Achieving self-organisation in network-based learning environments

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Abstract

This thesis is an investigation into how to exploit the unique features of computer networks (notably the Internet) to support self-organising groups of adult learners.

The structures of systems influence the behaviour of their parts whilst those structures are in turn influenced by their parts' interactions. Effects of structural hierarchies in popular systems of education may lead to poor learning experiences for some students. An alternative way of organising such systems is to decentralise control and to allow a structure to emerge from the combined actions of learners: a self-organised learning environment.

The functionality of a teacher often has the largest effect on the dynamics of an educational system. This is therefore a good place to concentrate efforts to encourage emergent structures to develop in adult education. The thesis attempts to classify that functionality, abstracting the roles a teacher may perform.

The Internet (especially the World Wide Web) has more of a network than a hierarchical structure and, being a virtual space, provides relatively virgin ground on which a less centralised model of educational organisation might develop. The thesis considers how self-organised learning may arise in existing Internet-based environments. It identifies a key weakness of existing systems to adequately address the varied and ever-changing needs of learners.

A number of studies performed as part of this investigation centre on the construction of a series of software products explicitly aimed at enabling the self-organisation of learners. They achieve this through the adaptation and evolution of metadata at different structural levels, thereby dynamically adapting to learners' needs as those needs develop.

The thesis concludes with a set of guiding principles for those seeking to build self-organisation into learning environments.

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Preface

Context

Although much of this thesis revolves around education, it will not be much concerned with theories of learning, but instead with the kind of environments in which learning happens. In Socratic terms, its objective is to discover what makes a good midwife, not a good baby. Although the two are intimately linked, I believe that it is possible to meaningfully consider either in relative isolation.

Mostly this thesis will be concerned with adult learners and my own studies have been conducted entirely within the confines of a traditional university system. However, when discussing historical and theoretical issues the boundaries will blur from time to time with issues that affect other kinds of learner and different forms of learning.

Research methodology

The main research question

This thesis is the result of a search for principles and guidelines for the construction of network-based learning environments where organisation and control arises from the combined actions of learners using networks rather than from designers or managers of learning. The big question is therefore:

how should self-organised network-based learning environments best be constructed?

The answers I shall give to this question will be based on an investigation of the nature of educational systems, of self-organising systems in general and of instances of self-organising systems on the Internet. Above all, they are based on the ongoing development, use and evaluation of a piece of Web-based software known as CoFIND (Collaborative Filter in N Dimensions). CoFIND is designed to facilitate self-organisation of learning by providing an environment created by and adaptable to the learners who use it, primarily through the sharing and rating of resources using evolvable user-supplied metadata.

The main research approach for the bulk of the thesis is based on action research, as defined by Burns (2000, p. 443) as:

> the application of fact-finding to practical problem-solving in a social situation with a view to improving the quality of the action within it.

Why action research?

At the outset my research questions were fuzzy. I knew that I wished to explore ways that evolution could help groups of learners on the Internet manage their own learning, but beyond that I had little idea of the specific ways that this might occur. With its focus on clarifying and exploring, action research provided an appropriate means of helping to clear up this fuzziness.

Given the fuzziness of the questions I have used predominantly qualitative methods as my key objective is to generate hypotheses. Burns (2000, p.13) quotes Barton and Lazarfield as describing a qualitative approach thus: “like the nets of deep-sea explorers, qualitative studies may pull up unexpected and striking things to gaze on.” Mainly through a process of building and evaluating computer systems I have been seeking the unexpected, which by definition will not succumb to a scientific method of inquiry and analysis. The central purpose of this research is discovery, with the forms of explanation supporting and determined by the results of discoveries as they arise:

> Action research does not know what questions to ask until it has interpreted the present.
>
> (Burns 2000).

In the process of performing my research I wished to create usable tools and methodologies to assist my teaching. A key strength of action research is that it is generative. My intention has been to create as much as to describe or explain. I therefore needed a set of methodologies that was responsive, adaptable and creative. Cohen & Mannion (1994) characterise the key goal of action research as “to add to the practitioner’s functional knowledge of the phenomena she deals with.”

I wished to combine my research with my teaching. Action research is an effective approach for improving and extending both. Braa and Vidgen (1997) observe that action research can be seen as “a way of building theories and descriptions within the context of practice itself". It is also a feature of this approach that I have been bound by the ethical demands of my profession as a teacher. I could not reasonably perform experiments on my students which I did not perceive to be in their own interests. This usually requires a greater degree of intervention and involvement, invalidating any claims to "objective" truth.

Much of my research revolves around the creation and use of a Web-based application called CoFIND (Collaborative Filter in N Dimensions), discussed in Chapters six and seven. CoFIND's primary function is to allow learners to find resources which are organised and filtered through the combined activities of its users.

CoFIND is an exercise in model building, an attempt to make use of principles of self-organisation to achieve form and structure. Some people build models to demonstrate things they already know, like those perfectly constructed Lego houses based on the plans that come with the box. Others throw away the instructions and begin to build. As the Lego models develop, so their earlier features determined their later form, usually leading to unanticipated constructions which might be inspired or simply awful. This latter approach underlies the design of the CoFIND system. Through the process of building and testing I have explored possible forms of educational self-organisation by trying to encourage them to happen. I have been testing hypotheses through the construction of systems but at the same time using those systems to generate hypotheses.

Each CoFIND system has incorporated the ability to measure many aspects of how it is being used. This ability to self-document is a notable advantage of working in virtual space and allows examination of the use of the system in ways that would be difficult in a traditional face-to-face environment.

I have made use of techniques which seem appropriate for each stage of my research. For example, in investigating the interactions in a newsgroup I adopt a broadly ethnographic approach, while in analysing the effects of some aspects of my system I employ a quasi-experimental method, comparing control groups to identify differences in their behaviour.

Details of my approach

The traditional approach in action research, following from Lewin, is to break the process into two stages:

1. A diagnostic stage to analyse problems and diagnose solutions and

2. A therapeutic stage, where experiments are performed and their results observed closely (Burns 2000; Cohen & Manion 1994).

Various authors further break the process down into a number of distinct sub-stages. There are various possible ways of doing this, such as the seven stage model specified by Burns (2000, pp. 445-449) and Checkland's soft systems method. For mainly aesthetic reasons I have chosen to roughly adhere to Susman's approach to action research. The framework suggest by Susman (1983) consists of the following five stages:

? Diagnosing: this stage is concerned with the formulation of the problem or area of interest

? Action Planning: for the purposes of this research, this stage mostly consisted of the generation of a new iteration of software or a new way of using it, occasionally taking in information from research literature in the process

? Action Taking: this stage involves actually performing the intervention and allowing it to run its course

? Evaluating: critically assessing the results of the intervention, as well as any unexpected new information arising from the study.

? Specifying learning. at this stage the data is interpreted and new knowledge identified

At the end of the cycle the process starts again, hopefully improving understanding with each iteration.

I have treated this as a loose framework which does little more than to allow the process of research to be managed. On occasions it is inevitable that the stages will get mixed up as well as result in scaling effects, with smaller eddies of miniature research cycles within larger cycles of diagnosis and therapeutic action (Figure 0-1).

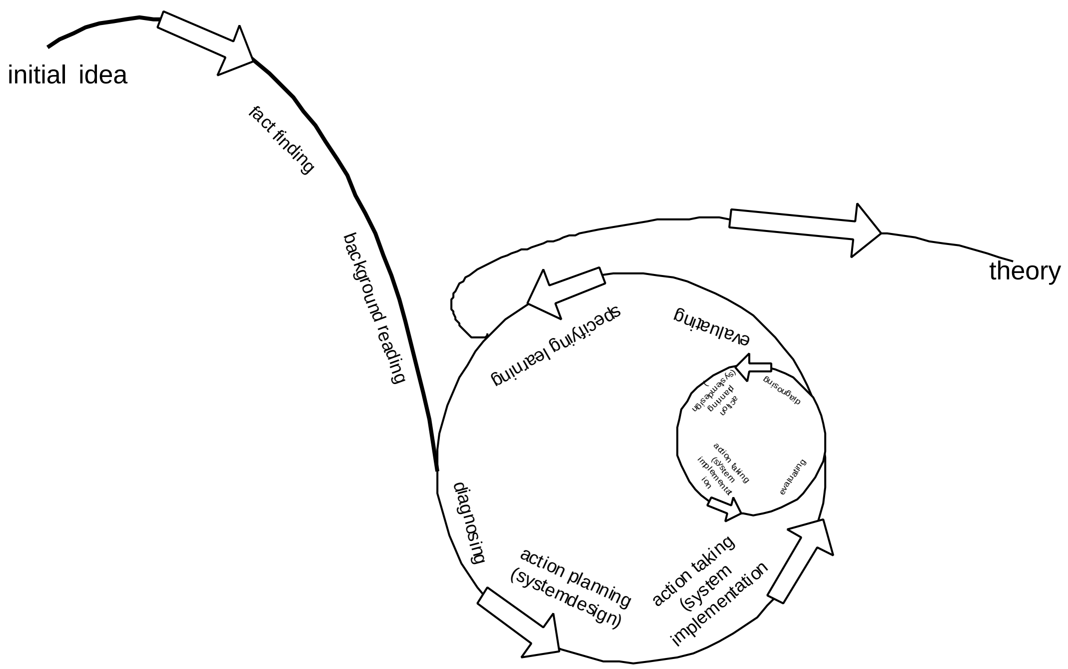

Figure 0-1– research methodology overview

To summarise, the intended result of this process is twofold:

? to use action research as a framework for approaching the design of the software and processes which surround a self-organising learning environment

? based on existing literature and systems together with various experiments and studies to attempt to generate reasonable hypotheses or generalisations about the construction of self-organising learning environments. Although these will not be rigorously proven by experiment, I hope to provide at least the groundwork for a set of design principles which will allow the generation of other such systems in the future.

