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Theoretical Deliberations on"Regulation as Productive Tool Use"

Summary:
This paper is discussing some central points in a dissertation for the degree of dr. phil., "Regulation as Productive Tool Use – a Participatory Observation in the Control Room of a District Heating System." An earlier version of the paper was presented by the author as part of the defense of the dissertation at Roskilde University Center June 14 2002. As suggested by the title, the dissertation was an empirical study of regulation in a control room. The object of the authors participatory observation was how the operators in the control room followed rules when they regulated a highly automated plant. When I was shown the plant I was told that the technology ran smoothly and without error. Its control structures are based on formal logic and mechanical principles, all the same human beings are required in the control room to take care of anomalies. Among other things, the observations provide an opportunity to discuss the limitations of psychologies that study human beings on the basis of formal principles.

The present paper focuses on two characteristic aspects of this discussion in the dissertation. First, it takes its point of departure in some practical problems of the control structures of the control room. It will demonstrate that the practical problems are problems of principle, and that formal principles are not adequate to study the object of human sciences, namely, human beings.

Second, it sketches out what is required of a conception of human beings. As human beings are trusted to handle anomalies, we must explain how they are able to act on an incomplete understanding of the situation. And since they are able to identify what is wrong, we must explain how they develop new knowledge.
The paper presented at the defense summarized the main arguments of the dissertation and alluded to an expansion of the main point using a particular instance. Here the weight is shifted to the latter expansion.

The Control Room as a Basis For Differentiating Formal Systems and Subjectivity

To illustrate how the operators identify errors in the course of regulation we shall examine a brief episode from the control room. Before going into this observational material, however, we shall describe the plant they were regulating. Then we shall look round the control room and discuss the problems that force us to differentiate between machines and subjectivity. Following that, the observational material will be discussed.

In the control room the operators regulated the flow of water of a district heating system that involved 52 km of pipelines in the Copenhagen underground. Power plants produce heat and distribute it to the district heating system and electric power production facilities. The system delivers hot water from power plants to end-users. The end-users may be local district heating systems or homes. The district heating system can thus be understood as an aspect of the distributed functions of societal heat and power production.

Although it is ultimately necessary to understand such activities as occurring within distributed functions, it is customary to separate work functions in industrial plants and to perform them one at the time for the sake of efficiency. According to this way of doing things, regulation of the system is separated from other functions by being located in the control room. This has been made possible by the technology of electronic control structures. The isolation of the function is mirrored in the design of the room. Originally it had air-conditioning but no windows. It was thus isolated from diurnal rhythms, climate, and the plant itself. It may have seemed a good idea to the designers of early control rooms to promote operators concentration and efficiency. But the operators asked for windows because their regulation consisted of finding connections. Windows allowed them to view the weather and the position of the sun while making regulatory decisions. Moreover, the designers of the work functions in the present district heating system allowed the operators to make their rounds in the plant and thus connect with repairmen performing the various repairs. Also, the technology of the electronic control structures actually made it possible to regulate the system from anywhere and to integrate regulation with other activities. In fact, the system could be regulated from a Pacific island or from the street if need be. More realistically, there had even been plans to have the operators regulate the system from their homes, thus combining work and family life that have become separated since the advent of mass production.

The fully automated plant of the district heating system runs according to control structures executed as computer programs. When human beings regulate a plant running with such a control structure, the problems arising from practice provide an opportunity to properly differentiate the processes involved, and thus to get a better understanding of themselves and of the plant as well.

The identification of what is human and what is machine is not easy to make. There are many possibilities. One might find that subjects and control structures in the computers are alike: they both process information with logical structures. Or one might find that the processes are different: the computer processes bits with structures of logic automatically and without insight, while human beings act on insight. Moreover, any difference can be ascribed to the one or the other. For example, it could be claimed that the insight of human beings does not differentiate them from computer programs, since programs represent the logic of insight, confirming once again that subjects and computers are alike. To find a distinction based on experience one must bring together a host of aspects from different practices. This was attempted in the dissertation and is summarized and elaborated somewhat in the present paper.

A good way to begin the differentiation between subject and control structure is to investigate a concrete instance. An instance with profound implications for the differentiation of subjects and the plant will be examined, that of spurious alarms. These reveal a fundamental problem of formal systems and demonstrate the limits of their determinate stability.

