Chapter 2

Communication, Co-ordination, and Collaboration in Design

2.1 Four elements and a theme

The objective of this thesis is to make explicit how collaborative design is co-ordinated so that it can be supported through the use of appropriate technology. The chapter develops the background to this, laying the foundations upon which research in the thesis will be developed. The four elements central to the thesis are therefore carefully examined in detail: co-operation, collaboration, communication, and co-ordination. This involves examining the issues surrounding collaboration, and the methods for examining collaborative work. The nature of design is also examined, showing where gaps in existing research exist, and where the research forming the basis of the thesis strives to make a contribution. Finally, techniques for developing technological systems to support collaborative work are explored in the application of social science to systems development.

The terms of co-operation, collaboration, communication, and co-ordination are ill-defined and used in a confusingly range of ways in the literature (see Oravec, 1996). In order to better understand the distinctions between them within the scope of this thesis, they are defined below:

Co-operation - A form of activity that involves individuals working together, using each other as resources for learning, sharing cognitive tasks, and as memory aids. To achieve co-operation in work, individuals must somehow co-ordinate their behaviours, by sharing their goals, plans and motivations with each other. When engaged in joint activities, actions must be negotiated to synchronise and co-ordinate individual activities, so as to avoid conflict (Norman, 1992). This exchange of information is managed through interaction and communication between the participants.

Collaboration - The work that is carried out by people who are acting together; it is a subset of co-operative work, differing in that the individuals share a single goal that is larger than their individual goals (Branki *et al*, 1993). Collaborative work is more than an individual effort: it involves the aggregation of many plans and goals held by individuals which are subsumed into a greater task. It involves agreeing on the shared goals, planning the allocation of responsibility and co-ordination, and keeping track of goal solving progress (Terveen, 1995).

Communication - Defined as the exchange of information (Connors, Harrison and Summit, 1994). Communication is the process by which individuals make known their wants, needs, expectations and future behaviours to others. This may be achieved through verbal and non-verbal forms. Communication is the cement that binds the organisation together; the greater the need for co-ordination and co-operation, the greater the necessity for communication (Brehmer, 1991). However, communication requires resources (both mental and physical) that are additional to the task being performed.

Co-ordination - The process that allows individuals to work together, which involves communication between the participants. Malone and Crowston (1993) define co-ordination as ‘the act of managing interdependencies between activities to achieve a goal’ (p.379). Through organising themselves into a unit, individuals can perform complex work distributed over time and space. Co-ordination is the means by which the distribution of labour is achieved, and may arise through the actions of an ‘executive’ (management role), or through emergent properties of the work that allow ‘naturally arising’ co-ordination.

Defining the relationship between these elements clarifies the nature of what is meant by collaborative design: communication is the mechanism used to co-ordinate co-operative and collaborative behaviour. Communication, by itself, does not cause collaboration, and simply increasing communication will not necessarily cause better collaboration. Co-ordination involves bringing together individuals so that they can work in a purposeful way, both breaking activities into parts that can be performed by individuals, and putting these parts back together to achieve a collective goal. This must involve communication at some stage. Collaboration appears to be mediated through socially encoded protocols (Ellis *et al*, 1991; Hutchins, 1995a), and it is these channels of communication that bring the actions of agents into co-ordination with one another to perform productive work. If technology developers are to generate a means of supporting collaborative design, it is essential that we understand the operation of these co-ordination activities to guide the appropriate use of these technologies (Marmolin, Sundblad and Pehrson, 1991).

If co-ordination is central to collaboration, computers and communications technology developed for use by collaborating designers should therefore focus on providing support for co-ordination events. As applied social scientists, we need to understand how this relationship between communication and co-ordination operates within the design environment, and how these are used to achieve a single, negotiated goal. Computers can support co-ordination not simply through just establishing a communications link between people, but by helping to co-ordinate collaborative activities and supporting joint problem solving (Bannon, 1986). This thesis therefore involves an interdisciplinary study of the nature of work, bringing together cognitive, social and organisational aspects into a unified understanding of how design is performed in, and across, organisations.

2.2 Collaborative design

2.2.1 The character of generic and engineering design

The meaning of the word ‘design’ has been hard to establish. Simon (1969/1981) defines design as being concerned with the state of how things ought to be, and with devising artefacts to attain goals; designers are those ‘who devise courses of action aimed at changing existing situations into preferred ones’ (p.111). The final goal of the design process, he continues, is to specify another artefact that solves the problem. The eventual artefact of the design process will set the initial conditions that the designers leave to their successors. The process of design, according to Simon is analogous to problem solving, where design involves a search process through a ‘problem space’. However, this definition of design is not precise enough to use in an examination of engineering design. Attempts at reducing the scope of study were brought about by Simon himself (1973) who described problem solving activity as falling into a continuum between well-defined and ill-defined problem spaces, depending on their level of specification for goals and operators. Ill-structured problems are problems that have no clear definition: it is not always clear what the problem itself is, much less the solution, because there is not a fully specified goal, only an identified problem area. This more closely resembles the task of engineering design.

The term ‘generic design’ suggests that design is distinct from non-design activities, and that it can be abstracted from a specific task to a generalisation of a set of tasks that relate these activities (Schön, 1983; Goel and Pirolli, 1989; 1992). Design can be observed as moving through a sequence of steps: exploration and task decomposition, identification of requirements, solution of sub-problems in isolation, and combination of answers to sub-problems into a global solution (Alexander, 1964; Simon, 1974). Effectively, design involves determining that a problem exists (although it may be unclear at an early stage) and having a set of possible resources available to solve it, which may include, capital, time, intellect and physical materials (some of which may be interchangeable). Designers then match the available resources to the problem, so that the original problem ceases to exist (Rzevski, 1981, 1984). However, in most circumstances there may be multiple ways that this mapping can occur - choosing between them is a matter of compromise, because there is no single, 'right' answer, just good and bad ones for a particular purpose (Rittel and Weber, 1984).

One cognitive strategy that *individual* people use with complex design problems involves task decomposition into modules. Task decomposition is used to combat complexity in design problems (Simon, 1973; Chandrasekaran, 1981; Thomas and Carroll, 1984), breaking the task into manageable work units. However, this may be over simplistic, because such modules can be highly interdependent upon one another (Luckman, 1984; Goel and Pirolli, 1989). In such cases, individually optimal sub-units of design are not necessarily optimal when considered over the design as a whole (Luckman, 1984). It may not be possible to break a design task into problem modules and then to integrate the component solutions; the interdependency of modules means that activities have to be dynamically co-ordinated to create a unified design. When *multiple* designers are involved, co-ordination of design modules moves outside the individual's cognitive domain into a social one, involving communication to co-ordinate the division of work. Group design, as well as being made up of individual cognitive problems, also involves building a problem space collaboratively - discovering what the collective problems are, as well as solving them collectively.

