forces back into the shadows objects and questions which were to have peopled his sphere. He reintroduces quite other certainties, takes other facts for granted, borrows other instruments from solid state physics, quantum mechanics, nuclear magnetic resonance . . .

All these problematisations come to life, they complete each other, expose each other, join together, separate, and they all share an identical structure. In what follows I clarify just what that structure is.

General Structure of Problematisations

The various problematisations that have just been evoked employ a dual mechanism.

First of all an initial frontier is traced between what is analysed and what is not, between what is considered relevant and what is suppressed, kept silent. The problematisation carves out a territory which it then cuts off from the outside, forming a closed domain with its own coherence and logic. Through this type of operation private 'hunting grounds' are created. A division is suggested between what will be the property of scientists and what will be left for outsiders. Looked at from outside, this mechanism is no different from that leading to the setting up of a black box.

Next, a second frontier is traced between what is intangible, taken for granted, and what is problematised or unknown. In other words, in order to formulate problems and mark off zones of ignorance, protagonists necessarily take as their basic concepts, systems of interpretation and reasoning which are then given the force of certainties and thus totally escape suspicion. Problematisation does not necessarily attack previously fabricated knowledge, or established theoretical systems (14). On the contrary, problematisation must of necessity rest on elements of reality (concepts, proposals, matchings up, results . . .) which are considered irrefutable and firmly established. A protagonist never places himself completely on the side of order, nor on the side of disorder. Disorder only forms against a background of order and certainties. The latter form specific configurations which involve systems of

lacunae, in their interstices lodge pockets of problematisations. Thus problematisation must also be described as a process of certification and of objectification. Conversely, to objectify involves making choices, imposing associations, deductions and, consequently leaving empty spaces, laying aside questions without a reply. The construction of reality functions like Carnot's heat cycle; using a hot source (problems) and a cold source (acquired knowledge). If one of the sources disappears, production is interrupted. Hence Figure 1.

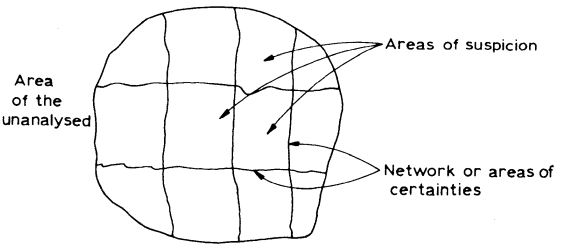

Fig. 1.

Before going any further with our analysis of the process of problematisation, let us stop for a moment and look at a few results of the type of analysis chosen.

Problematisation culminates in configurations characterised by their relative singularity. There is not *one* single way of defining problems, identifying and organising what is certain, repressing what cannot be analysed. Witness the different paths followed at the same time by X and Z, or by A and B. In this case the configurations are in opposition with each other. However, there is plenty of variety within each of these main options. Though there may be strong similarities (which enable problematisations to be grouped together) there are always differences, however slight. Each protagonist organises and problematises reality in his own original manner in keeping with his own idiosyncracies, his own background and the particular conditions in which he finds himself (15). Henceforth we shall no longer make a distinction between an actor and his problematisation. Identifying a problematisation postulates the existence of an actor.

As the cases of X, Y and A show, hierarchical relationships often exist

between problematisations. Hence the idea of a *degree* of generality of a problematisation. When X proposes a demarcation of zones of research, he defines several themes which are independent one of another: photovoltaic cells, fuel cells ... Each of these themes build up and closes around itself a specific reality which defines an area of research. The functioning of the fuel cell, which is considered problematic, must be studied as such. A statement of this type, however decisively expressed, is in no way irrefutable, proof being Z's opposition. X puts forward hypotheses, the result is not a foregone conclusion. He has his first success when Y develops his own problematisations within the territory marked out by X. Y can be said to have set up house in X's rooms (he makes his own problematisation dependent on that of X). As this is true of X and Y, so it is of Y and A. These problematisations are enclosed within each other like Russian dolls ($A \subset Y \subset X$). Precisely because of this system of inclusion, it can legitimately be stated that X's problematisation is more general than that of Y, the latter in turn being more general than that of A. X has shown Y a black box in which Y has agreed to shut himself (the same is true for Y and A). However, this is not a result of the 'quality' of the problematisations involved. The degree of generality only indicates the extent in which the particular problematisation has been accepted as a basis for further work. It is inseparable from the balance of power set up. Y agrees to occupy the place X has prepared for him. A is equally docile with regard to Y.