The control structures of the fully automated district heating system appear to be perfect, as if errors in the automated system

should be impossible. Nevertheless, surprising accidents occur (cf. Perrow, 1984). This apparent contradiction can be investigated by examining the problem of spurious automatic alarms. They were an everyday annoyance in the control room, and at a conference organized by a control room association the reasons for the spurious alarms were a topic of conversation in the hallways of the conference building. The designers set alarms to go off when any measured indicator exceed a specified range. If a reading is outside the range or if a configuration of readings is considered to be not appropriate, an alarm sounds. This effect is achieved by a simple control statement in a formal language on a computer. It appears to be a wonder of modern technology: the system can think for itself. But in fact the operators claimed that the alarms were a nuisance, since many of them are false alarms. It is easy to see why there are so many false alarms. Sometimes a reading must be out of range to avoid another more precarious deviation. Sometimes an apparently dangerous configuration of readings is perfectly safe because other conditions are met that were not specified for sounding the alarm. In such cases, it turns out that no action is required, even though an alarm sounds. The alarm is spurious. Moreover, the operators stressed that when nothing happened it could mean that something was wrong. Once an operator wondered why the phone did not ring for a few hours. When he lifted the receiver he discovered there was no dial-tone. An apparently normal state may be an alarm state, an apparent alarm state may be a normal state, and a response is not necessary in some alarm states, while it is necessary in some apparently normal states. We might say that an alarm is a regular irregularity, since the alarm appears regularly and the regularity of the control structures cannot handle all of the states properly. In the dissertation such phenomena are described as "the vengeance of the concrete". They are seen as an indication of the fact that the most disparate things go together in the most surprising manner and produce unexpected events on which action must be taken. This circumstance has serious consequences for the assessment of risks in high-tech plants. In the 1970s scientists believed that it would be possible to calculate the frequency of accidents in automated plants in advance. But such calculations can only have real value if plants are isolated entities in which literally all possible types of events can be listed. It occurred once that a candle was left lit in a cable tunnel causing an incident in a nuclear power plant. Some of the scientists saw the implication: the candle left was not an event contained in the list of possible events used for computation. This meant that the list was not complete, not closed, because the plant was not an isolated entity. The plant was, among other things, subject to the unanticipated odd acts of a repair man needing to see what he was doing in a cable tunnel. However strictly a plant is managed, "the vengeance of the concrete" cannot be avoided. We cannot specify events in such complete detail that the unexpected connections in regulation can be specified before the fact. Therefore the surprises can only be acknowledged when they happen. This makes not only complete statistical computation impossible but also the expansion of the control structures to achieve complete control. Such expansion also depends on listing all possible events to be regulated in advance.

Now, as can be seen from the discussion of the assessment of risk and from the optimistic installation of automatic alarms, some believe that "the vengeance of the concrete" is a practical problem that can be solved within the framework of the theories used for risk assessment and control structures. But in fact, it can be argued, "the vengeance of the concrete" points to fundamental problems in those approaches, problems that cannot be overcome within their understandings.

To get an idea of the problems we shall

examine the control structures and the nature of those formal systems with which they are managed. The issues referred to are fundamental and extensive. This is because of the implied relationship between causal and formal structures. To come to a full understanding of the problems involved, the issues should be considered from several perspectives: philosophical, evolutionary, and historical. This task is undertaken in the dissertation. The fundamental issues are present in various forms everywhere: they are certainly present in the confrontation between man and machine in the district heating system that we shall be discussing. But even here the validity of the deliberations depends on the limitations of formal systems and their alleged consequences. In the dissertation they are spelled out in some detail; here only the main outline of the limitations is given.

Control structures of machines can take many forms. They have appeared as holes punched in bands of cardboard that curbed the patterns of weaving in weaving machines. A later example is that of mechanical relays opening and closing valves in chemical plants. Now they are mostly electronic impulses emitted from computers. All these different control structures work in such a way that can be mimicked by formal systems consisting of predefined symbols and operations. A production system is a design of symbols and operations. The symbols have pre-set limitations on their values, and their operations are predefined. Symbols are assigned values by the operations. A production system can be executed like a control structure. Assign the value of a to b: if b is less than or equal to c then do A, if it is larger do B. This formal production system may mimic the control structure of sounding an alarm if the temperature of the water is above a certain temperature. The elements of production systems, their symbols, and operations may change. One predefined symbol, operation, or combination can be substituted for another. In the case given, the value of b is replaced by the value of a, and the operation A is substituted for B. Any change is a determinate consequence of the assigned values established at the starting point of execution of the production. The symbols must remain within their limits and the operations within their definitions in order for the system to work according to the intentions of its designers.

As stated the formal systems are working inside themselves, independent of what is outside their limits. What is outside is undefined. This means that what is inside is already known, while there is no way of identifying the nature of what comes in from the outside, except to identify it as one of those elements existing inside. Further the value of what comes in is not necessarily limited. If the value is not checked it may allow the system to deviate or even destroy the system, the value is wrong. What is inside works, is defined according to the system, is right. In this sense the use of formal systems requires that what enters them must behave in specific ways such that it works right. The use of formal systems is a project of standardization, of normativity.

Thus, formal systems are isolated entities. They have an inside and an outside with no connection between the two. They form two different unconnected worlds, a situation that has been termed dualism. The isolation of the formal system is a consequence of its predefined symbols and operations. It may change symbols or operators, it may substitute one element with another, but the elements are always of the same kinds as those defined at the starting point of its execution.

This is a big advantage of control structures, since it ensures that processes of the same kind always achieve identical results, as long as they work within the definitions of the production system and thus according to the designers' intentions. The control structures are perfect and independent of what is outside their limits.