For an engineer, design is described as making something that has not existed before (Petrosky, 1982), and engineers tend to take the words "engineering" and "design" to be synonymous (ibid.). Petrosky describes engineering as involving the articulation of an idea and rigorously testing it to ensure that the designed solution can perform its desired function without failing, according to the specifications (set out by the client) and known standards relating to the components and their interactions. Design involves constant revision, where alternatives are narrowed down to a single form which becomes *the* design. Designers are therefore placed in a position where they have a huge number of possible solutions and must select the most desirable one (Alexander, 1964). This involves two operations that must be performed: firstly, the designers must generate a number of alternatives and encode these symbolically. Then, all criteria must be expressed in the same symbolism to allow comparison and selection of the most appropriate solution (Alexander, ibid.).

This engineering process appears to be far more grounded in the real world than that of 'generic' design elaborated upon earlier; yet at a fundamental level, engineering design relies on the underlying cognitive, social and physical factors (Rzevski, 1984) that characterise ill-structured problem solving. These 'real world' conditions are largely ignored in 'high level' cognitive analyses of design. However, these conditions, embodied in the constraints and available resources (i.e. the context, or situation) that actual design problems exist within, are central to engineering design (Bucciarelli, 1988, 1994). This occurs because the structure of the setting itself imposes organisation onto the activity that occurs within it.

2.2.2 Collaborating for design and designing for collaboration

Many designs cannot be generated by a single individual and involve the co-ordinated effort of many individuals (Curtis, Krasner and Iscoe, 1988; Günther, Frankenberger and Auer, 1996; Popovic, 1996) and there are several possible reasons for this. In general, this occurs when the workload is too great to perform within a limited time, and the technical skills required assume too much knowledge to be held by a single individual. As a consequence, many people become involved in the design of large systems, such as roads, buildings, manufacturing processes or computer products, and their activities are co-dependant on the simultaneous decisions of the other people and design groups working on these systems.

Simon (1973) discusses 'organisational design' (design by a hierarchically structured group) as an ill-structured problem. This activity begins with tentative specifications and becomes well-structured through subdivision into components that are solved by groups of experts who have been delegated sub-tasks, a process that involves negotiation to co-ordinate their activities. The organisation of the agents in the hierarchy itself makes the problem transparent - which is the goal of problem solving (Simon, 1981). Organisational design appears to be similar to the ill-structured activity characterising generic design: the problem domain and architectural implementation is different, yet the problem area clearly retains characteristics of its generic parent.

Large, multiple participant design projects necessitate close co-operation between their co-designers to allow the seamless integration of their work. However, collaborative design is a highly complex activity: decision makers and designers may have different problem conceptualisations, solutions and personal agendas that they wish to pursue, and which may not be compatible. The collaborating designers also may have different levels of problem understanding, and experience in different domains; the design is therefore emergent, arising from the combination of expertise and perspectives of the collaborators (Muller, 1992). This specialisation of intellect, combined with the complexity of a problem means that few, if any, participants will understand the design as a whole. Designers already have tools that can reduce individual cognitive demands, but designers could also be helped by providing tools to support the collaborative aspects of their work. Providing tools to support the collaboration of the various ‘stakeholders’ in design is therefore an important goal which has already been the subject of research in the CSCW community (e.g. Boland *et al*, 1992; MacLean, Young and Moran, 1989; Muller, 1992; Lu and Mantei, 1993).

In general, outside CSCW, social and organisational co-ordination issues have been largely ignored by technology developers and researchers (Anderson, Button and Sharrock, 1993), who have tended to concentrate on aiding individual problem solving (Cross and Cross, 1996), rather than on design co-ordination. However, little research has been conducted into the process of co-ordinating distributed work, in areas such as control, management, negotiation, delegation of responsibility and exchange that are central to group cohesion (Rogers, 1992). This divorce of work and co-ordination is artificial: collaboration is emergent (Schmidt, 1991; Goguen, 1994) and situated in the activity. It cannot be examined independently of its human context - the tools and processes of design themselves have aspects that help co-ordinate collaborative activity.

The ‘process’ of design has also been largely ignored in the literature on design in the cognitive sciences, as well as by commercial tool developers (as noted by Taylor, 1993 and Marmolin *et al*, 1991). Design aids, such as CAD (computer aided drafting), simulation and scheduling software have been developed largely for single users, not as collaborative tools, and their communicative aspects have been ignored. However, the nature of *process* is central to all design activity; designs do not suddenly leap from the mind to the drawing board - they are discussed, transformed into external representations, discussed again, compared to alternatives, tested, and so on. This process is iterative (Bucciarelli, 1988; Pidd, 1989; Taylor, 1993; Lu and Mantei, 1993), and to focus effort onto supporting the individual at a single snapshot in time means that many problems in design will not be addressed by technology and technology-oriented research. The potential danger of implementing technology that fails to accommodate this feature of design is the development of a technology that does not ‘fit’ the needs and expectations of its user group.

There is a gradual recognition that design is an iterative and collaborative process. This is illustrated in the development of concurrent engineering as an area of applied research. Concurrent engineering applies computer technology to propagate a design model throughout the design process (Easterbrook *et al*, 1994; Prasad *et al*, 1993). Its aim is to integrate all parts of the design and engineering process so that the design decisions made are based on the most up to date information available. This recognition of informational importance in design is clear evidence that design is perceived as a collaborative process, and that present technology is inadequate because it is based in the ‘lone designer’ paradigm. However, concurrent engineering has taken a technology centred perspective of design, and human interactions within the concurrent design process have not been considered in detail so far (e.g. LeBlanc and Fadel, 1993; Pohl and Jacobs, 1994; Anumba *et al*, 1997). Most research in concurrent engineering has so far been at a highly technical, architectural and implementational level, and as a consequence, little theory as to the mechanics of *how* people interact in design has emerged. System designers have only recently begun to consider these areas (Bentley *et al*, 1992; Heath and Luff, 1991; Robinson, 1993b, Easterbrook *et al*, 1994), and as concurrent engineering matures, greater emphasis may be placed on psycho-social and organisational factors.

The problem of providing appropriate technological support for design has become complicated recently through the development of commercially available technological infrastructures for communication. Technology has moved on from just involving the use of telephones to incorporate the fax, email, the networked computer aided drafting (CAD) system, and more recently, video-conferencing technology. These technologies have been introduced into engineering design projects, often informally, and have allowed designers to work in a way that was not possible even a few years before, an example of this being that designers are able to be spatially distributed even for projects that require a high degree of interaction. Projects now regularly involve companies in different locations, even trans-continentally, and there is the further possibility that current organisational groupings could fragment as designers no longer need to work in the same locations. Technology, however, can cause as many problems as it solves through mis–co-ordinating activity (for example, groupware masking the occurrences of breakdowns in understanding [Easterbrooke, unpublished]). Technology to support designers must therefore make use of a better understanding of the role of technology and communication in collaborative design.