What I have not done

An action research variant

Although I have described my approach as based on action research, I have deviated from standard practice in a number of important respects. In particular, most of what has been achieved is not a team effort, although it is concerned with changing the nature of communication between learners by adding to their repertoire of possible ways of interacting. I have used it more as a development methodology for a computer system, with theory spinning off as a significant side-effect.

Quantitative research

In taking on action research as an approach I have made a number of trade-offs, most notably in generally avoiding quantitative methods, thereby perhaps reducing the generalisability of my findings. The lack of scientific validity seems a small loss compared with the generative gains and the learning which is entailed.

Measurement of effects on learning

On the whole I have made little effort to measure whether the results of my research have a positive or negative effect on learning, although the theoretical basis of the research does provide grounds for asserting that it *is* a learning environment. At the highest level of generalisation this means it is an environment where learning can potentially take place with greater ease than in its absence. The focus of this thesis is to demonstrate that self-organisation within a learning environment is taking place. My concern is with the construction of an educational environment which meets a set of criteria that define it as such. Evaluation of that environment’s effectiveness in enabling learning to occur would require another PhD. I hope to show that there are underlying principles of this kind of environment that are independent of its consequences.

My decision is coloured by the hope that the kinds of learning that occur in higher education are (or should be) the result of a far more complex and interesting process of accommodation, assimilation and adjustment than any reductive study will ever reveal.

The process – a reader's guide to the chapters

In chapter one, based largely on existing literature, I argue that most educational systems result in and from complex systems behaviour. This behaviour affects the constituents of educational systems in ways that are sometimes antagonistic to learning. Few of these observations are original, though because of the purpose behind them (to provide a theoretical foundation for building self-organising learning environments) the specific way in which they are combined is unusual.

Chapter two investigates ways in which complex systems arise in general, drawing on theories surrounding evolution and complexity to lead to a discussion of how such features might relate to existing educational systems. I arrive at conclusions about the features of such systems which should be examined in order to produce self-organising versions of them. In particular, I conclude that the most interesting results are likely to be achieved if we concentrate on the role of the teacher within any system that we build.

Chapter three follows from the conclusions of Chapter two and is intended to abstract significant features which characterise the roles of the teacher or manager of learning. The purpose of this is to identify what it is that we are aiming for in a learning environment.

Chapter four looks at systems which may have (or may be adapted to) some educational purpose. The systems discussed are not designed with any inherent self-organising characteristics but none-the-less, because of the ways that individuals use them, exhibit self-organised behaviour in greater or lesser degrees. The chapter includes a piece of research which attempts to identify ways in which self organisation is possible within a system not explicitly designed to organise itself. This takes the form of three related studies in which I applied a series of interventions to identify some of the effects of structure and stigmergy (communication via the environment) on the dynamics of a discussion forum.

Chapter five looks at Internet-based systems with features which are either explicitly designed to enable self-organising behaviour or which exhibit that behaviour because of implicit mechanisms built in to them.

Chapter six describes the development of a group of systems (CoFIND, Collaborative Filter in N Dimensions) which are explicitly designed to enable self-organisation to occur. It includes descriptions of the systems, some studies performed, an explanation of the interventions I made and the effects that these had on ongoing development.

Chapter seven takes the form of an extended set of conclusions to Chapter six and contains a discussion of the shortcomings of such a system as CoFIND and suggestions for future potential developments.

The final chapter summarises the lessons learnt and attempts to extract a set of rules for building self-organising learning environments from the results of the foregoing chapters. It finishes with a description of a potential truly self-organising network-based learning environment.

Chapter 1 : Organised education

About this chapter

In this chapter I will be looking at educational systems and the importance of structure in determining their nature. In general (as throughout this thesis) the emphasis will be on adult learners with a strong bias towards traditional academic systems typified by universities. However, where appropriate, I will occasionally extend the boundaries to provide a more inclusive view of education.

The chapter provides rationales for modifying the structure of an educational system to achieve different and (perhaps) better ends, as well as laying the groundwork for a discussion of the behaviour of complex systems which have fed into various studies described and discussed later in the thesis.

A part of the chapter will be devoted to attempting to understand how structure in systems develops in general. This will include an investigation of how the components of any system are affected by their relationships to each other and to *negasystems*, those features which fall outside the system under observation yet which interact with it. With this systems-oriented perspective in mind, I will look at educational systems at a number of scales, building up from the systemic nature of individual learning, to the dynamics of group learning, to the effects of complete educational systems on their participants. I will attempt to show that in many ways these effects can be positively detrimental to the desired outcome of learning. However, the field of distance education (especially when conducted using computer networks) offers opportunities to deconstruct then rebuild educational systems in different and perhaps better ways.

Education

Some actions will lead to improved learning. I will follow common usage in this thesis and call the process which includes these actions, their effects and their consequences *education*. The process minimally involves a learner, and may also include one or more of

? participants and drivers such as educators, technicians and administrators

? resources such as books and the libraries that contain them

? actions such as lively discourse in an academic community or learning events such as tutorials, seminars and lectures

? a support structure composed of such things as classrooms, laboratories, toilets, canteens and cloakrooms

? other learners

There may be a host of other factors which affect its dynamic progression. The word *education* refers to some kind of interaction where there is an involvement of the educator, the learner, what is to be learnt and an environment. In a word, it is a *system.* It is composed of many interacting subsystems, the libraries, resources, curricula, social demands, political initiatives, geography, educational theories, teachers, students, administrators, institutions, employers, the academic community and so on. The interactions of these different subsystems form the character of any given educational system.

Beginnings

My interest in this area was sparked obliquely by a comment from Brad Cox in his paper on evolutionary methods of organisational learning, “Evolving a Distributed Learning Community” (Cox 1997). Cox speaks of education as a complex system and observes:

> what governs complex systems is rarely the industrial age’s notion of design at all. Rather, they evolve, shaped by an interaction in which system and environment minutely adjust to each other as biological organisms evolve within ecologies.
>
> (Cox 1997)

I was struck by the elegance and simplicity of this. Cox talks of a community and course which he developed, the power of which lies in its distributed nature:

> Although central planners can process formal knowledge effectively, they are unable to collect or process tacit, local, informal and unarticulated knowledge of taste, preferences, scarcity and opportunity as effectively as a fully distributed system of independent decision-making entrepreneurs.
>
> (Cox 1997)

Its success is due to the fact that it mobilises the combined intelligence, curiosity and enthusiasm of the learners themselves. This theme will recur throughout this thesis. I wish to suggest that for too long we have attempted to apply an industrial, engineering approach to education, to design a one-size-fits-all piece of machinery for filling heads with what passes for learning. Its most dismal reflection is the uniform lecture format. Such approaches are doomed to mediocrity. As Laurillard describes the centralised, mechanistic mass-lecture process, “This is insanity. It is truly a miracle, and a tribute to human ingenuity, that any student ever learns anything worthwhile in such a system.” (Laurillard 1993).

My perspective throughout this thesis is one that seeks to avoid centralised control and that tries to discover ways in which communities themselves are the generators of control, order and knowledge. To reach this point, we must have an idea of the nature of decentralised systems and how they behave.

Characteristics of complex systems

Parts and wholes

> And I know not if, save in this, such gift be allowed to man
> That out of three sounds he frame, not a fourth sound, but a star.
> From Abt Vogler, Robert Browning

In the latter half of the twentieth century but with roots stretching back to the works of Charles Darwin and beyond, there has been a paradigm shift in scientific thinking. The success of traditional scientific ways of thinking was underpinned by a process of reductive abstraction and decomposition into primitive parts, from which all manner of theories and engineering marvels could be assembled. The power of simple laws and discoveries of the sorts identified by Newton, Galileo, Keppler, Voltaire, Rutherford, Einstein and a host of other luminaries has led to results as wide-ranging as space travel, mass transport, genetic engineering, disease control, atomic power, plastics, electrical power, and television. Reductive science works in a lot of different contexts. However, it has gradually been realised that (perhaps) the majority of interesting phenomena are not susceptible to reduction of this sort. Much of what affects us most deeply is the result of the behaviour of systems, large-scale behaviours caused by small-scale interactions and (just as interestingly) complex interactions leading to simple behaviours. Cohen and Stewart call these, respectively, *simplexity* and *complicity* (Cohen & Stewart 1994).