They achieve perfection through the isolation of their formal systems. But "the vengeance of the concrete" means that the control structures must deal with undefined elements. To be perfect in achieving identical results they must be isolated and work with well defined elements; to handle "the vengeance of the concrete" they must deal with undefined aspects. Their isolation is both a great advantage and a serious limitation.

This has been known for a long time. There are those who think that the limitations of the formal systems can be overcome (Newell & Simon, 72), or that we should wait and see (Harré 96) or that they are not really limiting at all. Here, it is argued that the requirements of closed systems and their consequences are problems of principle. The fact that formal systems are necessarily unreliable and fail to yield identical results with undefined symbols and operations is an indication of in-principle limitations of formal systems that make their inability to handle "the vengeance of the concrete" inevitable. Confronted by the unknown, our understanding should not and does not always break down. We should be able to develop and learn. We will need to find processes of another nature in order to understand how we identify the undefined.

Regulating from the Control Room

There have been many attempts to identify the processes we are looking for, and which are an important aspect of regulating from the control room. The sheer number of attempts indicates that the process is still not well understood. Nevertheless, we can try to characterize it by examining empirical findings and articulating principles as suggested by them.

Once I talked with the operators about how they identified a problem during regulation, how they came to know that something was wrong. This became a discussion of how they performed work related to the sounding of an alarm. Their first and spontaneous response was that (closed) lists of possible problems are of no help. One can run them through to the end and still have no idea of what is going on (Axel, 2002, p. 328). We may add that a list of possible problems presuppose that somebody has found out in advance what could be the matter. A practical list is necessarily finite and short, and the operators know by experience that such a list is never sufficient. There is always a possibility of at least a new twist on old problems. The operators also said that previous situations ought to be ignored. Only by investigating the matter could they find out. Problems in regulation could be anything, even unknown things. Preconceptions didnt help. However, to let go of preconceptions, that is, of what is already known, does not mean isolating oneself. One must throw oneself into the situation, be able to work with connections, follow them in many directions, recognize that things are many-sided. One depends on the concreteness of things, on the connectedness of the world, of which one's understanding is a part. Understanding cannot be stable. One must reorganize oneself according to the conditions, which do not remain the same. One must be able to develop new conceptions that were not there at the start. On the other hand, new conceptions don't come out of the blue. If that were the case, then the identification of the unknown aspects of the situation would be arbitrary and accidental, depending solely on chance. Since one can do something about it, although not always, one's ability to identify the unknown must be connected to something, somehow. One must find new ways on the basis of old, even when one tries to overlook them. Old elements are not exchanged for new ones, but new elements result from modifying what is there maintaining the situation. One acts in the situation, thereby modifying it. At the same time the situation is seen differently: the observer is himself modified. These are some of the reasons why a

human being is not a formal system.

We have talked about identifying a problem as a human achievement in which what is there is modified, including the human being. It is important to see that the issues involved in identifying a problem are fundamental and extensive. They are about reflexivity and self-modification, characteristics that do not apply to formal systems. When formal systems refer to themselves, they break down. (Epimenides tells us that people from Crete lie. Epimenides is from Crete. Therefore he lies when he asserts that people from Crete lie. Therefore people from Crete speak the truth. Therefore it is true that people from Crete lie.) But any life form must in one way or another modify itself to find out what is the matter and do something about it. This has been characterized as "the activity of self-maintenance through distinguishing itself from what is other, so that change comes about through internal development instead of through external determination" (Farrel, 1994, p. 17). In the dissertation the evolutionary aspects of this phenomenon were traced. We shall not go into this here. Instead, we shall examine the process as "the self-relating-in-relating-to-otherness that characterizes thought" (ibid). In this examination we shall see repeatedly that identifications are achieved through connections. They thus become reciprocal differentiations. If anything may be the matter, I must be prepared in the same act to modify anything in my relations, including the way I see myself and the things around me.

We are differentiating between man and machine, identifying what human beings do and machines don't. We have identified human beings' reflexivity, the reciprocal modification of what is involved in the identification of things. Let us go further into the investigation by discussing a brief episode from a video tape recording from the control room (Axel, 2002, p. 274ff). Two operators are deliberating how to proceed in relation to a repair job. The recording is from a cold winter morning. The operators were assessing the situation, the extensive use of heat, the water temperature, and resources needed to carry the water through the pipes. Two operators were recorded at their keyboards. They talked in front of the camera and their discussion was recorded. On the screen they can be seen deliberating the situation of a pump being repaired. They are concerned with how to modify the repair procedure so that it does not impede regulation as much as it does. It is apparent that their deliberations are not directed at the control structures of the high-tech plant, but at the question of how to arrange the technology in order to better follow rules for regulation and repairs. With this material we shall first identify their subjective acts and their connectedness; later we shall discuss connected acts, that is, praxis.

It is tempting to understand human acts as the execution of plans in the same manner as we understand that machines run according to their control structures. The act would then be a constant test of input information about the present state compared to the goal state. The act would follow the rules of the plan in a determinate way and it would not break any rule. In conceptions of this sort the agent is influenced by previous events, in our case, by the information about the present state. Such understandings are mainly found in psychologies that are more or less clearly open to formal principles, as, for example, in cognitive psychology.