Summing up, design can be classified as encompassing all of the features that the ‘design activity’ brings up. Design, in the real world, is not simply a particular type of cognitive activity, but is situated within a social and organisational context. Harrison *et al* (1990) claim that focusing on design as communication and not as a creative process has ‘profound effects on how we view it and hope to improve it’. This idea is central to the thesis, because design is a socially mediated activity (Bucciarelli, 1988; Branki *et al*, 1993; Harrison *et al*, 1990, Radcliffe, 1996), as well as a cognitive one (Simon, 1981; Goel and Pirolli, 1989, 1992; Dwarakanath and Blessing, 1996). Communication itself is mediated through the transfer of representations, and focusing on these representations, or artefacts, that the communications are embodied in, should therefore prove a worthwhile research pursuit.

Although collaborative design has been extensively researched (e.g. Marmolin *et al*, 1991; Anderson *et al*. 1993; Bucciarelli, 1988, 1994; Branki *et al*., 1993; Peng, 1994; Brereton *et al*, 1996; Cross and Cross, 1996), the mechanisms underlying collaborative activity in the workplace are rarely discussed. Additionally, a number of assumptions have been made about the design process in this body of work. These include assumptions on *who* the designers are (generally concentrating on white collar workers), *what* the design work involves (generally brainstorming activities), *where* the design occurs (office based work), and the *timescale* (short term computer support for meetings, rather than project support over months or years). These assumptions are challenged through a naturalistic study of the design process in later chapters.

2.2.3 Collaborative design as a communication issue

Communication is essential to co-ordinate and organise the collaborating participants in an activity. This communication can be achieved in a number of ways; it may occur through face-to-face meetings or, more recently, through telecommunications and computer technology. Communication between designers may be one to one, one to several or one to all, and it may be synchronous, partly asynchronous, or totally asynchronous. The communications they use may take many forms, via speech, non verbal communication, texts, drawings, photographs, or a combination of these. In addition, they may be consciously generated, or arise naturally (as an emergent phenomenon) out of activity. One feature of this multitude of communications is that they are hard to track and keep aware of, both for the design participants and researchers studying them.

One of the features of design is that it occurs on a representation (either mental or external) and not on the object of design itself (Simon, 1981). Working on an external representation, such as a calculator, CAD/CAM software, a database, or a simple pencil and paper diagram, allows a greater degree of flexibility for the designer than working with the details mentally: resources can be brought to bear on the problem that are not dependant on the cognitive structures present in an individual's mind. Many of these representations are visible to all of the designers and the representations are encoded in symbols that can be interpreted by many or all of the designers. This shared awareness is believed to be crucial in collaborative activity (Harrison *et al*, 1990; Dourish and Bellotti, 1992). These representations, or 'objects of co-ordination'[1], allow work to be propagated around a work system without the constant negotiation of understanding that would otherwise be required.

[1] Barry Brown, personal communication.

2.2.4 Mechanisms of collaboration - the 'objects of co-ordination'

When examining problems from a task based perspective (such as *'design'*), people can be observed to use a number of resources in work, including artefacts (tools) and other human agents. To solve a problem, these components must be organised effectively, so as to contribute to the task goal. Several studies have attempted to describe the nature of these co-ordination behaviours (e.g. Heath and Luff, 1991; Marmolin *et al*, 1991; Murray, 1993; Heath *et al*, 1993), although descriptions of underlying structure of the co-ordination activity have been elusive. This is partly because many studies in CSCW are underpinned with an atheoretical, ethnomethodologically motivated approach (see section 2.4.3), but also because real world situations are so rich in information that it is difficult to see any underlying structure without a framework to use in analysis. Such frameworks are only now being developed, driven by the recent need for studies of technology in use. Some of these are described below.

Rogers (1994) describes several forms of representation used to co-ordinate behaviour, some of which were designated explicitly in the organisation of work, whilst others were used informally. The task she describes involved drafting files on a networked CAD system, with several designers in an open-plan office. To prevent 'file clashes' when two people tried to open the same file (not a feature supported by the technology), a system had been organised where file users wrote up the name of the file they were currently using on a whiteboard. However, use of the system was not rigidly enforced: sometimes users just called out that they were using a particular file, at other times they called out and wrote down the filename, and at other times, they did not inform the other users at all. Various problems were documented with the different mechanisms used to co-ordinate file use. However, through making information public, users were creating a 'shared awareness' that allowed them to co-ordinate their behaviours and avoid clashes, each of the mechanisms having different costs and benefits. Rogers describes these co-ordinating representations as 'mediating mechanisms': representations that allow individuals to co-ordinate their behaviour with each other. These can arise as a natural product of work practice, or as described by Rogers, as a deliberately designed mechanism of co-ordination. Mediating mechanisms are a class of 'common artefacts' (Robinson, 1993a) where operations on these artefacts by one person can be used to co-ordinate the activities of others.

Robinson (1993a) uses the example of a hotel key rack to explain this. Simplistically, hotel key racks allow keys to be stored. However, the structure of the key rack is such that a number of other non-storage functions are possible. Thus, the key rack allows the receptionist to see whether a person is in the hotel or not, and messages can be stored with the key and handed to the occupant when they collect or deposit their keys. Common artefacts allow people to interact with one another *through* the object itself, as collaborating participants' activities are mediated and rendered visible through them (Heath and Luff, 1991; Robinson, 1993a). The use of common artefacts also means that collaboration does not have to involve face-to-face activity, and can occur through peripheral monitoring other people's work (Heath and Luff, 1991), through direct, or indirect observation of the results of actions performed on the common artefacts (Bannon and Schmidt, 1991).

Star (1989) discusses a similar form of artefact, the 'boundary object', which acts as a device for communication between diverse groups or individuals in a process. In the example given by Star, animal skins are used as a boundary object between trappers and museum curators. Neither knows much of the work of the other, but each can interact with each other at the 'level' of the pelt - it is the boundary where their worlds meet and the two groups can speak a common language. Henderson (1995) develops the idea of a boundary object into that of a 'conscription device', where engineering drawings are used as 'network-organising devices'. These drawings enable group activities, they act as receptacles of knowledge, and they can be further developed through the interactions of the collaborating participants. The artefact provides a common experience of the design, and can be transmitted between experts in different domains.