Systems thinking covers a broad range of related schools of thought, concepts and theories, including evolution, cybernetics, chaos theory, system dynamics, fuzzy logic and the science of complexity and simplicity, collectively christened by Murray Gell-Mann as 'Plectics' (Gell-Mann 1996). The underlying strand of thought that relates these various fields is the idea that the behaviour of all systems follows common principles. We can see "patterns that connect" (Bateson 1972) in systems as diverse as computers, animal bodies and cells, population growth, financial systems, the spread of ideas, the growth of cities, central heating systems and cloud formations. We even see them in systems of education.

We are going to be looking at systems without governors or central controllers, which have properties of emergent order. That is to say, we are looking at systems which are more than the sum of their parts, as the chord in Browning's poem is more than the sum of its three constituent sounds, a point taken up by the Gestalt theorist Wertheimer (1938), who writes on the subject of how notes form a melody:

> What I really have, what I hear of each individual note, what I experience at each place in the melody is a part which is itself determined by the character of the whole. What is given me by the melody does not arise (through the agency of any auxiliary factor) as a secondary process from the sum of the pieces as such. Instead, what takes place in each single part already depends upon what the whole is. The flesh and blood of a tone depends from the start upon its role in the melody: a b as leading tone to c is something radically different from the b as tonic. It belongs to the flesh and blood of the things given in experience [Gegebenheiten], how, in what role, in what function they are in their whole.

The notion of the relationships between the parts forming a whole which is greater than the simple sum of those parts is central to a view of the world from a systems perspective (Holland 1998). Systems are recognised and defined by their connections, patterns, interdependencies and emergent behaviour. By identifying repeating patterns within different systems we may see connections between different subjects and disciplines which transcend their subject matter.

Complex Adaptive Systems

There are widespread classes of systems which have been identified by Holland as Complex Adaptive Systems (CAS). Prigogine describes these as dissipative structures, open systems which exchange matter, energy or information with their environment and which thereby exhibit order (Hartwell 1995). Examples might include tornadoes, whirlpools, population changes, movements of money markets or evolution. Prigogine demonstrates that only closed systems move towards entropy, whereas open systems move towards some form of organisation. A CAS exhibits a range of interesting properties, particularly that it generates emergent properties of structure. Such properties are not predictable from any individual input but are the result of the behaviour of the system as a whole. Self-organising systems are those where patterns form and acquire order and structure through interactions internal to the system (Camazine et al. 1999). They do so through a combination of positive and negative feedback mechanisms, the positive feedback providing change, the negative feedback stopping that change occurring. The patterns which arise do so not because of a high level rule but as a result of individual actions within the system. Camazine et al give the example of the formation of colonies of birds, all of which follow the rule “I nest where you nest” (positive feedback) “unless it is too crowded” (negative feedback). The result is separate colonies (Figure 1-1). This is an example of what is meant by *emergent* behaviour. There is no grand plan which the birds are following to form a colony. It just happens because of positive and negative feedback rules, which determine the structure of the system in terms of the relationships between its parts.

Figure 1-1 – colony formation in birds

A systems view of education

Considering educational systems from a systems perspective can yield important insights. As Senge (1993) has persuasively argued, structure influences behaviour. A wide variety of behaviours are born out of the nature of systems, not the individual constituents of those systems. Senge provides an extended example (originally developed by Jay Forrester) in the form of the Beer Game, where retailer, wholesaler and manufacturer are caught up in a vicious cycle of supply and demand which, when not viewed in a systemic way, leads inevitably to cycles of over-ordering, depleted inventories then heavy over-stocking. The problem arises out of the nature of the system, which includes varying degrees of latency between deliveries. Retailers, responding to a consistent slightly increased demand for a certain brand of beer, increase their orders from the wholesalers. The wholesalers increase orders from the brewer. Because of inherent latencies within the system, partly due to delivery cycles and partly due to how long it takes to brew beer, orders are not immediately met, so everyone perceives increased demand and an inability to meet it. To compensate, the retailers increase orders to cope with the backlog, the wholesalers follow suit a little while later, the brewer brews more beer to cope. These effects are magnified as they rise through the system. Eventually, the backlog of orders are met, at which point all players in the system have a massive over-stocking of beer, orders are cancelled and all players suffer accordingly (figure 1-2). This game demonstrates system generated behaviour of the sort which can be seen in the wildly fluctuating availability and pricing of microchips, for example. Senge gives many more examples of such unwanted artefacts of system behaviour, including arms races, bank runs and fuel crises, where individual decisions are made based on rational grounds as a result of a perceived stimulus yet the overall effect of the system acts to the benefit of nobody. The nature of such systems is to cause emergent behaviour which is not predictable by examining a part or parts of the system in isolation.

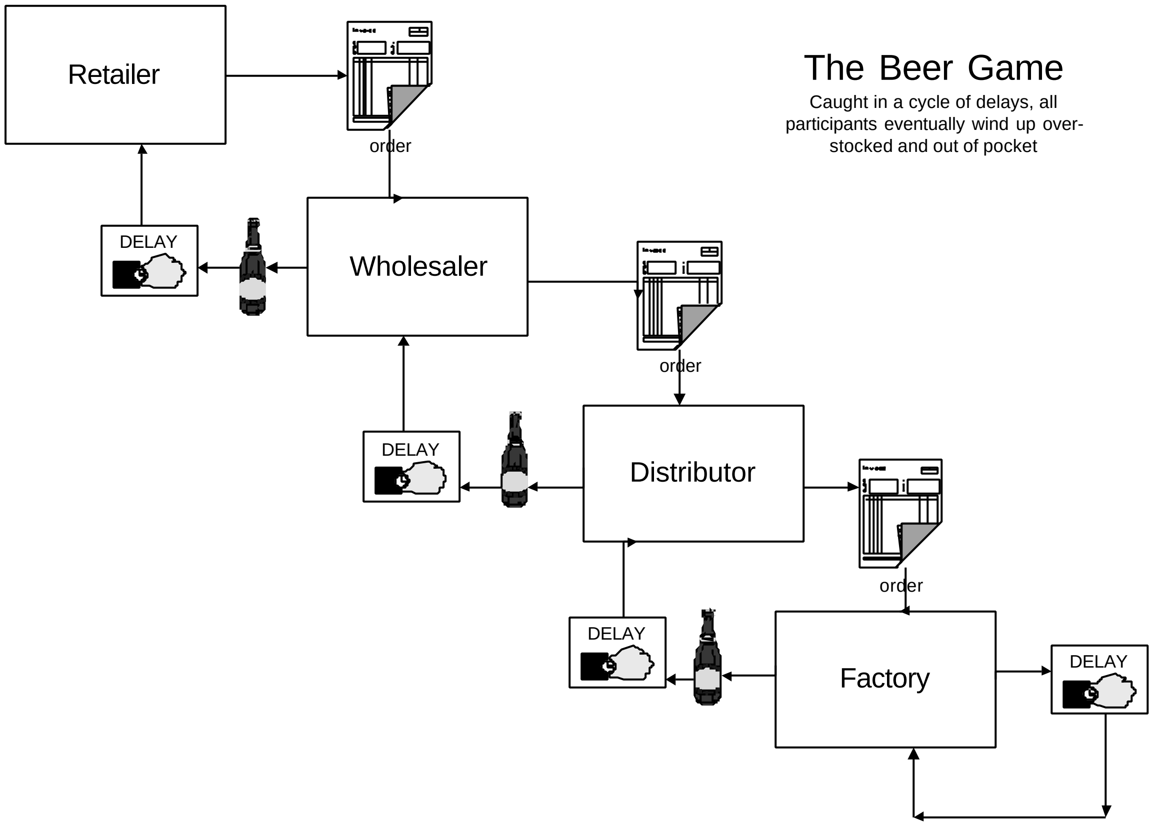

Figure 1-2 – The Beer Game

Positive feedback loops (which create) and negative feedback loops (which constrain) drive systems to a state of self-organisation. This self-organisation can occur spontaneously even in simple systems. Chaos theory shows us many examples where strange attractors emerge out of apparent chaos, like the rhythms of dripping taps, the patterns of snowflakes, or Jupiter's centuries-old storm forming its famous red spot (Figure 1-3),

> a self-organizing system, created and regulated by the same non-linear twists that create the unpredictable turmoil around it.
>
> (Gleick 1988, p.55)

Figure 1-3 – Order from chaos – Jupiter's red spot

A good example of the importance of structure in determining the fate of its parts lies in the concept of an ecosystem. Here, a delicate and always shifting balance of predators, prey, consumers, producers and the environment in which they live (and often, as notably displayed in the case of rainforests for instance, create) determines the forms of all the organisms within it. No single factor can account for the forms which arise, but the overall structure results in distinctive flora, fauna and all the other myriad taxa of life within a given area.