Following this conception we can see how the designers of the system have laid down rules for the operators to follow. There are official documents stating how the workers should proceed, how the operators must stop a pump to be repaired, and how the repairmen must wait for the pump to cool down before they open it. The workers must follow the rules in this document and do nothing else. To demand this of the workers makes sense according to cognitive psychology, with its understanding

of acts as linear and isolated. According to cognitive psychology, solving the problem of how to do a job and the routine operations involved in doing it can be separated. For people involved in such proceedings the hope is that the separation will ensure a solution of high quality that can be repeated with no errors.

But following a procedure automatically is only possible if conditions are well defined and don't change. This is hardly ever the case. The repair servicing of the pump must be performed under contradictory conditions that are open to complex evaluations that take many different aspects – or many sides – of the situation into consideration. The repair involves an exchange of filters on the pump. Some nuts must be removed. The pump is full of hot water and the repairmen must wait until it cools down. But waiting means that the operators have fewer pumps with which to move the water. In order to support the operators, the repair men unscrew the nuts while hot and thus run the risk of damaging them.

We see that the right procedure, to wait for the water to cool down, is wrong with respect to time used, and the right procedure with respect to time used is potentially damaging the object of repair. The operators talk about the repair job because they have to accommodate the repair men while supplying end-users with hot water. As human beings they must act on previous experience but without any guarantee of sufficient and necessary knowledge in this situation. Therefore the operators must do what they do: they discuss other possible arrangements of the repairmen's job. The operators must be prepared to organize the situation in other ways so that it better suits their abilities and what they have to do. The operators must be involved in rearranging their conditions of work, since their knowledge is partial and they need to know more to handle the variability.

Thus, in the observational material we can see that through their discussion the operators do more than react to what has happened a short time earlier or to what is happening at the moment. They are not acting in a stepwise pre-ordered sequence to reach a goal. They are not acting on a pre-established goal to which they need to relate, nor are their acts a formal test on how to reach such a goal. This particular morning they are deliberating aspects of the situation that they are not expected to deliberate. Anticipating what could impede regulation, they are deliberating other ways of doing things. This many-sided relation of apprehension to the situation is content-driven (Axel, 1997): the contradiction between repair and regulation is something about which they must decide. This relation of apprehension and the included self-modification constitutes an initial identification of subjectivity. Further, we see that what the operators apprehend are aspects of the situation meaningful to them and their regulation. As subjects they explore the possible meanings of the repair job as a condition for their regulation (Holzkamp, 1983). The meaning of the repair job appears as a dilemma in regulation to be solved anew each time.

The operators may be discussing the options for repair for the benefit of the camera, but also decidedly because they must act in relation to the written rules laid down for them. In order to take the possible and many-sided changes of conditions into account the operators will have to be sensitive to possible problems so that they can vary their acts while following the rule. The operators' acts demonstrate a constant interplay between regularity and variability. They break a rule because they must not follow it exactly the same way each time. We might even speak of unruly subjectivity which breaks rules to keep them. The operators break the rules by doing something they are not supposed to do but must do. The operators think about the repair job; they reflect on possible ways of doing it; they discuss how the repair men follow rules. In this we note several things.

First, we see a parallel between following

the rule and knowing the rule, between act and knowing. Acting and knowing are aspects of something more. When we act, we take part in societal and natural aspects of the world. We cannot oversee them completely, even though we need some kind of overview. This means that when we know, we never know enough, but we are under the constant obligation to know more. Meaning is part of something more, of societal and natural aspects of the world. The subject's explorative relation to its constantly varied conditions means that its notions are distinct, unfinished, with a constant possibility for development.

Second, on the one hand the operators must follow the written rules, on the other they must vary the rules to accommodate their varied conditions. The regularity for which the rules were written is thus achieved by the operators varying their acts in order to compensate for varying conditions.

Third, it is these varied acts which force the operators to differentiate in various ways between the object and themselves. They (and we) know the world by being in it, by acting in it, they know it through their concrete or many-sided relations of their actions. It is all the specific aspects of the repair job that make them see the general implications for the rules and thus leads them to understand in new ways how the rules should work. The general appears through the specific concrete aspects of the situation. In the dissertation this is asserted by stating that meanings are the unity of the general and specific. This unity is not a determinate unity. One day, stable supply of water must be ensured when pumps with no back-up are stopped for repair. Another day, the stable supply must be ensured when a pipe is subjected to maintenance. There is an accidental aspect in the unity of the specific and the general: there are many different repair jobs, they vary, and each of them makes the regulation vary.

Fourth, we see that the isolation or closedness of formal systems is gone. There is no dualism between the world on the one hand and the subjects acts and understanding on the other. The subject is part of the world, takes part in it, seeing and understanding it through its acts. I see the thing in itself as it appears for me. Since the general appears through the specific, since regularity is produced in variable situations, we cannot tear our acts and understanding apart from each other. The general aspects of the situation are tied to the perspectives of the subject. The subject may see the general in many ways, depending on the perspective and the situation. This means that there is not one correct way of seeing or doing something; there are many ways of doing something, and they all contain truth.