The 'objects of co-ordination' include a whole class of artefacts that are used in work processes as a medium for both getting the work done, and co-ordinating that work. They enable collaboration to arise by allowing the natural sharing and dividing of work (Bødker, 1993). These objects have a representational function beyond simply reorganising the cognitive task, because they extend the work into a social domain, by structuring work activities. The representations can exist in a number of different artefacts, generated, modified and transmitted between people, such as drawings, letters, forms, post-it notes, speech, and so on.

Within particular situations, certain representational media may be more appropriate in co-ordinating activities because:

• they are unambiguous,

• they may be able to be quickly interpreted and processed, or

• easily passed on to the next user of that information.

The most likely naturally arising objects of co-ordination in design are 'cognitive artefacts'. Cognitive artefacts are tools that aid thought (Payne, 1992), and are defined as 'an artificial device designed to maintain, display, or operate upon information in order to serve a representational function' (Norman, 1991, p. 17). Essentially, cognitive artefacts are tools to aid individual thought. However, Nardi and Miller (1989) describe how cognitive artefacts provide a point of contact mediating co-operative work, using a spreadsheet as an example of such a mechanism (it is therefore a common artefact). They propose that the visual clarity of the spreadsheet exposes the structure and content of the individual user models (of the work) to encourage sharing knowledge amongst different people. The emphasis of such research on common, cognitive artefacts has been one of the most fruitful areas in CSCW research, and has usually been centred on how the design of these artefacts can be improved upon to enhance their collaborative qualities (Hutchins, 1988, 1995b; Nardi and Miller, 1989; Heath and Luff, 1991; Tatar *et al*, 1991; Nardi, 1992; Boland *et al*, 1992; Hughes *et al*, 1992; Robinson, 1993b).

Not all communication occurs through physical artefacts, but when work is systematic and process based, such as engineering design (also navigation and piloting aircraft [Hutchins, 1995a,b]), and the process has itself been designed, their use appears to be commonplace. In these situations, the artefacts (encoding representations) move through a system, where they are operated upon, the outputs of which become the input to another part of the process. It is important that these artefacts flow through the system smoothly and require as little cognitive processing as possible to be interpreted or used by the receiving participants (Hutchins, 1995a). This is an area that CSCW can and should be examining.

2.2.5 CSCW - collaboration and technology

Computer support for collaborative design (and CSCW), involves two central points of interest concerning this thesis: it is involved in the study of the practices that constitute work, and in developing technology to support those work practices. The two have been hard to reconcile, one drawing its inspiration, language and techniques from the social sciences, the other developing technology (both hardware and software) from a software engineering and systems development perspective (Bannon and Harper, 1991; Robinson, 1993b).

Many research areas, such as information systems, groupware, computer-mediated communication and participatory design, have the similar concerns to CSCW, but the focus of CSCW lies in uncovering the requirements of co-operative work (Bannon and Schmidt, 1990) to use in the implementation of technology to support it. One of the distinguishing features of CSCW is that it draws from both multi-disciplinary[2] and interdisciplinary[3] approaches, considering the psychological, social, organisational and artefactual dimensions of work.

This study draws from a background of workplace studies in CSCW, including studies of air-traffic controllers (Hughes *et al,* 1994), London Underground controllers (Heath and Luff, 1991), designers (Murray, 1993), a CAD group (Rogers, 1993), a printing organisation (Bowers *et al*, 1995), a clothing design company (Bowers and Pycock, 1996), and too many others to document in detail. Interestingly, many of these studies have not been centred on CSCW technology; they have been much more concerned with the activities involved in co-ordinating work. Some very general findings have arisen out of these studies, of which, possibly the most fundamental observation (Heath and Luff, 1991) was that of perceptual monitoring, where co-located workers maintained an awareness of each other (allowing the co-ordination of their activities) by observing the physical actions of the people working around them.

A number of technologies fall into the category belonging to CSCW, although several were in use even before the domain came into being. These include email, group editors - ShrEdit and GROVE (Dourish and Bellotti, 1992; Olson *et al*, 1992; Olson *et al*, 1990), tools for conflict negotiation and immersion scenarios, such as meeting support and GDSS tools (Karat and Bennet, 1990), including Colab (with Cognoter and Argnoter - Stefik *et al*, 1987; Tatar *et al*, 1991) and gIBIS (Conklin and Begeman, 1988), 'conversation' management (GroupLens [Resnick *et al*, 1994] and THE CO-ORDINATOR™ [developed from Winograd and Flores, 1987]), shared calendars, shared information spaces (Trevor, Koch and Woetzel, 1997), and video-conferencing and Media Spaces (Dourish and Bly, 1992). There are a huge range of technologies that have been developed to support co-operation and collaboration. However, the tools that have been developed tend to support only small groups of people and the tasks that they support have been restricted to highly focused domains of study. These tools are therefore not necessarily appropriate for supporting design work in construction. To understand how to develop and apply tools to a particular problem domain, such as construction or manufacturing, CSCW research must examine the nature of design as it occurs in the workplace.

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2 - being the use of many disciplines in combination with one another; for example carrying out psychological and social analyses in parallel.

3 - being the combination of disciplines to form new methods and frameworks for enquiry; this might involve an interwoven psychological and social approach.

2.3 Cognition in design

2.3.1 Design in the wild

Design is traditionally thought of as a conceptual discipline, concerned with creating solutions for ill-structured problems (section 2.2). However, it is essential to recognise that design work is centred on activities based in the world and distributed over a diverse range of people and organisations. It is not only a mental, but a situated activity in which a number of constraints act on the design process. Simple, low level task analyses and laboratory studies cannot capture the form of information required to inform system developers about these real world activities. To develop assistive technologies, developers therefore require information derived from different analytic techniques to understand design systems.

Previous research has demonstrated how the tools and context are integral to the organisation of design work and the importance of considering these when providing technology to support collaboration in the design process. However, to begin to understand the mechanisms involved in co-ordinating design work and their relationship to context, a framework or theory is required to link the component parts together. A range of approaches have been adapted and developed in pursuit of this ideal that might allow the analysis of design and designers, and which can account for more than the individual cognitive properties of the designers themselves.

2.3.2 Moving out of the lab: the systems approach to task analysis

A growing number of influential researchers, (e.g. Vygotsky, 1978; Bannon and Bødker, 1991; Carroll, 1993; Zhang and Norman, 1994; Hutchins 1995a) have moved away from purely psychological studies of mental activity in human activity. They claim that an approach biased towards the agency of 'mind' is flawed in our understanding of human behaviour, because the world is full of stimuli, interacting with each other, placing demands on people that are not experienced in the laboratory. They conclude that whilst laboratory studies may well be important in understanding the lower, more basic functions of the brain, they have been singularly unsuccessful in informing scientists about human behaviour in the real world.