As this thesis progresses, I will attempt to identify ways that we can make use of such structures to achieve positive educational benefits, but for now I will look at the ways that existing educational systems are constructed.

Individual learning as a complex adaptive system

Cafolla and Kauffman (1999) provide an elegant proof that the very process of learning is non-linear. They simplify the learning model by assuming that the state of new information received is related to the state of information already learnt, and that there is a certain (unspecified) amount of degradation that occurs in the information retained. The combination of these factors leads to a simple equation ($x+1=L\ x_i(1-x_i)$) which, when graphed, shows chaotic patterns of sensitivity to initial conditions. Thus, even without the massively large number of potential influences on learning, as a self-contained occurrence it may be seen as a complex adaptive system.

Piaget has exerted a strong influence on educational thinking for many years as one of the main debunkers of the behaviourist paradigm of education which still exerts its unholy influence on the processes of formal education. It is interesting that his structuralist perspective coincides somewhat with the ideas of systems thinking. Piaget writes:

> As a first approximation, we may say that a structure is a system of transformations. Inasmuch as it is a system and not a mere collection of elements and their properties, these transformations involve laws: the structure is preserved or enriched by the interplay of its transformation laws, which never yield results external to the system nor employ elements that are external to it. In short, the notion of structure is comprised of three key ideas: the idea of wholeness, the idea of transformation, and the idea of self-regulation
>
> (Piaget 1970)

Hence, the underpinnings of Piaget's ideas are firmly rooted in the notion of learning being a complex and dynamic system with feedback at its heart. Piaget's form of structuralism has much in common with the ideas of Goodwin (1994) and other complexity theorists who identify the emergence of form as a separate (if complementary) issue to that of evolution. For Piaget, structure is an emergent property which feeds on itself and its environment to maintain its stability through assimilation, adapting and changing into a new structure by a process of accommodation. In other words, a disturbance to this system will result in the transformation of old structures into new structures. It is this process that leads to learning. If we are to consider this in relationship to the structure of teaching, we can see that in order to achieve learning we must provide resources which provide knowledge which can be assimilated and, as with Vygotsky (1978) and his zones of proximal development, aimed at just over the edge of that boundary between the continuation of the old structures and the creation of the new.

Group processes

Piaget's and Vygotsky's models of learning stress continuous interaction with the world and other people. Gordon Pask's conversation theory places this process of communication at the heart of learning. He is also an early proponent of viewing educational systems in their entirety, not divorcing teaching or learning or administration or any other factor from his systems approach. Pask's view of the systemic nature of education considers the individual as a subsystem within a system. Rocha explains Pask's view of the internal system of learning and its relationship to the educational environment thus:

> [Pask] developed an extensive theory of conversation that proposed the abandonment of the concept of learning as a one to one mapping of real world to mental categories, for a dynamic,

> internal, self-organizing process of coming to know, constrained by developmental interaction with an environment and fellow 'knowers.'
>
> (Rocha 2000)

For Pask, learning is truly situated and contextual, an iterative process of construction which incorporates previous knowing with new knowledge in a process of interaction between the learner and other learners, the learner and the teacher and the learner and the learning resource.

In "Teaching Strategies: a systems approach," Pask & Lewis (1972) analyse four teaching approaches in terms of systems thinking, looking at the extent to which they make sense as an educational system. In systems terms, these can be divided into those which exhibit central control and those where control arises from interactions of individuals within the system. The characteristics of systems which are controlled from the centre have a basis in the reductive theories of the behaviourists, whereas those which are more distributed borrow more from systems theory and lead inexorably to a variation on constructivism.

Control from the centre

Pask & Lewis describe two centrally controlled systems for teaching, the *behaviour shaping* and the *reinforcement menu* curricula. In these approaches to teaching, "the learner does things and the things he does are influenced by things done to him" (Pask & Lewis 1972). This method of design deals in measurable behavioural outcomes. It is much the same method that Houghton (1989) equates with "an engineering approach of scientific management to the problems of education," not in keeping with the complex, situated nature of education. A central problem with this approach is that the behaviourist cannot say with certainty that the learner has a concept, merely that the learner acts as though he or she has a concept. The measurement of this behaviour is problematic and does not necessarily lend itself to generalisation. To take a trivial example, the ability to divide 100 by 10 does not necessarily transfer to the ability to divide 101 by 11. Motivation is provided by rewarding the learner (rather like Pavlov's dogs) to reinforce learning goals. In this model the teacher is a simple regulator, taking a list of desired facts or behaviours and rewarding the student (usually with good grades or words of encouragement) for displaying those behaviours. This model, though common, does not often result in deep knowing:

> It is not unusual to find learners, with perfect terminal behaviours, who cannot answer a single generalization question. Nor is it very unusual to find that a learner who has successfully completed a programmed text fails dismally if interrogated the next day.
>
> (Pask & Lewis 1972)

This view is echoed by Houghton, who claims that further consequences are that such an approach "renders the unplanned unlikely....eliminates innovation ...is crashingly dull, uninspiring, and unmemorable except for its boredom." (Houghton 1989). A similar point is made by Saba (1999a), adding the important insight that, even where such an approach is successful, it is inappropriate to student needs:

> this model of instruction might have been useful for uniform industrial processes, when standardization of tools and manufactured products was a challenge and a desirable goal to achieve. In the foreseeable future, the challenge for most front-line workers will be how to deal with unpredictable situations with novel solutions.

The application of reductive scientific methods leads to an industrial paradigm of measurable inputs and outputs. Ramsden writes:

> the significance of independence and choice emerges repeatedly in research on student ratings and perceptions of favourable academic environments, at higher and upper secondary education levels. Yet most prevailing systems of learning in higher education adopt mass-production standards; they handle each individual student in the same way, even though we know for certain that they operate in different ways.
>
> (Ramsden 1992, p. 101)

A proud flower of this reductionist paradigm is the external examination, which Whitehead rightly defames as 'fatal to education' (Whitehead 1929). The use of summative assessment lies at the heart of much of formal education and creates some of its greatest weaknesses. By attempting to stamp a particular body of uniform knowledge onto the learner and to set rigid criteria by which the learner can be measured, the system makes motivation extrinsic to the task and so disassociates it from the desire to learn and explore. Holt puts it well:

> when we reward children for doing what they like to do – find out about the world- they soon learn to do it *only for rewards*. Since the rewards of school only go to a few winners, most children, the losers, stop asking questions. This is one of the flaws in the idea of positive reinforcement; it only works as long as we keep it up.
>
> (Holt 1977)

The examination becomes the end, not the process of learning. The point was equally well made over one hundred years ago by Dewey, who wrote:

> I believe that much of present education fails because it neglects this fundamental principle of the school as a form of community life. It conceives the school as a place where certain information is to be given, where certain lessons are to be learned, or where certain habits are to be formed. The value of these is conceived as lying largely in the remote future; the child must do these things for the sake of something else he is to do; they are mere preparation. As a

> result they do not become a part of the life experience of the child and so are not truly educative.
>
> (Dewey 1897)

It is disappointing that this point still needs to be made. Like Pask, Dewey's view of the educational process is one primarily rooted in communication and, like Pask, Dewey sees the process as extending beyond the barriers of a simple fact-laden curriculum.

Decentralised control

As alternatives to centralised control, Pask & Lewis (Pask & Lewis 1972) describe the processes of *guided discovery* and *conversational learning* curricula, both part of a constructivist ethos aimed at the construction of an elaborate network of concepts, or structured knowledge. The learner is seen as a problem solver, with a rich level of interaction with colleagues and teachers towards that goal. In the *guided discovery* curriculum the teacher exerts more control, allowing the learners to construct their own learning but within the constraints and towards the end intended by the teacher. In the *conversational learning* curriculum (Pask's paradigm of good practice) the learner may potentially take many paths to reach the goals, allowing knowledge to be structured differently from one learner to the next. The conversational process encourages reflection on the learning process, with the teacher acting only as a kind of help desk, albeit an active one concerned with asking questions and pointing out possible directions. As a result, the learner is able to form links between concepts, ideas and practice and is able thus to accommodate knowledge into existing schemes more effectively and to apply knowledge in a variety of contexts. A complex set of feedback loops results in a system where both teacher and learner adapt. In both guided discovery and conversational learning curricula the interactions between learners, subject matter and teacher are significantly more complex than behaviour shaping and reinforcement menu curricula, with a rich variety of interactions (questions, answers, guidance, confirmations) at different points in the iterative learning process. There is a positive feedback loop between teacher and student in this conversational process, so that the teacher has the power to adapt teaching to the learner's needs. Pask & Lewis write "the nature of a curriculum scheme clearly hinges on the sort of system a learner is supposed to be" (Pask & Lewis 1972). Through this style of curriculum the learner comes back into the picture as an independent and actively influential entity. Instead of a closed feedback loop of incentive and reward acting upon the student (the teacher merely acting as a kind of thermostatic control) the main agents in the system interact with and affect each other in a manner resembling an op-amp circuit, driven by positive feedback. As well as negative feedback loops there are also positive loops, which lead to creativity, motivation and emergent knowledge.