The chain of inclusions could be continued in both directions. X has not called into question the general theme of energy conversion. On the contrary, his problematisation has helped to consolidate it. A has appointed assistants, technicians to whom he sub-contracts part of the operation. In theory the chain is unending. By these closing mechanisms, by allocating positions, by constructing black boxes, the chain simultaneously relates and distinguishes scientific policy and specialised research. This remark leads me to emphasise the general nature of the problematisation process. It indiscriminately affects areas which are normally considered to be scientific, technical and economic, and it actively participates in setting up these categories. X establishes close links between machines and scientific phenomena. (Thus he links the destinies of the fuel cell with those of electrochemistry). For Z the intimate interdependance of science and technology must be called into question. Thus every problematisation works out on its own account what is internal and

what is external, what is scientific and what is technical, the links which should exist between the two, etc . . .

These final remarks raise new questions. How is it possible for problematisations, though different from each other, to form connexions with one another? A reply to this question will be found in a description of the special logic which problematisation obeys.

Problematic Situations and the Socio-logic of Translation

Each problematisation process results in the formation of what I propose to call a problematic situation. A characteristic feature of this situation is the specific demarcation it creates between three fields or areas: the un-analysed area, the area or network of certainties, and the area of suspicion (see Figure 1). Problems are identified and rendered autonomous; established facts are stated; links are postulated; whole sections of reality are pushed back into the shadows. The problematic situation is thus a dual process of construction and de-construction. Forms are created, outlined, recombined, questions posed. If we look at the situation from this point of view, we can legitimately call it the expression of a balance of forces. The origin and nature of the forces are of small importance. The study of their effects is sufficient: on the one hand, certainties are combined and stated, on the other hand, suspicions and queries are formulated. But how is this balance of forces created? How can we describe the work of construction/deconstruction, identification and shaping into form?

Let us first of all turn to the centre of the process, the area of suspicion. For that we must return to *Y* and his problematisation, as its general outline is represented in Figure 1. In the research programme that he put before the committee *Y* not only outlined the main problems that needed to be solved, but he also suggested which research centres might take charge of them (column 3). In addition he gave estimates of the funds that might be allocated to each theme. Thus his table has a dual message. Firstly, the one we have looked at so far which brings out the problems and the links between them. Secondly, he shows the relationships between the protagonists as well as the relationships between the problems. In fact each of the eight study areas chosen by *Y* is associated with interests and potential actors. We must stress

that these are only proposals. *Y* is not certain he will be able to impose his problematisation. However, the important point is that for *Y* the social and the cognitive, the problems and the actors are arranged within the same structure. To each of his problems corresponds a place and a position attributed to an actor. The actor may be named, or his identity remain unknown. Moreover, the relationships between the protagonists and their positions are clearly identified through the relationships postulated between the problems. Thus, properly speaking, the cell exists in two ways: one we might call techno-scientific, the other social, for it is not distinct from the social group approached to carry out its elaboration and production. Problem definition, as practised by *Y*, is a highly strategic activity, aiming as it does to interest varied groups in an enterprise whose development as a whole they will not be able to control.

In what we have called the area of suspicion, which forms the heart of the problematic situation, there is no divergence between organisation of the social field and that of the cognitive field. Definitions of problems and the links between them cannot be distinguished from the work of organising fields of interests to be aggregated – witness the question marks that figure in some squares of the table. Definition of a problem implies definition of a group, even if no empirical unity can be named. *Y* gives shape to the social, he builds a field of positions.

We can go further. The list of problems as suggested by *Y* cannot be *deduced* from the state of scientific and technical knowledge (*Z*'s active criticism provides proof of this). *It translates a determination to incorporate interests*, and to interest those who are still only potential partners. In fact *Y*'s programme represents an attempt to mobilise social groups. I propose to call this particular logic by which problems are directly associated with groups; the socio-logic of translation (16).

Why this expression? To justify its use I need only analyse the mechanism at work. What *Y* is saying can be summed up thus: "I define a series of problems P1, P2, P3 ... P8 and assign them to groups G1, G2 G3 ... G8 (see Table 2). I state that a sequential solution of these problems would lead to solutions of the problem posed by *X*, that is how to build up and acquire scientific and technical mastery of fuel cells".