The modern tradition of psychology, especially the cognitive experimental variant that has achieved particular prominence in the last 30 years, has failed to deal effectively with 'real world' cognitive activity. The current research paradigm attempts to consider a single variable in a situation, by performing experiments that alter the parameters of that variable within a laboratory setting. However, humans do not exist in such a resource limited world: we rarely perform behaviours that are not mediated through the use of tools or that exist outside complex and informationally rich environments. Whilst experimentalists attempt to map out an architecture for individual cognition, they have failed to deal with the complex structure of the world and the real problems that people face in it - with a resultant loss of ecological validity (Neisser, 1967). Through simplifying the problem to a manageable level of detail, the experimental approach disallows the study of behaviour within complex and unpredictable environments in which multiple resources for action may be selected.

Cognitive models of human activity fail because of their focus on th

ganisational context,
is the user the person who performs the task, or the person who the completed task is passed on to? In a multi-user environment, such as a video-conferencing or email system, are they the conglomerate of all of the users, or should the analyst consider the individual perspectives of all of the participants? A grain of analysis based on the individual cannot deal with the complexities of CSCW systems, and other approaches that can deal with these issues have moved to centre stage.

Traditionally in HCI, a micro-structural analysis of behaviour was considered to be the appropriate grain of analysis for developing computer interfaces. The cognitive paradigm and the information processing approach (Newell and Simon, 1972) was initially adapted to examine an individual's behaviour as problem solving, in terms of the problem structure of the activity. Task analyses (Johnson, 1992) were developed to break down the structure of activities into their component parts, often down to reaction times, such as the GOMS and Keystroke Level Models (Card, Moran and Newell, 1983). A range of such techniques, including variants on GOMS (e.g. Kieras, 1991), and task action grammars (Payne, 1984), amongst others were developed, but despite the early promises of such work, these methods have never been integrated into mainstream (i.e. academic or non-critical) systems design (Johnson, 1989). A fundamental problem with these forms of analysis was that they fail to take account of the larger task that such molecular activities are embedded within. The task analyses also focuses on the knowledge held by users about the system, and do not account for resources in the environment that are used to organise behaviour. Only recently have approaches been made to counter these criticisms of task analysis, although they are at an early stage of development and are largely theoretical at present (van der Veer, Lenting and Bergevoet, 1996; van der Veer, Hoeve and Lenting, 1997).

The gradual acknowledgement that a ‘micro-structural task based analysis’ did not consider the global task that such micro-level activities were embedded within has led researchers towards a greater consideration for artefact centred, contextual and organisational studies of activity more concerned with ecological validity than these early approaches. These ‘ecological’ approaches are particularly appropriate for the study of engineering design because of the nature of the design process, which operates in an environment rich in organising resources, such as tools, other people and a structured approach to problem solving. Ecologically valid research considers the work *system* as a whole and has more to offer systems design in generating appropriate (i.e. useful and usable) recommendations for technology to support design activities within a setting than the smaller granularity task-analyses.

A systems view (Norman, 1991; Zhang, 1992; Green, Davies and Gilmore, 1996) of design, with its focus on interactions between the artefacts and the human cognitive elements offers a more appropriate, higher level of analysis. In this systems perspective, it is the system, rather than the cognitive properties of the individual or the design of the artefact that determines overall performance at the task. Problem solving is distributed between the mind and the mediating structures of the world (Simon, 1981), and the systems view takes an approach to the analysis of design that considers all of the factors encompassing the process.

2.3.3 Ecological, contextual and situated approaches to systems analysis

An important change in psychology on the role of artefacts in the world on cognition was the concept of the ‘affordance’ developed by Gibson (1979), who proposed that people used features in the world to structure their ongoing activities. This ‘ecological’ approach to psychology linked perception and action through objects in the world that ‘afforded’ certain forms of use. Affordances were proposed as a method by which people could interact with their environments without the need for internal representations of the world (Norman, 1988). Gaver (1991) further developed the notion of the affordance being shaped by culture and experience.

Other influences of the systems approach to human activity were the Soviet cultural-historical psychologists (Vygotsky, 1978; Luria, 1979) who moved the study of psychology away from the examination of cognitive resources in the mind of the individual to the social, situational and cultural resources available in the world around the individual - tools, language, other people, and the division of labour that formed the ‘functional system’ of activity. This was also recognised by Wundt, one of the forefathers of scientific psychology, who placed great emphasis on the role of ‘historically accumulated, culturally organised knowledge’ in behaviour (Cole and Engeström, 1993). This cultural-historical knowledge cannot be explored with the experimental method, and has therefore been largely ignored in mainstream psychology.

More recently, research into situated cognition (Lave, 1988; Henninger, Lemke and Reeves, 1991, Agre, 1993) has embraced an anthropological approach to examining cognitive activity; like the Soviet psychologists, the claim is made that:

> “Cognition” is seamlessly distributed across persons activity and setting...thought (embodied and enacted) is situated in socially and culturally structured time and space (Lave, 1988, p.171).

To Lave, the unit of analysis should not be those of cognition or culture, but that of ‘activity-in-setting’. She goes further and states that the environment cannot be simply considered as a resource for consulting (for example, as a memory), but as an active resource in achieving the system goal, allowing cognition to be stretched over mind, body, activity and setting.

Although a significant amount of research has already been carried out into the area of communication, co-operation and collaboration (sections 2.2.4 and 2.2.5), there is only a certain amount that we can learn from such abstract understandings - because behaviour is highly situated and context dependent - and generalised theories of collaborative behaviour are unable to answer all questions across these different settings. Indeed it has been argued that modelling co-operative work for CSCW systems cannot provide useful insights for the reason that activity is contingent on its highly variable circumstances (Suchman, 1987; Schmidt, 1991). However, this strong stance is not taken in this thesis, and its implications should reach outside the domain of engineering design in construction and speak to other research areas, because although collaborative design has some unique features, it is a subset of work in general, and the findings may be broadly applicable to other areas of activity.

To build usable computer based systems (or new work systems of any kind), an analysis must take into account the social nature of work in the system, the tools used in it, and the context that this work occurs within. The development of the systems approach to understanding human activity has drawn from a number of intellectual traditions, although the area has only recently achieved a high level of prominence. These areas are elaborated on below, setting the background to the methods that will be used to examine the organisation of collaborative design activity in this thesis.

2.4 Extending the boundaries of cognition

2.4.1 Theoretical approaches

Why do we need a theoretical approach? Why does the research need to be structured within a framework? These are quite reasonable questions that might be asked by software engineers and systems developers. The answer to such questions is that with a problem area as diverse and complex as collaborative design, theory provides a background with which to frame the problem, to pose questions, to analyse, to describe and to explain the results (Rogers, Bannon and Button, 1994). Without a theory to structure the data, interpretation of its underlying form is not possible, and the data collected may be meaningless.