In common with many educational theorists Pask is abstracting idealised behaviours from what are always (as his own analysis clearly shows) more complex systems than can be characterised this way. In real life, it is very hard to find a pure behavioural model of teaching with no feedback between teacher and student, even if this is only in the form of a yawn from the back of a lecture theatre, As Wiener tells us:

> there is no task harder for a lecturer than to speak to a dead-pan audience. The purpose of applause in the theater- and it is essential- is to establish in the performer's mind some modicum of two-way communication.
>
> (Wiener 1950)

There are also feedback loops extrinsic to the subsystem of teacher and learner, such as quality assessment bodies, the work of educational theorists and the interactions between students outside the classroom, which make even the dullest of behaviourist curricula part of a more complex set of feedback loops. It is equally rare to find a pure model of constructivist teaching which involves no centrally generated prescription of form and content, nor extrinsic incentive or reward. However, Pask's way of seeing the world in terms of interacting agents gives a strong indication of what features a complex learning system needs. In the guided discovery and conversational learning curricula, there is a move away from central control towards a feedback model where all participants in the system are active agents. As a theoretical basis for a self-organising learning environment, therefore, the conversational framework that Pask proposes seems powerful and persuasive.

Education through communication

There is a close correspondence between Pask's concepts of guided-discovery and conversational models, and the *structured* and *emergent* collaborative events discussed by Nachmias et al (2000). Structured collaborative tasks are "well planned didactic solutions that follow the conceptual guidelines proposed by collaborative learning researchers and practitioners." They are therefore subject to central control. Emergent collaboration, on the other hand, is "the process by which group configurations and transactional patterns evolve among participants during the course of learning in a specific course.” Tasks are defined in terms of goals and constraints, with the implementation of solutions involving potential shifts in perspective, fluid sub-groupings and varying roles. This perspective is helpful in providing a structure in which to create innovative and student-led environments where (for instance) students collaborate to create a knowledge base of educational resources according to agreed criteria, or suggest uses of discussion groups based on their experience. This sort of direct iterative feedback mechanism should be seen as a vital part of the process of constructing self-organising learning environments. Nachmias et al report on student moderated discussion groups, noting that student moderators “invested a lot of time and creativity to create a contextual framework to the discussion, and used email to encourage their classmates to participate.” The fact that students were able to effectively perform this role is encouraging. It suggests that one of the more ‘human’ of teacher roles might well be performed by untrained learners. However, the report notes that teachers were still available to guide and support the moderation groups’ work, which implies that the roles were not emergent but structured from above.

Pace Marshall draws lessons from the paradigm shift from Newtonian science to systems thinking and complexity. She observes that we have constructed our educational systems “by drawing lines and boxes around everything and by separating things into discrete observable, measurable categories. We created dichotomies, divisions, departments, boundaries, and closed systems.” (Pace Marshall 1995). This has resulted in what she describes as “learning-disabled institutions” which have suppressed creativity and challenge “the personal, active, volitional, and social dimensions of learning that are so essential to authentic meaning.” Her rally call is that:

> As complex learning systems, schools are far more organic and dynamic than linear. We, therefore, must design them to function less like clocks, and more like kaleidoscopes.
>
> (Pace Marshall 1995)

This organic view of education resonates with a number of the themes that characterise learning theories of the twentieth century, where learner-centredness implies that control is derived from the periphery, not the centre. The industrial model which still sits at the heart of all major educational institutions (observable in schools, with their national curricula, planned lessons, timetables and specific targets, or universities, which still insist on the bizarre practice of expecting hundreds of students to learn the same thing in the same place at the same time with little or no active involvement or communication) exists in the face of overwhelming evidence that learning occurs despite rather than because of its structure. There is a case to be made for suggesting that what actually forms learning is what happens at the periphery of such structures, the (sometimes informal) surrounding activities of communication and active experimentation and construction. If we are to take the constructivist ethos to heart, it is only in actively making connections and building knowledge on an edifice of previous knowledge that deep learning takes place.

Robert S. Houghton's PhD thesis (1989) argues that an emergent paradigm (based on principles that allow for self-organisation, sensitivity to initial conditions etc) better characterises the educational process than the industrial model:

> Perhaps the principle conclusion derived from chaos theory and the larger emergent paradigm for education is simple and basic: interact. To interact is a fundamental directive for education as a system and the individual as a learner.
>
> (Houghton 1989)

In keeping with our systems view of education, for Houghton interactions form the structure of learning. Any system is defined by the interactions of its elements: these interactions make it a system in the first place, as opposed to a group of static elements. Dewey believed that this was the main thing that needs to be said about education (Dewey 1916,pp. 8-9). Hunter and Benson similarly argue that "all learning and all knowledge is the result of different realities co-existing in the world, at one time and that we create these realities through social interactions " (Hunter & Benson 1997). However, the degree of interaction and the types of interaction are still very much up for discussion.

David Pines, a researcher at the Santa Fe Institute, provides some fascinating insights into the ways in which universities exhibit the characteristics of complex systems at many levels. He identifies that "universities may be viewed as a collection of interacting communities each of which functions as a complex adaptive system" (Pines 1998). It is instructive to note the many levels of self-organisation that Pines identifies. An educational system is not just a single entity but a collection of systems which themselves are collections of systems. He cites interactions between disciplines within faculties and between faculty and students as clear examples, although notes that the latter interaction has an unfortunate tendency to be one-way.

Different interactions result in different emergent structures, with varying degrees of order and chaos. The IFETS (International Forum of Educational Technology & Society) electronic discussion from 1-10 November 1999 was centred around the importance of Moore's transactional distance theory. In the pre-discussion paper Lowe pointed out that there was a danger that too great a move to dialogue might lead to the original learning objectives being compromised (Lowe 2000). Communication is a necessary but not sufficient condition for achieving learning through teaching. Although it can provide positive feedback loops which generate new knowledge and connections, it can run out of control or dissipate. Saba noted that "instructional systems design must include negative feedback loops to optimize interaction at a distance and keep learning sessions productive" (in Lowe 2000). It is not enough for communication to take place, but at least some of that communication has to be affective. Systems are constituted in the relationships between their elements. If elements do not affect each other, we are not looking at a system but at a set of discrete parts.

Like Pask, Diana Laurillard views the educational process as one involving an interacting loop of conversations between its key participants. These interactions constitute a set of feedback loops which implicitly leads to a self-organising system, involving teachers, students and learning resources. It is informative to distinguish this from such theoretical systems as the Kolb cycle, which characterises the learning process as a cycle of abstraction, reflection, experimentation and concrete experience. This cycle says nothing about the control mechanisms which operate to produce it. Laurillard's conversational framework is explicit about the effects that each actor in the system has on each other:

> given ... the integrative nature of the learning process, the inseparability of knowledge and action, and of process and outcome, there is no logical ordering of parts of the process, as each part is constituted in its relation to the other parts
>
> (Laurillard 1993, p.50)

It is impossible to consider isolated features of an educational system- changing one part changes them all. This is a feature which may affect virtually all systems, educational or otherwise. By its nature, any system is constituted from the relationships of its parts. Changing parts or their relationships alters the behaviour of their nearest neighbours. If those neighbours are altered then they in turn affect their neighbours and so on throughout the system. Sometimes these effects will be small, sometimes they will just flip the behaviour of the system to another similar state, sometimes they will change the system utterly.

Distancelearning systems

Many authors have recognised that it is not possible to consider a part of an educational system outside the context of subsystems which it contains and other systems with which it interacts. Of these, Michael Moore plays a key role in the growing perception of education as a total system. In particular he is interested in distance learning, especially significant due to the focus on network-based learning that informs this thesis. Distance learning is different. Moore is keen to emphasise that distance learning represents a departure from the 'craft' approach to teaching:

> A distance education system should be thought of as a network of knowledge sources, processors, managers, communication media, and learners
>
> (Moore 1993)

The interdependency of each part of the system means that making a change to one part means making a change to the whole:

> For example, the exact nature of the design, the communications technology used for delivery, and the interaction depend on the sources of knowledge, the student needs, and the learning environment in the particular course. Selection of a particular delivery technology or combination of technologies should be determined by the content to be taught, who is to be taught and where the learning will take place. Design of the instructional media depends on the content, the delivery technology, the kind of interaction desired, and the learning environment. All these will be influenced by policy and management. Furthermore, changes in one component of a distance education system have immediate effects on all of the other components
>
> (Moore & Kearsley 1996, p. 13)

A complex set of interactions is typical of a system with emergent properties. Moore's notion of transactional distance is similarly systems-oriented. The essence of this theory is that there is a linear relationship between the amount of communication (dialogue) involved in a distance learning course and the amount of structure and associated detail. The influence of this theory has been quite widely felt, presenting one of the first coherent theories of distance education as distinct from co-located education.