Definitions of P1, P2, P3 ... and statements of their interdependence follow a *socio-logic*. In fact to state that P1, P2, P3 ... are "logically" linked

(by the problematic unity of the cell) is to state that a community of interests exists between G1, G2, G3 ... This puts forward the hypothesis that G1 will take charge of P1, G2 will take charge of P2, and that G1, G2 ... will accept the idea that a relationship exists between P1, P2 ... , that is to say that social intereaction between them is conceivable. In short, *Y* constructs a system of social interactions. We do not find on the one hand social actors, on the other knowledge. There is joint, programmatic organisation of both knowledge and of social actors. Hence the idea of a *socio-logic*.

The statement that P1, P2, P3 ... can stand in relationship postulates: (a) that a set of related significations exist for problems formulated within different territories, and (b) that the solution to a problem (mastery of fuel cell functioning) can be achieved through a series of displacements of problems. The word 'translation' corresponds precisely with these two meanings. Considered from a very general point of view, this notion postulates the existence of a single field of significations, concerns and interests, the expression of a shared desire to arrive at the same result. Though translation recognises the existence of divergences and differences that cannot be smoothed out, it nevertheless affirms the underlying unity between elements distinct from one another. Translation involves creating convergences and homologies by relating things that were previously different. In the more limited case we are examining, translation first of all assures that intelligible connexions exist between questions concerning, for example, diffusion in electrolytes, kinetics of reactions in electrodes and performance of the cell (measured by available potential and intensity of current). Proposals, results and appreciations can be converted from one to another so as to become comparable. For example, a particular modification in electrode structure and the distribution of the catalyst will react upon the operation of diffusion, the latter in turn will modify the kinetics of the oxidoreduction reactions; the result will be a variation in the intensity of current with consequences for commercial implications. Translations like these are never a foregone conclusion. They are formulated as hypotheses which will be judged convincing or otherwise, (*B*, unlike *A*, is not convinced) (17). However, simultaneously, and this is its second significance, translation emphasises the interdependence of problems. Solution of a problem depends on the prior solution of a whole series of other problems (to improve kinetics implies previously improving diffusion; achieving control of an outlet involves agreeing to study the

structure of electrodes). Translation asserts the necessity for some detours, and indicates the required changes of route. The concept of the socio-logic of translation stresses that these conversions, and changes of route, are valid simultaneously for the problems and the actors. The problematic zone (or area of suspicion) is a zone of *fusion* where the cognitive and social mingle in the same logic.

The area of certainties is organised according to the principle of *fission* (not fusion). It includes and connects elements on which it confers a status of certainty. We must add, and this is fundamental, that it creates simultaneously clear distinctions between, for example, technology, science and the social. Let us return to *Y*. The notes that accompany his table enable one to reconstruct social, technical, scientific and political reality. We find the DGRST and its policy, the budget allocated to the energy conversion concerted action, CNRS policy with regard to electrochemistry, also the double layer surrounding the electrode, Tafel's law establishing a relationship between tension in the electrodes and the density of current, Nernst's law which links tension and energy of activation. The area of certainty does not only include the cognitive and technical. It is a multiple, differentiated world composed of heterogeneous elements that are stable and identified. *Y* combines these previously different elements, organising them according to a logic that respects the divergences rather than cancelling them out, that reinforces various certainties and established facts rather than eroding them, and which does not call into question the final integrity of the individual elements. Respect for these elements is the price that has to be paid in the course of problematisation. Fusion only operates when surrounded by fission. But here again a balance of forces is involved. Everything seems to indicate that *Y* was unwilling to pay the cost of calling various elements of reality into question. He is not able, or does not wish, to alter the DGRST's policy to 'modalise' Tafel's law. He does not possess the resources to carry out the job of reconstruction. Of course, by thus revealing his lack of power he actively helps to consolidate realities like the DGRST's policy and Tafel's law. These realities have not been enunciated once and for all. They only exist as long as the protagonists take them for granted, (perhaps because the latter do not have resources with which to challenge them). Once again, we are faced with a socio-logic – not to call into question Tafel's law or the DGRST's policy means one is not willing to present a challenge. In this case

the socio-logic is one of fission which respects and builds up differences and distinctions.

All we need to say here about the structure of the un-analysed is this: its structure resembles that of the unconscious. It represents what is kept silent so that the rest may be stated.

Success or Failure of Problematisation: From Consent to Resistance

We must now describe the process by which a problematic situation succeeds in incorporating interests, that is, to impose its own problematisation.

The committee asked *Y* to draw up a research programme on fuel cells. He puts forward suggested themes, and says which laboratories he thinks might be responsible for them. So far these are only conjectures. We have seen that underlying them was a will to incorporate interests. In other words, *Y* will only impose his problematisation if the groups approached agree to take part. Therefore, his success depends on the reactions of G1, G2, G3 . . . and on *Y*'s ability to convince them and persuade them to accept P1, P2, P3 . . .