The theory to apply in the analysis of the data collected requires a great deal of consideration. The failure of the existing information processing model of human cognition to deal with the issues of "context" raised by HCI and CSCW, the renewed interest in the role of artefacts in human activity, and the role of social interactions in creating meaning determines the form of theory that will be needed to conduct analyses of complex activity systems. The theory chosen must deal with these issues if it is to be a serious contender in identifying areas relevant to systems design. This has led CSCW researchers to adopt the theories and techniques of social science in an attempt to integrate these issues in order to investigate work from a systems perspective.

In applying the methods of social science to inform systems design, CSCW researchers have encountered a problem, because their techniques were not originally developed as applied disciplines. In particular, the techniques associated with the theories used in CSCW must be able to adequately identify, describe and analyse the relevant aspects of work activities to inform systems development. Relevance to developers was not a central concern during the historical development of most social science disciplines. Systems developers also require information in a very different form to that which social scientists usually provide, which tend to be lengthy reports that deal with a vast range of issues and covering a multitude of areas that the developers may or may not be equipped to provide support for. These reports tend to be descriptive results rather than providing the prescriptive information that developers expect and require to build new systems.

The interdisciplinary techniques used by social scientists involved in CSCW have attempted to deal with these problems, with varying degrees of success. An early naive approach in the design of collaborative technology was that social science would provide a framework for understanding human activities which could be directly translated into guidelines for design; however, the mapping of behaviour patterns directly to systems redesign (particularly through the introduction of technology) has been largely unsuccessful, and CSCW researchers are now looking for other interfaces between social science and systems development.

Some interesting theoretical approaches that could be applied to the domain of CSCW and CSCD are outlined below, and summarised in table 2.1 at the end of the section. It must be stressed that these are all evolving frameworks (Nardi, 1992) and are constantly engaged in cross fertilisation, drawing inspiration from the others. In addition, the different theorists who have come up with these theoretical categories do not always agree with each other on the minutiae of the frameworks.

2.4.2 Activity theory

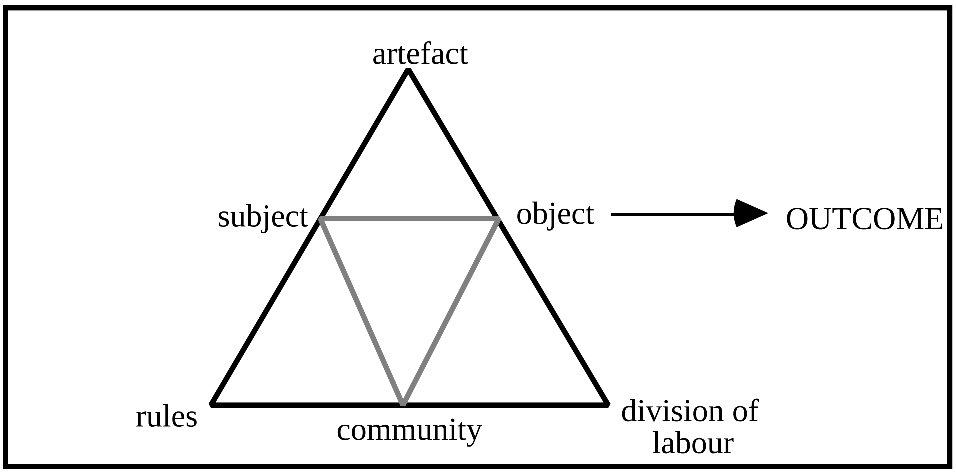
Activity theory (AT) is a relatively recent area of research in the field of HCI and CSCW (Nardi, 1992; Bødker, 1991, Kuutti, 1990; 1991; Aboulafia, 1994). Its adherents claim that it provides a framework for multi-disciplinary research, allowing researchers to link different types of information within a unifying framework (Kuutti, 1991). In AT, the technical, social and cognitive aspects of work are all considered as components that contribute to the unit of analysis, the *activity*.

Social interaction and the artefacts that mediate it (tools and words), are seen as central to mental thought in activity theory. Activity (corresponding to the cognitive psychological term, ‘task’) is distributed over people and the technical tools (computers being highly adaptive tools) which mediate activity[4]. Hypotheses are generated about specific factors and studies can be set up to test these at a more specific level of analysis (Aboulafia, 1994) using descriptive methods to study them.

The AT framework allows researchers to structure the component parts of an activity into several dimensions; along the primary entities of subject (human actor), object (something or things to be transformed through the activity) and tool (or artefact, mediating the relationship between subject and object). Yrjö Engström (Cole and Engström, 1993) develops this further by adding another unit, the ‘community’ (others engaged in the activity), that can mediate activity in a different way to the ‘tool’. Interaction between the subject and the community is mediated by social rules, and between the community and the object of activity, through the division of labour. This is shown graphically in fig. 2.1. (ibid. 1991, p. 257).

[4] Suggesting that it is not just the tools that can be redesigned (the traditional HCI approach) but the whole of the work activity, including its content and organisational structure.

Fig. 2.1. Mediation of activity in Activity Theory



Using an example of knitting (following Boden's [1977] use of a gender reversed example[5]) a description of activity in an AT framework would consider the knitter as the subject, the needles and the properties of the wool as tools, and the wool itself as the object, when transformed into a pullover. Using knowledge drawn from the community, transmitted through the rules of interaction, the subject could have learnt to knit and gathered patterns to use. If there were several knitters, the community could be organised to knit the sleeves, the body and other subcomponents through the division of their labour. Thus, the activity, encompassing several forms of behaviours, can be broken into segments that can be analysed separately, using appropriate techniques for the unitary components.

This arrangement of entities provides a means of breaking down the activity into smaller, well defined constituent parts, each of which can be examined either alone, or through the relationships between the components. This structured approach gives a structure to the descriptions of social interaction that many other methods do not express; however, as yet, despite its apparent potential, the framework has not been used extensively within either CSCW or systems design. It has also been criticised, even by its proponents (e.g. Kuutti, 1990) for being overcomplicated, slow and difficult to use.

2.4.3 Cognitive sociology and the ethnomethodological approach

Sociology is concerned with the nature of work and social organisation, and in essence, this is what this thesis attempts to examine in groups of designers. However, its concerns are typically with society at large, not groups, and thus it appears to contribute little to the development of CSCW technology. Nevertheless, sociology,

[5] The all too obvious cliché being the description of driving a car.

and in particular, one variant of sociology has been adapted to the study of collaborative work.