Saba has refined Moore's theory of transactional distance and tested it experimentally, using a subtle form of discourse analysis to demonstrate the interactions of structure and communication (Saba 1999a). Saba is one of the few authors to make the link between this explicitly system-oriented view of distance learning and self-organisation:

> The concept of self-organization is central to the understanding of distance education, which is a radically different kind of educational organization than the place- and time-bound systems currently at work in most educational institutions.
>
> (Saba 1999b)

Distance learning, by changing the nature of the surrounding systems, changes the nature of the processes of education. It Saba is right, it may hold the key to the central theme of this thesis and so is an area worthy of examination in greater depth. Distance learning encourages a re-examination of the roles and functions that enable learning to occur.

Independent learners and teams of teachers

Traditional co-located courses and methods of training have tended to extract learners from their everyday contexts, fill them with knowledge and send them back out again, like cars being serviced. Although this model is still prevalent, it has been joined by a more flexible approach to teaching and training which dates back to the middle of the nineteenth century, when Isaac Pitman created the earliest correspondence-based distance learning courses. A key feature of these courses has always been that learners could to a large extent choose when and where their learning takes place (Moore & Kearsley 1996, p.21). Institutions provide structured course materials and asynchronous feedback, allowing the students to exercise a great deal of control over the learning process. Pitman's system and those it inspired came to be known as 'independent study', a clear indication of the importance of the learners' control over their own learning. This close association of distance learning and independent study pervades the whole area, although the association is not essential. For example, a learner given tuition by 'phone or video-conference could hardly be said to be independent and indeed there is a sense in which a distance learning course, through its structure and design, provides very little more independence than a traditionally taught course. This is where Moore's theory of transactional distance comes in: it is not the physical distance which is significant but the amount of communication. Where there is more structure there will be less communication (or dialogue) and vice versa.

The realm of distance education has had a profound impact on the ways in which we approach the business of learning. Although some functions of the traditional educational system are farmed out to others (procurement and management of buildings, books, food etc) and establishment of curricula and their associated examinations are often centralised, the delivery and much of the form of the education experience is largely left up to the individual teacher. Distance education provides an opportunity to rethink that model, with the necessity of deconstructing it to identify what is required to achieve effective learning. As a result, it has long been a fruitful area of innovation and careful analysis of roles, needs and requirements.

The notion of independent learning firmly took hold in the 1960s and 70s with the establishment of a variety of open universities, the most famous of which was and is the Open University (OU). The OU owes a significant debt to Charles Wedemeyer, director of the Articulated Instructional Media project whose early experiments and theoretical underpinnings played a large role in its inception and form. However, the OU has been hugely influential in its approach to the educational process. Moore & Kearsley suggest that what distinguished it was a “total systems approach to distance education” (Moore & Kearsley 1996, p.27). The OU is fairly big by most standards applied to educational institutions, with around 130,000 enrolling students per annum. Dedicated from its inception to distance education with no campus-based courses, Walter Perry and the other creators of the OU were able to examine the teaching process closely and abstract its functions, creating production teams more akin to theatrical troops or film production teams than the traditional hierarchies of individuals and self-contained groups characteristic of campus-based universities. By dividing up tasks the OU is able to maximise quality and to control costs due to its size and consequent economies of scale. Moore & Kearsley provide a useful way of understanding the benefits and potential barriers to such a process, dividing the commonplace ‘author/editor’ model (where an editor or editorial team takes the work of a content expert and turns it into a course) from the ‘course team’ model, pioneered by the OU:

> Each course is designed by a team which might consist of as many as 20 or more people, each of whom is a specialist. At the design stage of the ISD [Instructional System Design] process a group of academics, content specialists in a subject area, writes outlines of what should be taught in their particular specialities and engages in extensive discussions regarding the objectives and content of each unit and module of the course. These outlines and objectives are debated not only by the academics and others but by the whole team, including producers, editors and external consultants. Eventually, after three separate drafts have been presented, a study guide on that subject emerges.

> As well as taking responsibility for the study guide in their speciality areas, the academics assemble books of readings, make audio- and videotapes, and design tests and supplemental materials, all with the assistance and guidance of specialists in these tasks. These technical experts include editors, graphics designers, radio and television producers, instructional designers, and librarians, even a specialist photolibrarian. A senior academic chairs the team and an administrator is responsible for ensuring that each task in the development schedule (which often lasts one or two years) is completed on time.
>
> (Moore & Kearsley 1996, p.105)

By splitting up the roles which are more often shoe-horned into an individual or arbitrarily spread across a group of individuals, it is possible to explicitly recognise a range of roles within the educational system. The roles divided up amongst the team at the OU are often played by a single individual in a more traditional environment, or a small group of simply differentiated or undifferentiated individual roles within a team. This may have positive as well as negative effects. On the positive side such a method will typically produce results more quickly than (potentially) the two years it can take to produce a complete OU course. On the other hand, it demands a great many roles of an individual, who may not possess the qualities required in equal measure for each role.

Excessivecomplexity

A complete and detailed description of the interactions and agents of an educational system would be improbably complex, though some have tried. Perhaps the most extreme incarnation of the view of education in a wider systems context is the application of SIGGS (Set theory, Information theory, Graph Theory and General Systems theory) to education. SIGGS was developed by Elizabeth Steiner Maccia and George S. Maccia in the mid nineteen-sixties. Frick (2000) has taken this model and applied it to education. It provides a complex and comprehensive systems-based model of education which aims, through the interplay of two hundred and one interrelated hypotheses, to describe the complex interactions of T*eacher*, S*tudent*, C*ontext* and C*ontent*, seen as the elements that make up an educational system. These terms are carefully defined:

? a Teacher is one who guides the learning of another.

? a Student is a learner who is guided by a teacher (as opposed to an independent learner).

- Context is the setting in which the guidance of learning happens, which might include everything from classrooms to books to cafeterias to blackboards.

- Content is that which is to be learnt.

The relationships between these four primitive types form a complete description of the educational system. This lies in relation to the educational *negasystem*, everything which is outside the system. There is a complex interplay between the negasystem and the educational system, with *toput* (everything which may feed the educational system, including people, money, books and even guns, gangs and drugs) being what feeds it and *fromput* being everything which results, from qualified students to the detritus of the student canteen and used syringes. The comprehensiveness of this model makes it difficult to make any sense of it at all. Although a vast number of relationships, causes and effects are specified including the effect of change in any one part on the rest of the system, the theory loses the woods for the trees. Ashby's Law of Pre-Requisite Variety states, "For a system of complexity n, we need to engineer a system of variety n+1 to manage it" (Owen 1999). Owen observes that "when systems theory is applied to education there is a tendency to attenuate complexity so as to have a manageable variety." This is not only unsurprising but also essential. SIGGS attempts to model the system in all its complexity, and thus obscures its own purpose. This is a pity, because there are many useful specific insights to be gained from such a model. Based on its two hundred and one hypotheses it would in principle be possible create a simulation of an educational system and see the results of any perturbations, from policy changes to an individual student having a cold (making the large assumption that every part of the theory is correct and every aspect has been correctly modelled). However, the complexity of the model, its specialised vocabulary and its over-numerous hypotheses make it too fine-grained to be of general use and, being a complex and chaotic system, the strong dependence on small variations in initial conditions (popularly known as the *butterfly effect*) would make any simulation based on its tenets virtually meaningless. What is significant for this thesis is that it illustrates in great detail the potential interdependence of a vast number of variables both within and outside an educational system which can affect the form of its self-organisation. SIGGS signally fails because it will never be able to model the entire system, any more than meteorologists will ever be able to predict the exact state of the weather, and for much the same reasons.

Another reason that an educational system is far harder to model than the weather is due to the wide variety of timescales which affect an educational system. The effects of a single sentence observed at the age of two can have profound consequences in later life. For example, if that sentence is “I wish you had never been born,” then it could potentially lead to a self-reinforcing complex system of self-disregard that could have massive implications for an individual and notable effects therefore on the dynamics of a classroom. Perhaps such events lie outside the system, but within the system, similar utterances by teachers (for example suggesting a lack of intelligence in a student as, for instance, through a poor grade in assessment) could have repercussions which echo not only through an individual’s educational career but to a lesser extent through those of all who are even slightly connected to that individual. Forrester puts it succinctly,

> In systems composed of many interacting feedback loops and long time delays, causes of an observed symptom may come from an entirely different part of the system and lie far back in time.
>
> (Forrester 1994)

Like many a system, small initial causes can have large effects whereas some sorts of change can change little at all. This is a feature of complex adaptive systems, observable at a number of levels.