What is likely to happen? In theory several situations are possible. We may conveniently distinguish five ideal typical responses. The people to whom the problems have been assigned (P1, P2 . . .), providing they agree to play the game at all, can extend their criticisms in two directions; (a) a first subject for discussion is the formulation of the problem allotted to them. Does it fit with their own understanding of the problem? (b) Are they in agreement with the general outline of the suggested problematic situation? This means, do they agree to the sequence P1, P2, P3 . . . , the choice of groups G1, G2, G3 . . . ? Do they consider *Y*'s problem to be unproblematic and vice versa?

TABLE 3

Reactions		Group's appreciation of the problem assigned to it	Group's appreciation of the problematic situation as a whole
Tagging along		+	+
Negotiation	1	−	+
	11	+	−
Opposition		−	−
Inertia		0	0

What is the significance of these various strategies?

Tagging along: The group approached recognises that its interests coincide with the solution of the proposed problem. Moreover, it endorses the socio-logic underlying the problematic situation which is in course of consolidation. This is *Y*'s position in relation to *X*. He agrees to take charge of the cell theme, acknowledging the field of research to be a highly interesting one for electrochemistry. He does not challenge the intellectual consistency of the problematisation (classification of energy forms, confusion between technical devices and theoretical objects), nor its socio-political consistency (energy conversion is a homogeneous field of research which should be financed by the DGRST rather than the CNRS). *A* adopts the same strategy with regard to *Y*. This 'tagging along' attitude is an expression of a balance of forces which ensures, locally and provisionally at least, the total success of the problematisation. Thus it is possible to conceive of problematisations which are deduced one from another, but only so long as it is clearly recognised that deduction is never more than a successful translation.

Negotiation 1: The group approached agrees with everything except with formulation of its own suggested problem so it launches into a limited, detailed negotiation. The context as defined is not called into question; the site (18) assigned is not contested. However, specific alterations are requested. For example, within the laboratory of which *Y* is the head, some researchers working in collaboration with *A* slightly alter the way the study entrusted to them is formulated, refining and articulating it. One researcher in particular, instead of investigating the catalysis of the depolarisation reaction, concentrates his attention on the reaction itself and its mechanisms. Thus, he diverges slightly from the originally proposed study.

Negotiation 11: The group approached agrees with nothing at all, except the formulation of the problem assigned to it. In other words, it is ready to launch into the specific research proposed, but it does not intend to fit into the collective enterprise outlined, nor will it accept the suggested socio-cognitive relationships as outlined. Here criticism can operate in several fields. Social: the group approached considers the proposed agglomeration of interests unnatural. Cognitive: it considers the relationships between problems postulated

are questionable. This is the opinion of the industrialists *Y* includes in his research programmes. They agree to the themes suggested, but refuse to cooperate, in the long term condemning the enterprise to failure (19).

Opposition: The group approached challenges the problematic situation as a whole. It actively contests formulation of the problem assigned to it, as it does the whole set of presuppositions underlying the problematisation. *Z* and *B* adopt a strategy of this type. *B*, for example, refuses to concentrate on catalysis of oxido-reduction reactions in fuel cells only. He shifts the question, transforming it into one specific aspect of a more general study in which the fuel cell and DGRST policy do not appear . . .

Because it is the expression of a wish to enlist a variety of groups the problematic situation leads to reactions. Through his problematisation *Y* invites G1, G2, G3 . . . to join his enterprise. These groups react in turn, each in its own way: *A* follows, *B* is in opposition, the industrialists negotiate . . . The translations are successful in varying degrees, the interests are only partially incorporated. The problematisation achieves support, in one place and provokes violent attacks elsewhere. *A* and *B* react . . . and this is crucial from a sociological point of view . . . because, despite themselves, they are implicated in *Y*'s problematization. Interaction is possible between *Y*, *A* and *B* because they are placed by *Y* in his zone of fusion.