Until now we have considered issues mainly from the point of view of an acting subject. But it has been implied that the subject is taking part in societal and natural aspects of the world about which it does not know everything. We shall use the term praxis for the connectedness of the acts of human beings, their objects, and their understanding (Bernstein, 1971), and when we talk of action we think of the anticipatory, intentional aspects of subjective acts that comprise praxis.

This distinction has several implications. Not only are psychological phenomena an aspect of praxis, but they must be understood as an aspect of the organization of praxis. The way we think takes form from the way we interrelated and distribute our potentialities and how we distribute ourselves in our shared world. We have different outlooks on what goes on based on the way we relate to each other. In each perspective there is truth, and each perspective is based on ongoing praxis.

This means that the interconnectedness of human beings is contested, we have no way of deciding the nature of the interconnectedness except from ongoing praxis. To decide its nature once and for all would imply that it is fixed and not modified and that it is possible to

get a notion of it independent of the variations in praxis. But since this cannot be achieved, we must talk about praxis as differentiated subjective acts and their coherence from the perspective of a subject.

To sum up: We cannot describe praxis from an objective point of view. Therefore we must incorporate the understanding of the subject when discussing the praxis of people. At the same time we cannot describe an act in isolation. We must describe the interconnectedness of acts in praxis.

The perspectives on praxis may take form from the way the acts of praxis are organized. In industrial plants some people arrange work procedures, while others must act according to these arrangements. In the district heating system engineers designed or arranged the pipes and pumps of the system and others laid down rules for their use. The operators follow the rules and make the system work. We have three acts or work functions – designing, arranging and making the system work – that are differentiated aspects of the praxis of the district heating system, each with its own perspective. Those who have arranged the work place tend to demand that the rules be followed without question. In continuation of the formal approach they tend to see the operators' acts as executing the rules.We have already seen that the operators know they are not simply following rules when they act. They must forget what they know and explore the problems to make things work according to rules (cf. Ingold, 2000). Now, is it relativistic to claim that there is truth in both views? Does praxis become whatever each acting person imagines? If we can leave the perspective of each participant in its own realm we have torn it away from praxis. Each perspective is connected to each other in praxis, forming each other according to the way the connections are understood. Those who have arranged the work place tend to want the operators to follow the plans without question. The operators must make room for their exploration and therefore must make counterclaims. Thus a conceptual dilemma about the understanding of praxis becomes the basis of conflictual cooperation in praxis, and its outcome depends on the conditions for cooperation, the privileges involved and the way they are defended, but in the end, it depends on the nature of praxis. The conflict may be reworked from any perspective, that of the engineers and operators as well from that of our observation of them. Nobody will be able to establish one absolute understanding of the problem as the proper understanding, but they have to work it out on the differences in praxis (cf. Dreier, 1991, p. 202). When we see that the operators do not follow rules but understand them and reproduce them constantly in their acts, then we must ask about the understanding of the subjects in their praxis. We must question the idea that it is possible to prescribe for people rules that they simply have to follow; we have to reorganize our thinking about designing and following rules according to our experience.

Thus the differentiation between machine and man is grounded as a practical problem of our time. The differentiation is historical: it depends on specific constellations of technology, privileges, and relations in praxis, and its differentiation can take many forms. The systematic, scientific investigation of the differentiation takes its point of departure in historical practical problems and incorporates the philosophical and scientific aspects involved.

The concrete many-sided aspect of praxis is explored further in the present paper. On the one hand each person's praxis is concrete, it is a microcosm of the surrounding practices. On the other hand each person's praxis is distributed, it is shaped specifically according to other persons' particular variety of praxis and other local conditions.

To unravel what all this means it will be necessary to return to a deeper consideration of the observational material from my research on the control room.

Design and Regulation are relations in acts and praxis

To sum up the argument to this point: We are identifying praxis as organized according to the way we are distributed and how we distribute ourselves in our shared world. We see the subject as varying itself in order to produce stability under variable conditions. This means that acts cannot be a linear sequence that reaches pre-fixed goals; they are many-sided processes according to changing conditions. Furthermore it means that acts do not come about by executing a fixed set of rules; they re-produce the rules they follow. We shall explore some consequences of this understanding. The many-sided connectedness of acts and their constant re-production of rules make acts contradictory: they are stable and varied. Their stability is re-produced through their variation. This means that an act is not simply a realization of a fixed control structure, nor is the act simply solving a problem. It is not only something in itself, it is related to other acts, it takes form from these, and is mediated by them. Each act is a variation of all other acts.

We can therefore proceed by identifying as many aspects of acts as we find relevant in the dialogue between the operators recorded on video. We shall mention those aspects we have met when discussing how the operators re-produce rules. We see that unruly subjectivity is not abstractedly *destructive*; it is *productive* by destroying one way of doing things. The operators don't perform uniform routine acts, and they do more than the problem solving of cognitive science. They discuss how their work *problems* should be *posed*, by discussing the connections of their work. They are involved in how to make rules work by modifying them, by *organizing* things.