An example: small events have big effects

A teacher is explaining a basic mathematical concept to a class of children. It is a sunny day and the teacher has left the windows open to keep the class cool. This leads to a wasp entering the room and stinging a child. The child is taken to receive medical care by the teacher, who leaves the class to work alone. As it happens, this is a borderline class and, very narrowly, its failure in maths leads to a poor maths result in the school league tables. More money and resources are pumped into improving the quality of maths. The teacher tries harder than usual and devotes more time to this. The result is to detract from the quality of teaching in art and music. Meanwhile, the poor results have led to a slower moving change as a few parents, wary of a school of potentially low quality, send their children elsewhere. This results in slightly lower standards. The process repeats, and the school gradually becomes a repository for the children no one else will have. Standards drop, while efforts to improve specific areas work to the detriment of others. Standards and morale continue to fall. Good staff begin to leave, poor staff stay. Standards continue to fall. By the time the stung child leaves school, it is a shadow of its former self.

Another example: big events have small effects

The director of a university observes that a particular department has a poor research record and it is getting worse. The answer is deemed to be to split up the department and move members to other, more successful departments, in the hope that this will lead to a more exciting research climate. As it happens, the main reason for the poor research record is actually the large number of teaching hours these staff members are responsible for. The members of the department experience a huge drop in morale. Not only have they been told that they are poor researchers but the team which helped to bolster them through hard times is now split up. Research suffers.

In both scenarios, the key features are that the systems are large and complex. Very small initial conditions (a stinging wasp) can have huge consequences, whereas very large changes (departmental shuffling) may do nothing at all or, at least, nothing in the context which we are looking at.

In both scenarios, it is not clear where the system should be taken to begin or end. For instance, was the initial cause in scenario A the wasp, the window being left open, the sunny day or some other? In B, problems arose because the administrators failed to take a sufficiently fine-grained view of the entire system. By focussing on short term goals, the longer term benefits were not attained.

Emergence of the unwanted

It should be clear by now that educational systems may be viewed as complex adaptive systems (Visser 1999). We have already seen how they are composed of interlocking systems at a wide range of scales which are linked through positive and negative feedback loops. They are open systems, constantly fed with information and interactions. Like all complex adaptive systems, educational systems exhibit emergent properties, not always predictable by looking at the individual parts of the system. In the scenarios which we just looked at, our God's-eye view made the sequence of events possess a curious inevitability, but a close-up observation of any single point in the proceedings would not have told us this. Perhaps we could say in each case that those who might have made the changes could, with more information, have foreseen and prevented the bad consequences from occurring.

Perhaps it is just a question of adequate controls and feedback loops. A more likely explanation is that individuals made perfectly rational decisions in relation to the circumstances in which they found themselves. A teacher faced with an injured child took the child to receive treatment. Parents seeing a school with a poor record did not want their children to suffer so kept their children away. Like birds in a flock, they applied simple rules, which led to overall system behaviours which might have been recognised but would probably not have been avoided, unless all actors in the system were systems theorists.

Onar Åm (1995) analyses the survival of the school system in systemic terms, noting that despite its manifest failings, turning children with an “intense, almost obsessive urge to learn” into those who are apathetic and reluctant to learn, it continues to thrive. Åm sees this as a self-reinforcing process. By systematically repressing curiosity and enforcing learning through the erosion of values, beliefs and attitudes, students become apathetic towards learning, preferring entertainment before academia. Thus, students, teachers and parents come to see learning as something that must be enforced to overcome apathy, and so the cycle repeats. Åm claims “the survival strategy of the enforcement system is to produce massive empirical evidence of student apathy which suggests that enforced learning is a necessity.” It does not have to be this way and Åm’s indictment ignores the many positive efforts made to encourage the joy of learning. However, his analysis of the school system is almost evolutionary, in a Darwinian sense. There is a cycle of reproduction, with variation and competition implied (Åm’s own paper is an example of this) and the evidence he gives of a self-reinforcing feedback loop which works to the detriment of the learners shows that evolution does not of itself result in a system best fitted to learning. It survives because it is good at surviving, not because it assists learning.

A similar point is made by Forrester:

> In complex systems, there are many interconnecting feedback loops. A new policy, which is intended to solve a problem, causes reactions in other parts of the system that counteract the new policy. In education, that reaction may come from administrators, from school boards, from parents who do not want new experimental ideas tried on their children, or from budget pressures.
>
> (Forrester 1994)

For those of us in academia, adult education generally equates to a significant part of what goes on in universities and colleges. These embody a group of systems that have evolved slowly (very slowly) over hundreds of years from early, largely monastic, beginnings. Centuries (even decades) ago, the university represented an efficient way of bringing learners into contact with like minded learners, with access to scarce resources and the learned who could in principle help them to make some sense of it all. There was simply no other way of bringing the knowledge and understanding of academics together. Similarly, it made sense to put expensive books and manuscripts in one place, where they could be accessible to those seeking knowledge. As Hutchinson (1995) puts it:

> …it was the purely physical restrictions on access to scholarly authority (whether medieval monk or Oxford professor) and to the written and printed word that necessitated the creation of bricks-and-mortar centres of learning.

Alternatively, it might have simply been greed, like the Sophists of whom Plato coined the phrase “a paid hunter of the young” who are credited with the first recorded instance of mass instruction (Bogus 1995). These pragmatically generated institutions thus formed the basis of an ecology which has developed in ways that might have been predictable but which had little to do with the overarching requirement, to produce research and learning. The system sustains itself in many ways, not all of them healthy. Illich (1971) likens the self-perpetuating cycle which encourages teachers into their chosen profession to the myth of Oedipus:

> Oedipus the Teacher, who "makes" his mother in order to engender children with her. The man addicted to being taught seeks his security in compulsive teaching. The woman who experiences her knowledge as the result of a process wants to reproduce it in others.

The following quasi-historical explanation of the growth of our present-day systems is almost certainly not completely true and is at best only a small part of the story. However, if there is the slightest glimmer of truth in it then the point is made that educational systems’ behaviour might lead to undesirable consequences. Consider this then as more of a parable than a stab at historical truth.

University systems developed around the simple requirement to provide geographically collocated learning. Degrees were invented as a means of rubber-stamping the learner as the learned and this required assessment. Since the institution had brought large numbers of students together, such assessments needed to be cost effective and easily and consistently applied. Thus evolved a range of examinations and essays which soon became more than a rubber stamp but instead were the central focus around which education revolved, forming a focus which often limited learning by providing second-order goals which actively detracted from the wishes and predilections of the learners themselves. Individual and small-group tuition, though recognised as desirable, became economically unviable, so the Lecture was born. Increasingly, through a set of interacting processes from within and without the institutions the educational system that we know and love today was born. Combined with other factors like the mechanistic world-view that inspired (and was inspired by) the Industrial Revolution, some behavioural psychology and improvements in mass-production techniques for books and journals, a system developed whose crowning glory was a method of teaching which, Ramsden observes, “is actually detrimental to the quality of student learning” (Ramsden 1992).

Traditional universities present many barriers to the development of more flexible learning. For instance, Robinson et al (1998) observe obstacles to open and online learning, many of which are a direct result of the institutional context in which they are attempted: the lack of focus on examinations, slow response times by tutors who are offered little or no reward or incentive to develop online delivery of learning, the ‘not invented here’ syndrome, performance measurement by short term measures of cost against exam results, faculty resistance and fear, lack of support staff (money is invested elsewhere), lack of skills or the incentive to learn them and many other issues. Most universities are not geared around the delivery of courses via alternative means to those which have sustained them for hundreds of years and it is not a practical proposition to attempt to make changes in one part of the system without accommodating that change throughout the system. This is particularly notable in the development of network-based education, with its natural emphasis on self-directed learning. It may be that the whole notion of education as a commodity to be peddled by educational institutions is wrong. Even the most liberal of policies, where (for instance) commitment to lifelong learning and self-directed study are encouraged, are liable to attack on the grounds that the notion of educational delivery implies a system which constrains and disempowers learners by taking away responsibility for what is to be learnt from the learner. Universities thus stand in the way of change, whether intentionally or not. As Illich observes:

> Creative, exploratory learning requires peers currently puzzled about the same terms or problems. Large universities make the futile attempt to match them by multiplying their courses, and they generally fail since they are bound to curriculum, course structure, and bureaucratic administration
>
> (Illich 1971, p. 19)

Unfortunately, this is the education system which not only aspires to lead us to a better life as fulfilled individuals, but which also supplies us with neurosurgeons and air traffic controllers. We need a better way. In later chapters I will be suggesting an alternative approach more closely addressing Illich's critique, a system which is designed to help like-minded peers to help each other to learn. It will be based on self-organising principles, to which we will turn in the next chapter.

Conclusions to this chapter

This chapter has been an investigation into the nature of education as a complex adaptive system. There are many processes and sub-processes involved in an educational system, not all of them related to the process of education itself. Systems shape the behaviours of their constituent parts. This can be detrimental to those parts, as is often seen in traditional learning institutions.