Thus, a chain of relationships, a series of shifts, and a sequence of translations are formed which induce consent or provoke resistance in the various groups. *X* problematises and mobilises *Y* who follows on. *Y* problematises in turn and mobilises *A* who also follows on. *A* problematises and . . . the sequence could go on for ever. However, quite a different chain of events would have been quite possible: *X* problematises, *Y* follows, *B* is in opposition . . . he builds up another problematic situation and begins to seek support in his turn. His growing success implies *Y*'s failure. A beaten man, *Y* leaves his post at the head of his laboratory. Let us go on looking at *B*'s career. He widens his empire, extends and imposes his translations. Never again will a problematisation like *X*'s have a chance of success. Very often there are forks in the path, deviations, sometimes reverse reactions, even loops whereby a protagonist can be eliminated. As a result of this never-ending movement in which translations are imposed and then break up, certainties are built up and categories of reality erected. Thus our analysis is contrary to that of J. Dewey

(20) though he used concepts similar to our own. The effect of the actor's action is not to create stability and order. It is to create local instability. With the creation of such instability the possibility of autonomy arises (21).

One last point remains to be made. We have just described strategies which arise as responses to a problematisation. But in what conditions do they appear? Why does *Y* follow *X*? Why does *B* resist? The answer is to be found in the concept of capital though not as this is understood by Bourdieu (22). Concept is not a stock. For example, *X*'s capital is more than his credit social relationships, prestige, and his influential position. He is more than a set of resources. Economists are well aware that identical resources can lead to different strategies, some ending in failure, some in success. Capital cannot be dissociated from the way it is utilised to incorporate interests, seek support, intervene, translate and convince. These valorisation strategies must be studied if the force of a problematisation and its power to enlist support are to be assessed (23).

Conclusion

(1) Using the concept of the problematic situation, with its distinction between zone of fusion and zone of fission, we can go beyond the natural opposition that often operates between the social on the one hand and the cognitive on the other. The analysis of problematic situations, showing how they are organised, throws light on the process by which the limits between the social and the cognitive are constantly re-defined. The zone of fusion is the crucible where practical categories are worked out, whilst in the zone of fission they are consolidated. However, it must be noted, that these cleavages are always linked to a specific problematic situation. In these conditions, surely, concepts like the *social context* must be cast aside. They fail to recognise the reality of problematisation and take for granted what is in fact at stake for the protagonists. To problematise is, among other things, to produce social context both for oneself and for others.

(2) In addition, the concept of the problematic situation makes discussion of the significance of the sociology of content possible, something which is everyone's dream. My view is as follows: It is only possible to discuss content from within a problematic situation, that is, after having defined what is considered problematic and what non-problematic. The sociologist is caught

up in the same situation as the scientist. He cannot avoid answering the question: where do the frontiers lie between what is certain and what is uncertain, between fusion and fission? In talking of content, the sociologist starts out from already existing problematisations. How in these conditions can he differentiate his enterprise from that of the scientist? This is a difficult question, but I think I have the outline of a reply. It is rare, perhaps even impossible, for a problematisation to impose itself without encountering any obstacle. Alongside it and against it, opposition and negotiation strategies spring up, even though they may well be condemned to final failure. The protagonists themselves operate an active, never ending criticism, with the result that a given problematisation is always parasitised by other problematisations (24). To parasitize, as its etymology indicates, means to place oneself alongside, to create a gulf, a difference whilst at the same time maintaining links. It also (in French at least) means to interfere with a message, to distort information. Interference can go on for ever, criticisms and reactions to them form a branching chain which is never broken – unless the parasite devours its host. And this occurs when one problematisation succeeds in destroying that which it was criticising. Sociological analysis must find its accommodation within this series of translations. The sociologist adds one more translation to those produced by the protagonists. He is a parasite living on other parasites. In this respect he is like all other actors. He cannot differentiate his enterprise in principle from that of the scientist. He differs only in that his practical focus of interest is that of translation – the sociologic of parasitisms. He is nourished by the eternally recurring parasitism he studies round about him.

Notes and References

* This research was financed by CORDES.

1. D. O. Edge, and M. J. Mulkay, 'Cognitive, technical and social factors in the growth of Radio Astronomy', *Social Science Information* **X11**, 25–60 (1973).
2. The classic distinction between scientific research and scientific knowledge as admitted by authors as different as K. R. Popper, *The Logic of Scientific Discovery*, Hutchinson, London, 1959; and G. Holton, *Thematic Origins of Scientific Thought, Kepler to Einstein*, Harvard University Press, Cambridge, Mass., 1973, is the vitable result of atheoretical choice of this type.
3. R. D. Whitley, 'Black-boxism and the sociology of science: a discussion of the major developments in the field', *The Sociological Review Monograph* **18** 61–92 (1972).