Furthermore, deliberating how to make the *repair* job run more smoothly, they discuss changing the installation. The newcomer has an expensive solution: a backup pump should be installed. This would make it possible to stop the pump to be repaired well in advance of the repair so that it could cool down. The experienced operator has a less expensive solution: wingnuts. The operators' discussion is a *redesign* of the pump from an operators perspective on the repair job.

Also, their discussion can be seen as an attempt to *identify an error*. Where is the source of the problem located? In the time constraints, in the design of the pump, in the handling of the dilemma? Their perspective was clarified for me by some other operators. I took it to be an implicit comment on the engineers' way of thinking. It is often said that the operators make errors when regulating because they break *rules*. But why doesn't anybody discuss the way the machinery is built? This is what the operators try to do, making room for their own work by modifying the machinery. They try to *remake their conditions of work* in order to work better.

We see, that the act of discussing the repair job apparently contains all the aspects involved in the repair job: unruly subjectivity following rules by breaking them, laying down rules, error identification, repair, design, organizing conditions. These aspects are differentiations of acts, deeply related: if one can only follow rules by breaking them, one is constantly reproducing them, committing errors, performing repair or redesigning and organizing praxis. These differentiations are made more marked and stable by the division of labour. Through the division of labour the differentiations are apparently extracted from acts and laid out as relations between them in praxis: some people design, others lay down rules, etc.. To many, the differentiations appear as separate elements in connected acts: those designing don't follow rules, those following rules don't design. But we cannot separate the differentiations, they are indispensable aspects of the subjective act of re-producing rules. This point I see

as general in relation to human acts: an act of any nature contains all aspects necessary for its completion, even though the aspects may be dispersed among acts in praxis, and at the same time the involved aspects are shaped specifically in each act according to relations in praxis.

We shall consider the relation between acts with different aspects enhanced and shaped specifically according to relations in praxis. We shall focus on how the operators re-produce rules in regulation. If acts are all variations of each other and connected in continuous varied repetition, we may wonder about the relation between an act and its context, which also contains other acts being concrete variations of the act on which we are focused. Each act takes form from its context. At the same time an act is recognizable as something in itself. Furthermore, the relation between context and act is accidental and necessary: the reason that the operator must use this pump here is accidental and necessary in many respects. For example the pump is there since it was available due to many accidental circumstances at the time of purchase. Also, it is a more or less good compromise between specifications and what was available. It is this openness which makes development possible. The way the pump meets specifications and the way conditions signify to the operators that they can improve their work make them discuss what can be done, as we have seen on the video recording. Such implications of the relation between the arbitrary and the necessary are very central. This is more so when they are not limited to video recorded conversations, but concern more important issues of development. The implications force us to investigate the relation between an act and its context.

We shall first look at the nature of specific personal regulatory acts in which operators reproduce rules. They are something in themselves, not isolated entities. They may turn into what they are not, they may develop, and they are concrete. Therefore each act is also its contradiction, the act of following rules is committing errors, since following rules implies breaking them and breaking a rule means committing an error. The act of committing errors is following rules, since the identification of errors is to specify the meaning of the situation, how to handle it, and thereby to re-establish the broken rule. To accommodate repairmen is to follow rules, but it also means to commit an error, since the repairmen cannot get access to the pump exactly according to their requirements. To deliberate the repair job is an error since one is not allowed to. But at the same time it is to follow rules, since it opens up relevant ways of accommodating the repair men. If any personal practice is a variation of all other practices, this is of course due to the fact that a human being is acting and that the act is concrete. Since an act is a concrete differentiation and since it constantly develops, it will accord with itself as a contradiction, consequence, etc.

An act in itself is then contradictory. The relation of a personal act to the acts of others must now be specified. To follow rules leads to errors, and erring leads to following rules. This not only means that deliberating the repair job and making wrong conclusions in this instance may lead to erroneous acts by other operators elsewhere. More importantly, it indicates the many-sided connections of acts. To accommodate the repairmen appropriately may lead to unstable supply to consumers and thereby to error, to accommodate the repairmen erroneously by allowng them to unscrew the bolts before they are cool may lead to correct supply. Such dilemmas never find a solution, but the contradictory requirements are a source of constant change and development of acts.

An act not only leads to other acts. The relations among acts in praxis form their context and constitute the acts. We can say that errors take form according to the rule which has been followed, and rules take form accord-

ing to the errors that have been committed. The unstable supply of heat is formed to some extent according to the way the repairmen are accommodated, and specifying rules that do not damage the pump may produce unstable supply of heat. Thus aspects of praxis arbitrarily related to each other, like heat supply and pump repair, are reciprocally constituting acts. But this does not mean that the constitution is arbitrary. Differentiating the aspects also means identifying a common and varied principle of regulation: heat supply and pump repair result from distributing social resources as a matter of technical arrangements. Such a principle is in itself contradictory. The reduction of social issues to quantitative technical matters assumes a stable social praxis and a distribution of privileges which makes it possible for everyone to participate more or less in the management of conditions. This becomes clear when there is breakdown of regular principles of distribution. For example, in other district heating systems we might find pumps that cannot move the water as required because somebody needed the proper pump somewhere else and had replaced it with an improper one. Yes, the nuts in the bad pump could have been removed, since somebody urgently needed them elsewhere, so that the bad pump did not work as required. Such findings belie the technical principles of distribution and point to serious problems in the distribution of social resources.