One of the central premises of sociology is that all activity is social in nature (Schmidt, 1991): it is situated within a social context, mediated by social pressures and learned in a social milieu. Work is a social activity, with goals and operations defined by the social context that individuals are immersed in. One particular group of sociologists - the ethnomethodologists - have dominated the study of the social organisation of work. Ethnomethodology is a variant of sociology that has come to be the dominant paradigm of analysis in CSCW, and inspired a large body of research papers in the area (e.g. Heath and Luff, 1991; Heath, *et al,* 1993; Randall and Hughes, 1995; Bowers, Button and Sharrock, 1995). Ethnomethodologists seek to try to understand how work activities are ordered through the process of interaction, and the approach has achieved a respectable position in CSCW in examining the social organisation of work.

One particular insight that the ethnomethodologists have provided is that they have begun to uncover the details of how work is performed, rather than the decontextualised ‘examples’ (Randall and Hughes, 1995) of work that traditional sociology describes as background material for analyses (Sharrock and Anderson, 1986); such decontextualised studies lose important understandings about how the structure of the work itself might interrelate with the organisation of the people performing it and the technology that they use.

A derivative of the ethnomethodological approach is situated action (SA) which has been developed particularly with human-machine interaction in mind. Rather than concerning itself with the social nature of work, it concentrates on other aspects of the situation that work exists within. Like ethnomethodology, it posits no deep structure on activity. Suchman (1987) contrasts situated action against cognitivism and artificial intelligence by rejecting internal representations as irredeemably decontextualised (disputed by Vera and Simon, 1993), denying a causal role for the goals and plans that the psychological sciences use to explain behaviour. Instead, the organisation of the environment is argued as central to actions performed in it, emphasising the emergent, contingent nature of activity (Nardi, 1992).

Suchman’s (1987) ‘Plans and Situated Actions’ has been the driving force behind much of the research into the role of context in activity. Cognitive plans, she argues are the result of *ad hoc* interpretations of actions in the world, although they are also used as resources for actions. Actions, driven by situations, are a focal point for the SA theorists in understanding the organisation of work. The resources that people use are opportunistically selected from those at hand, rather than driven through forward planning. Hence, the organisation of problem solving activity is emergent and situated in the environment in which the actor finds themselves:

> '...the organisation of situated action is an emergent property of moment-by-moment interactions between actors, and between actors and the environments of their action.'
> (Suchman, 1987, p. 179)

To summarise, the method used by ethnomethodologically informed researchers involves an analysis of the social interaction of individuals collaborating in their activities. Their focus is firmly on language, with close links to 'conversation analysis' (Cicourel, 1975). However, cognitive sociology fails to directly incorporate the use of common objects (section 2.2.4) into their analyses. Another problem in using ethnomethodological research in CSCW is that it takes a largely atheoretical approach to analysis, involving often long descriptions of activity as observed. They do not attempt to provide a theoretical basis for their findings (for philosophical reasons), and claim that 'the data speaks for itself', which does not lend itself easily to supporting the work of systems developers.

2.4.4 Situated cognition and distributed representations

Situated cognition (SC) is an approach that seeks to describe cognitive activity rooted within a physical and social context (Zhang and Norman, 1994). Like situated action, the SC perspective views activity as emergent, drawing from, and structured by, the resources available in the setting. However, SC is concerned with cognitive processes and the external representations in the world that are used to support actions in the pursuit of a goal - cognitive terms that situated action avoids. As with activity theory, SC considers the activity to be the fundamental unit of analysis.

Theories of distributed representations (Zhang and Norman, 1994; Zhang, 1990) and external representations (Woods and Roth, 1988; Larkin, 1989; Larkin and Simon, 1987; Vera and Simon, 1993) fall squarely into traditional cognitive science, in which tasks are decomposed into different forms of representations, and where 'the *representation of the world provided to a problem solver can affect his/her/its problem solving performance*' (Woods and Roth, 1988. p. 26). These theories posit two forms of representations, internal (in the mind, either serial or connectionist), and external (in the world, as physical symbols), which are combined into an abstract task space during problem solving activity. Through using representations available in the world, cognitive actors do not need to maintain complex mental representations. Perceptual information performs part of the cognitive task, and external representations become a component part of the human cognitive system. The physical constraints on activity that these external representations bring to cognition are important in reducing the rule base required to comprehend the world (Zhang, 1990), simplifying the task at hand, and fundamentally changing the nature of the task from one that is solely mentally represented (Zhang and Norman, 1994).

Essentially, for the distributed representation approaches, parts of the cognitive system knowledge can be carried in things such as numeric systems (Zhang and Norman, unpublished) or databases. These representational systems extend the symbol manipulation capabilities of the unaided human mind beyond that which they could accomplish without these artefacts. The situated properties of cognition (drawing from social and physical resources present in settings) allow us to sometimes avoid mental symbol manipulations (Zhang and Norman, 1994; Pea, 1993; Vera and Simon, 1993), and to use the representation to take the load of the information processing requirement.

In design, there are often many possible ways to solve a problem through the way that it is represented (problem isomorphs - Khaney, 1993), because there are many possible solutions. For each of these solutions, there are many intermediate pathways that can be followed. For example, engineering calculations can be done mentally, using a pen and paper, using a calculator or using specialist CAD software. Different problem isomorphs have different cognitive characteristics and place different cognitive loads on the agents performing the task. Designing systems to support collaborative design therefore requires identification of the problem isomorphs that appear the most ‘natural’ to the users, and that best carry the communication to co-ordinate the designers in the system.

SC and distributed representation theories take Simon’s (1981) notion of the human as a mundane processor of information to its logical conclusion through using situations as practical resources for thought. This is performed through breaking the boundaries between perception and cognition (Butterworth, 1992), as perceptual mechanisms are incorporated into information processing. However, so far, the distributed representation approach has only involved single individuals, rather than social groupings (although see Zhang, unpublished), it is possible to see how the world and artefacts in it can be augmented through the addition of other actors in a social context. However, such research is not informative about the social and organisational mechanisms of co-ordination, because of its preoccupation with determining the locus of the representation (i.e. internal or external) rather than their organisation in the performance of the task.

Table 2.1. Approaches for examining collaborative

Chapter 2 Communication, Co-ordination,				

	Activity is situated, mediated and learned in social context. Seeks to understand ordering of work through social interaction. Relevant to CSCW because interaction can change when mediated through technology.	Emphasis on language, not artefacts ignores organising features in environment. Descriptions overcomplex and leave much to interpretation.	Randall & Hughes, 1995; Bowers *et al*, 1995; Sharrock & Anderson, 1986; Cicourel, 1975; Heath & Luff (1991); Heath *et al*, 1993.
Situated action	Derived from ethno-methodological approach. Behaviour is emergent and opportunistic, not planned. Examines resources organising action. Developed specifically for CSCW.	Attention on opportunistic action - planning and rule following ignored.	Suchman, 1987, 1990, 1993; Suchman & Trigg, 1993; Nardi, 1992.
Situated cognition and distributed representations	Activity emergent and structured by resources in setting. Concern with external representations. Perceptual mechanisms incorporated into problem solving. Value to systems design in demonstrating representational organisation.	Focus on individuals in restricted domains. Fails to capture mechanisms of co-ordination in task performance. Oriented towards cognitive modelling.	Lave, 1988; Zhang & Norman, 1994, unpublished; Zhang, 1990; Woods & Roth, 1988; Larkin & Simon, 1987; Larkin, 1989.