4. B. Latour, 'Who is agnostic; what could it mean to study science?', *Sociology of Knowledge, Science and Art*, Vol. 3, Kuclick, H. (ed.) (forthcoming)
5. H. M., Collins, 'The Seven Sexes: A Study of the Sociology of a Phenomenon, or Replication of Experiments in Physics', *Sociology* 9, 205–224 (1975).
6. B. Latour, 'Is it possible to (re) construct the research process? Sociology of a brain peptide' (this volume).
7. T. S. Kuhn, *The Structure of Scientific Revolutions*, University of Chicago Press, Chicago, Ill., (1970); K. R. Popper, *Objective Knowledge*, Oxford University Press, 1973.
8. M. J. Mulkay, *The Social Process of Innovation: A Study in the Sociology of Science*, The Macmillan Press, London, 1972; D. Chubin, and K. Studer, 'The Place of Knowledge in Scientific Growth', Paper given at the American Sociological Association meetings, September, 1977. The archetypal opposition is that of K. R. Popper, *The Logic of Scientific Discovery*, Hutchinson, London, 1959; and 1973, *op. cit.* and J. Dewey, *The Quest for Certainty: A Study of the Relation of Knowledge and Action*, Minton, Balch and Co., New York, 1929. The former makes problematisation into a categorical imperative. The latter sees in de-problematisation the expression of an existential requirement (man abhors disorder and attempts to produce stability).
9. CNRS: National Centre for Scientific Research, the largest public research body in France with more than 7,000 researchers with special status, working in laboratories. The CNRS covers all scientific disciplines, being particularly orientated towards fundamental research.
10. DGRST: General Delegation to Scientific and Technical Research, formed in 1958, whose mission is to coordinate research carried out by the different public bodies and to support lines given priority. At the time we are investigating the DGRST wielded great influence within the administration.
    DRME: Direction of Research and Testing Resources, charged with coordination of Research financed by the Army Ministry.
11. R. Gilpin, *France in the Age of the Scientific State*, Princeton University Press, Princeton, 1968; P. Papon, *La Science et le Pouvoir en France*, Editions du Centurion, Paris 1979; K. Pavitt, 'Governmental support for industrial research and development in France: theory and practice,' *Minerva* **XIV**, (3) Autumn, 330–354 (1976).
12. M. Callon, 'De problème en problème: itineraire d'un laboratoire universitaire saisi par l'aventure technologique', CSI-Cordes, 1978.
13. We need only note here that established facts of quantum mechanics are ignored. The knowledge and facts used are those dating from the beginning of the century. The most striking feature is their wide diversity. They belong to the realms of physics, chemistry and thermodynamics.
14. From this point of view Mulkay's criticism of Kuhn is decisive. See in particular Mulkay, 1972, *op. cit.*, Note 8. See also G. Lemaine, 'Science normale et science hypernormale', mimeo, 1979.
15. This singularity, well brought-out by K. Knorr, 'Producing and reproducing knowledge: descriptive or constructive? Toward a model of research production', *Social Science Information* **16**, 669–696 (1977) is also valid for new knowledge seeking recognition, G. N. Gilbert, 'The transformation of research findings into scientific knowledge', *Social Studies of Science* **VI**, 281–306 (1976).

16. I owe the concept of translation to M. Serres, *Hermes 111, La traduction*, Paris, Editions de Minuit, 1974.
17. An analysis of translation mechanisms needs to be developed. We simply state that it is linked to the construction of problematic situations themselves. A problematic situation de-contextualises concepts, proposals and categories, and then re-contextualises them using its own logic. Thus problematic situations permanently create metaphors. The latter's existence make translation possible (for 'metaphorisation' see R. Krohn, 'The Social Process of Scientific Investigation', unpublished paper, McGill University, 1978).
18. K. Knorr, *op. cit.*, 1977, Note 15.
19. M. Callon, 'L'Etat face à l'innovation technique; le cas du vehicule electrice', *Revue Francaise de Science Politique*, 426–447 (Juin 1979).
20. R. E. Dewey, *The Philosophy of John Dewey*, Martinus Nijhoff, The Hague, 1977.
21. See the very fine analysis of a novel by M. Tournier put forward by G. Deleuze, *La logique du sens*, Editions de Minuit, Paris, 1969.
22. P. Bourdieu, *La distinction*, Editions de Minuit, Paris, 1979.
23. M. Callon, and B. Latour, 'Unscrewing Leviathan: How do actors macrostructure reality?', Forthcoming 1980.
24. M. Serres, *Le parasite*, Grasset, Paris, 1980.