But it is not only here that somebody reproduces a rule. A rule may be re-produced at different locations. A rule is dispersed in praxis according to its relevance and the resources already distributed. The rule for servicing the pump can be re-produced wherever there are pumps without backups in the system needing exchange of filters and the repairmen have to refer to the control room. The rules are dispersed in praxis, they are not lying around on location waiting for someone to come and be governed by them.

These deliberations point to praxis as a reciprocally constituted many-sided phenomenon. Only the dilemma around the reproduction of rules in regulation has been discussed. But earlier it was pointed out that the operators' video-recorded discussion was at the same time a re-production of rules, error identification, repair, design, re-arranging conditions etc. This means that each subject's acts can only be understood by differentiations in praxis, that each subject's praxis is concrete and many-sided and contains the aspects of the others. There are several important ramifications of these conclusions. Here I shall only mention two. The first ramification concerns the differentiation of subjects in praxis. Earlier, we mentioned the conflictual cooperation at a work place between those who arrange the work place and those who re-produce rules. More specifically it was said that the engineers tend to believe that the operators only follow rules. Actually, however, they are performing a complex function to make the rule work. They arrange conditions to better the possibilities for their own work; they grasp what other people do from their own perspective. This means that under specific conditions they will also be able to perform the work functions of the other workers without instructions (cf. Lave & Wenger, 1991). To specify when this is possible remains for future study. The second ramification concerns the understanding of social systems. It is an aspect of our conception of praxis that the differentiation of reciprocally constituted acts in praxis in turn constitutes and develops the social system. This analysis is inspired by Marx' discussion of production, consumption, distribution etc. in his *General Introduction* (MEW 13, pp. 623ff). He argues that any consumption is a production, any production a consumption, that production and consumption are required of each other in praxis, are reciprocally constituted, that production and consumption are distributed according to previously distributed resources and privileges,

and that the products are dispersed. I see analysis of reciprocally constituted differentiations in praxis as an opening for the understanding of social systems as containing phenomena not present in the acts of the individual and at the same time based on reciprocal acts of the individual. This is, however, something to be pursued in future work.

Here we shall limit ourselves to noting a central issue in understanding the relation between distributed acts and social systems. When acting, the operators take part in the workings of the plant. Even though we focus on the operators' deliberations about the repair we get a sense that their opinions are differentiated in relation to other workgroups and their perspectives on the situation. The dilemma of the repair job entails different requirements to which different work groups will relate differently. There are disagreements in the conversation on the video tape and made explicit in other contexts. These disagreements are worked on in conflictual cooperation. Different kinds of acts may coordinate things differently: to act here I may have to change things there so that I can act more effectively here. This way of being involved is one way of participating in the common management of common conditions, which is termed action potence. Since each of us wants to change the order of things, we become conditions to each other and we participate in the mediation of things. In each situation there is a possibility of restricting the possible arrangements to one's own way of arranging and seeing things, or a possibility of finding more comprehensive arrangements and understandings. Restricting the possible arrangements means struggling to demonstrate that one arrangement is right, good, and valid, while others are not. In such cases the concrete aspects of the general arrangement are overlooked; the arrangement is exclusive. If the engineers insist that the prescribed procedure should be followed, they would be obliged to say why it is the best solution. Finding a comprehensive arrangement means finding a concrete one, in which the perspectives in the common, differentiated praxis may become conflictually coordinated in new ways, opening up the possibility of wider participation in the arrangement. To mediate between not damaging the nuts and getting the filters exchanged quickly means incorporating different contested perspectives on the repair without ever finding THE solution, but always finding a good one. The struggle between restrictive and comprehensive solutions may furthermore involve issues of privileged resources and of recognizing other interests than one's own. It is in the struggle for restrictive or comprehensive arrangements that societal issues are mediated, maintained, and developed.

Before concluding, two comments must be made about the conception of notions presented. We are accustomed to think that notions are homogenous and consistent, thus ensuring that they can be handled by formal logic. However, in order to understand development and acts as taking part in praxis we have had to allow that notions are contradictory and unfinished. Much confusion appears to arise from this move. Here the following two issues will be noted.