2.5 Computer support for collaborative design

2.5.1 Context, HCI and CSCW

The social sciences have been appropriated into systems development because they are able to capture the rich levels of detail about the enacted performance of work that formal methods of requirements analysis cannot (Jirotka and Goguen, 1994). This is described by Anderson (1994) in the quote below:

> "What the user is held to know about and to orient to in the daily routine of their workaday world is the practical management of organisational contingencies, the taken-for-granted, shared culture of the working environment, the hurly burly of social relations in the workplace, and the locally specific skills (e.g. the "know how" and "know what") required to perform any role or task. Formal methods of requirements capture, or so it is supposed are incapable of rendering these dimensions visible, let alone capturing them in the detail required to ensure that systems can take advantage of them." (p. 154).

However, having slated the formal approach to examining social and technical systems, other approaches are required to fill the vacuum. The different methods of analysing behaviour summarised in the previous section have all been suggested as answers to this. They can all be described as different worldviews on the descriptions given to, and explanations of activity (Agre, 1993), and whilst they may be underpinned with very dissimilar theoretical understandings, at a simplistic level, they express similar explanations about behaviour, and advocate similar, methodological approaches grounded in naturalistic research. Whilst each has different grains of analysis in which the cognitive element is lesser or greater, they move the problem solving element of behaviour away from the neurological conception of 'mind'. Many of these approaches have arisen independently, but carry the same underlying ideas, whilst they can also differ significantly. Often these differences have arisen because of the different academic backgrounds of the theorists and the different problem areas and grains of analysis that the practitioners are wrestling with.

All of the approaches described above take a different perspective to that traditionally taken in HCI (Clegg, 1994), moving research away from an emphasis on the study of human behaviour as rational, planned and individually centred. Within the field of CSCW, where social and organisational behaviours are central issues, experimental and individual-centred approaches have failed to provide practical help in the design of useful and usable systems. Novel approaches that emphasise the role of context in behaviour, have risen to the fore and have contributed to a new understanding of behaviour, considering it as an emergent, rather than pre-determined activity, that arises through factors both internal and external to the individual.

2.5.2 Designing artefacts for collaboration

The development of technological artefacts has generally involved the computerisation of existing artefacts, for example, CAD replacing the drawing table in design. However, replacing the artefacts of work is not a simple matter of replacing one object with another, because artefacts have been designed and adapted to their use over time. It is therefore important when replacing old technologies, that artefacts should be examined in their contexts of their use (Bannon and Bødker, 1991) to see *how* they are used in the performance of work. The reason for this is that artefacts are often perceived to have a single function whilst they in fact support a number of non-obvious activities (Brown and Duguid, 1994; Robinson, 1993a). When considering redesign of an artefact, it is necessary to consider these contextual factors.

The relationship between context and systems design is considered in a special issue of the Journal of Human-Computer Interaction (Ed. Moran, 1994). In this issue, Brown and Duguid (1994) argue that the context of work is central to the co-ordination of that work, and what the users understand about the context must be understood when redesigning this work with technology. Artefacts are used as objects of co-ordination, because some features of these artefacts (the 'border resources') are used to mediate relations between co-workers. Indeed, there is a natural tendency for people to share tools, even when they are designed for personal use (O'Day, 1994). The social and work related nature of these artefacts are interwoven, and are hard to pare apart - changing the artefact could seriously impair the ability of groups to co-ordinate their activities.

CSCW needs to do more than theorise about the social organisation of work. It must also help inform developers about how to support the various divisions of labour that workers operate in (Bannon and Harper, 1991). In redesigning technology, and therefore redesigning work itself, technologists may remove seemingly anachronistic practices which may in fact have important co-ordination functions in the collaborative processes (Halverson, 1994). These are the 'borderline issues' (Brown and Duguid, 1994) where 'task non-essential' details are utilised to co-ordinate behaviour. CSCW must provide support for the development of appropriate technology by uncovering these border resources.

System designers need to have a better understanding of how humans act in their work environments to develop useful and usable tools, appropriate to that environment. Whereas Simon and the psycho-cognitivists consider problems as objectively existing, with initial states, goal states and operators, the more contextually aware disciplines view problems only in relation to actors and their environments. Context is a resource in design, possibly the dominant one, and must be taken into account (Henninger *et al*, 1991) in developing an understanding of the design activity.

2.5.3 Collaboration, technology and theories of design

A deep understanding of design to support the development of technology needs to take account of the culturally constituted and other situationally dependent contingencies that form the basis of real design problems. Building technology is not enough - we need to learn more about how groups, organisations and technology are organised. However, few researchers appear to have examined the design process as a whole. Design has been shown to be an iterative process, where research that concentrates on a particular component of the process neglects the whole, and failure to attend to the situation as a whole devalues such studies for their application in CSCW and CSCD. Of course, much of this limited understanding the design process has developed from the concerns of disciplines different to those of CSCW, and so do not attempt to capture these elements. As an emerging area of research, CSCW must not simply adapt research from other areas but develop its own techniques and theories so that it can make a real and discernible contribution to the development of effective collaborative technology.

The approaches described above have some of the features that research into CSCW requires to tackle in informing systems design. However, none of the approaches links all of the features of work activity (cognitive, social, situated, and mediated by artefacts) into a unified whole that can be directly applied to the analysis of collaborative design, which must integrate the social and organisational aspects of work with the objects involved in that activity and the problem solving nature of design work. This involves an integration of several disciplines which interweave the social and cognitive components of activity, the results of which must be in a form that can be used to inform the design of technology. A branch of cognitive science has been recently developed up that is attempting to seriously tackle these interdisciplinary issues. It is known as ‘distributed cognition’.

2.6 Summary

This chapter brings together current understandings about the component parts of the problem under examination: collaboration, design, methods for examining collaborative work, and their relationships to systems development. Current work on design is discussed, demonstrating how cognitive approaches have failed to explain the collaborative design process in settings supported with a range of physical and organisational resources. These current understandings about design do not describe the social and situated nature of activity well enough to develop technology to support design work, and new theories and analytic techniques are therefore required. Techniques based on the social sciences are discussed and compared as a means of making explicit the mechanisms used to co-ordinate activity. The issues that these techniques raise for HCI and CSCW are explored. The chapter concludes that another approach, that of 'distributed cognition' is best suited to describe the collaborative design process in the context of systems development. This is described in the following chapter.