The notion of rule-following as incomplete and therefore possibly developing has been characterized as rule breaking. This indicates that a notion is not a homogeneous, delimited substance, but is distinct, unfinished, concrete, and its own contradiction. This presumably creates problems. Notions may turn into each other: error identification may become design. The stability of notions becomes a problem if they mix promiscuously and we have no way of deciding what they mean. From the analytic point of view this problem must definitely be avoided. But the way we handle it in everyday thinking demonstrates, that, in fact, the problem is only apparent. In the situation we have no trouble identifying the concrete, contradictory meaning of an act. When a designer talks

about the essentials of design and claims that we all design – and this can be seen in everyday discussions such as about which nuts to use on pumps – we all understand that the act of discussing nuts is designing. Some would claim that design has a special meaning that does not include worksite discussions among operators, and that it is only similar to design. They miss the point that the operators' ideas may be a good solution that can be followed up by redesigning the pump. Also, when an engineer claims that regulation is following rules with no discussion and that the operators commit an error by discussing, we all understand that discussing is not redesigning but an error. Some of us would claim that it is not really an error, since the discussion points to relevant issues, even if the suggested solutions are wrong. But we would miss the point, that discussing is an error since it may disturb their accommodating the repairmen. We must therefore maintain that concepts are as stable as praxis, that they change with relevancies in praxis.

We also note that when talking about development we may appear to cheat. If individual praxis contains all aspects in a many-sided concrete activity, we may as well claim that there can be no development, since everything is there before development starts. We have substituted development with change. When something changes, as when nuts are changed on a pump, the location goes from one state to the other, from ordinary nut to wing nut. If there is a wing nut after a change, there can be no ordinary nut on that location. Furthermore, one cannot see on the wing nut that the ordinary nut was there before. Change is concerned with one aspect, and the aspect of the beginning has to disappear to make the aspect of the end be present. There is no connection between before and after, and there are not necessarily more aspects after a change. To understand development we cannot study the mechanical aspects of substituting things, we must incorporate their meaning in praxis; we must actually focus on praxis. Development is driven by dilemmas, and it may take place in this local praxis or in that one over there, or that one, or that one.. all of which share dilemmas with this one. A development could also mark itself by the local praxis over there having dilemmas of another nature mediated by those in this local praxis, so that they want to do something about our praxis. The dilemma of repairing pumps and supplying heat can modify praxis in many ways. When ordinary nuts are substituted with wing nuts, the praxis around repairing pumps and supplying heat is modified or develops. Development is a modification of concrete, many-sided praxis in which many aspects from before can be recognized in the after. When something develops, what is there is reorganized. The reorganization may mean that something is lost or something new appears, and much in the result can be recognized although modified. Development is thus a continuous process in which each stage is dependent on differentiations around it and at the same time is becoming a new way of working that is a modification of the old way in response to the dilemmas. Development shows a connection between before and after. It may be a differentiation of what was there before, that is, a more detailed procedure may appear, or it may be a simplification, a collapse, a withering away of unnecessary procedures. However, there is no repeated sequence of stages. Development may take many courses. Nobody claims that switching to wing nuts is the necessary solution to the problem; it is simply an available solution, a developing praxis. Other solutions, like a backup pump, would also get things going. We note that since development is concrete it is based on something which is there before development and can be recognized in the new situation after development. This means that we are not cheating when we presume everything at the beginning. We must simply specify how everything was differentiated and modified when things became reor-

ganized. An implication of these deliberations is that social analysis should focus on present problems and their possible solutions. To set up utopias, to ground present acts in visions of the future may mean overlooking present contradictions in social conditions which must be incorporated in order to find realistic alternative ways of doing things.

Conclusion

An empirical study of regulation in the control room of a district heating system was the basis for presenting an action-based conception of human beings. The paper took its point of departure from the fact that fallible human beings are trusted to handle anomalies in high-tech plants that run with a perfection not attainable by human beings. This confrontation between man and machine provided an opportunity to differentiate between the control structures of machines that follow formal logic and the self-modifying thinking of human beings. Formal logic is characterized as abstract and isolated. Its symbols and operations must be given in advance in order that it runs properly. Therefore it cannot develop while running. Human beings handling anomalies must take part, explore, and make connections in order to develop their unfinished understanding of the anomalous situations. Human beings take part by – among other things – arranging their conditions for acting and participating in the common management of conditions. Their acts in praxis are shaped by and give shape to their understanding. This means that each understanding is a situated perspective on praxis. It also means that there may be different understandings of what goes on. On the one hand engineers claim that the operators should only follow rules, on the other the operators must make the rules work. The different perspectives mean that cooperation is conflictual and the outcome depends on the conditions of praxis and how the nature of praxis appears in the cooperation. The scientific investigation of the differentiation between man and machine is a systematic reworking of these problems in praxis.

Some exploration of concrete many-sided praxis is attempted. It is argued that an act of any nature contains all aspects necessary for its completion, even though the aspects may be dispersed among acts in praxis, and at the same time the involved aspects are shaped specifically in each act according to relations in praxis.

It is further stressed that therefore the division of labour cannot mean that some subjects only design and plan, while others execute the plan by following rules. When we are investigating those who are supposedly only following rules, the possibility always exist, given favourable conditions, that without instruction they will also be able to perform the work functions of other participants without instructions. The grasp of other work functions they have gained by performing their own work belies that they are simply following rules as conceived by the formal conception.

It is lastly argued that the reciprocal differentiations of action in praxis is a key to understanding the relation between social systems and subjective acts.

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