Distance learning frees educators from the kind of restrictions that are enforced by the systems which develop within a traditional co-located environment. Distance learning environments therefore provide a potential opportunity to re-examine, deconstruct and rebuild educational systems differently. This opens the door for the use of network-based learning environments, which will form much of the subject-matter of this thesis.

The next chapter looks at the nature of self-organising systems in an attempt to identify those features which most affect their overall behaviour, which will make it possible to give informed consideration to different ways of constructing educational systems. This will feed directly into later chapters where I will discuss ways of building self-organising learning environments

Chapter 2 : How systems change

About this chapter

This chapter will explore a range of related theories which explain aspects of how self-organising systems and their component parts develop. Its purpose is to seek ways that systems are constructed so that some control may be exerted over their behaviour, which will be important in later chapters when I describe the development of systems which are to a greater or lesser extent self-organising learning environments.

In looking at the construction of self-organising systems I recognise that emergent properties of systems may not (by definition) be *designed*. However, a watery environment does not usually encourage the development of creatures which breathe air nor do desert plains usually have inhabitants well adapted to climbing trees. In the same way, the eventual goal will be to seek to identify the characteristics of an educating environment, where forms of learning are the likely outcome.

The chapter begins with a look at evolution and the requirements for a system to evolve, giving examples of how it may be applicable to educational systems. In particular, I observe that the kinds of systems considered in the previous chapter owe a lot to evolutionary mechanisms, and attempt to identify ways in which such systems gain their form. With a goal of identifying how structure might develop from the bottom up, I then investigate some of the issues raised by complexity theorists, especially with regard to the ways that order develops, as Kauffman (1995) puts it, "for free." The chapter continues with a discussion of the importance of scale and choice of perspective, leading to important conclusions about an appropriate point of view when dissecting the dynamics of educational systems. This will lead to the conclusion that educational systems are driven by many things including learners, their environment and what is to be learnt. However, the most significant part of what shapes educational systems will be seen to be the mediator or manager of learning, a role most commonly embodied in the teacher.

Evolution

One of the most powerful mechanisms driving the emergence of order in educational systems is that of evolution, whereby the combination of chance, reproduction, variation and competition results inevitably in a speciated ecosystem. Åm's example in the previous chapter shows, the kinds of species which develop may not be desirable. My purpose will therefore be to identify the features of an evolutionary system which most drive its development, with the intention of later mirroring those features in a system which evolves to suit its users.

A word of caution

The word *evolution* suffers from many abuses, partly as a result of the redefinition of the word following Darwin (despite the fact that he avoided it himself):

> Evolution is to allegory as statues are to birds. It is a convenient platform upon which to deposit badly digested ideas.
>
> (Jones 1999)

When I use the term *evolution* I will be applying the strong Darwinian sense of the word. I will not be using it as a synonym for change nor for a process of steady improvement.

The principle of evolution can be expressed very simply: if there is reproduction with variation together with competition between the items which reproduce, then those items which are fittest will survive whilst those which are not will die out. The consequences of the theory are immense and profound, playing a large (if not the largest) role in generating the massively diverse order found in nature as well as some of the patterns of history, the spread of ideas and (I suggest) the nature of educational systems.

Darwin Lamarck and others

When Darwin published the Origin of Species in 1859 our understanding of the world changed forever. Although the theory was controversial it was quickly and widely accepted despite resistance from those involved in formal religion. Its shock value was caused less by the fact that it dispensed with several predominant notions of the role of a god, but more that it applied a new way of thinking to observed phenomena in the world. Darwinism was the application of a very small number of simple rules to produce a complex system. The power and profundity of this way of seeing the world continues to influence new scientific theory to this day.

Before Darwin proposed the theory which came to be known as *evolution* it had already been observed that adaptation towards a state of fitness occurs, not least by Charles Darwin's grandfather, Erasmus Darwin. Dyson (1997) claims that "Erasmus Darwin identified the essential principles of natural selection, descent with modification, and other pillars of evolutionary thought." However, the elegance and sheer weight of evidence with which Charles Darwin made his argument make him the one that we now consider the father of evolutionary theory and it is to him that I shall be referring when I speak of 'Darwin'.

Lamarck

Darwin himself gives credit to Lamarck, an early evolutionary protagonist. Lamarck's evolutionary theory relied on the inheritance of acquired characteristics, citing for instance the growth of muscles in blacksmiths, suggesting that the effects of increased muscle bulk are passed down to the offspring. For Lamarck, improvements to the phenotype (the physical manifestation of form) caused by the behaviour or reactions to the environment of a given organism would be transmitted to its descendants.

True Lamarckianism has been widely held in disrepute as a mechanism to drive biological evolution, but the Baldwin Effect has been touted as a close approximation of this. Here, learnt behaviours affect the ability of the organism to survive, thus favouring those organisms who can learn a specified behaviour. Those organisms which can more easily learn such behaviours (e.g. through instinct) are better adapted (Baldwin 1896). The idea is updated by Wilson in the form of what he defines as 'Epigenetic Rules', whereby culture affects selection which in turn reinforces the rules. For example, poisonous snakes are probably best avoided. This could be a lesson passed on culturally, those who heed it surviving more effectively than those who do not. This in turn eventually leads to a population with a 'genetic' fear of snakes (Wilson 1998, pp. 139-140). This idea straddles the divide between the concept of evolution and that of self-organisation. A similar notion is found in Bateson's notion of somatic adaptation and C.H. Waddington's 'genetic assimilation' (Kelly 1994, p459).

Although Lamarckianism is at best only a small contributor to the evolution of present populations, Dyson (following on from the work of his father, Freeman Dyson) raises the interesting possibility that replication and reproduction might not have evolved together, and that reproduction without replication might indeed have led to Lamarckian, not Darwinian evolution. If some form of replication occurred without the intercession of genes (for example, we can still see this in the growth of crystals) then changes to the parent could be transmitted to the offspring. It is only when there is an independent underlying pattern of the sort found in genes that the phenotype and genotype lose their strong interdependence. Dyson writes, “We should think twice before dismissing Lamarck because Lamarckian evolution may have taken our cells the first – and most significant- step toward where we stand today.” (Dyson 1997). A similar claim is made by Margulis (1998, p. 36) whose concepts of symbiotic evolution allow for the “infections” of a parent (notably beneficial infections which led to mitochondria and chloroplasts, for instance) to be passed on to the offspring, thus improving the offspring’s’ chances of survival. It is also notable that the concept of memetics developed by Dawkins owes more to Lamarckian mechanisms than Darwinian. A meme is a contagious idea, one which competes in a Darwinian sense with other memes for space in our minds, but there is no underlying pattern or genotype (Dawkins 1986, p. 194). If a meme evolves, the pattern is entirely visible- the medium is the message. It will become significant to this investigation that the mechanisms of evolution may actually in some ways work better when Lamarckian mechanisms (as opposed to chance mutations) operate, as demonstrated in computer simulation by Ackley & Littman (Kelly 1994, p. 393). As Kelly puts it, “Lamarckian evolution produces smarter answers because it is a smarter type of search.” Unfortunately, pure Lamarckian evolution is just too complex to operate in the evolution of species. There is no logical reason why there should not be a flow of information from the somatic to the genetic. However, there is no way that the body could identify from the complex system which generates form through genes which genes are responsible for a particular effect. The process of creation of form is far simpler in terms of information flow than the unravelling of how that form can be created, like attempting to extrapolate from the current shape of a cloud the positions of its individual molecules at some moment in the past.

Lamarckian evolution remains significant as it appears to be at least one of the mechanisms underlying, for example, cultural and technological evolution (Price 1997). If any mechanism of evolution underlies systems of education, it is likely to be Lamarckian in nature. Changes and improvements to the phenotype will be passed on through reproduction. For example, good practice in teaching may be mimicked and successful organisational structures will be duplicated. In a sense, perhaps the structures might be seen as genotypical whilst their expression might be the individual instances. However, these structures develop through usage and it is those developments which are passed down. Given that many interconnected systems of this nature will develop, competition will arise. There are, for example, finite ways any individual can teach, and any mode which is selected will have succeeded at the expense of other plausible alternatives. It should be noted that this does not imply that the factors affecting selection of a given mode will correspond to improved learning outcomes. Lamarckian evolution plays a prominent role in CoFIND, the system which I shall be discussing in later chapters.

Characteristics of evolving systems

Of all the systems views and theories of complexity, evolution has among the longest of pedigrees and perhaps the greatest elegance. If we are to use an evolutionary model of educational systems it is therefore important to understand the effects it brings and how it brings them.

Survival of the fittest

The 'fittest' in any given system is that which survives in that system. This does not in any sense mean survival of the 'best' using terms which relate to anything outside that system. It does mean that death is the greatest teacher, and weaker or simply unluckier parts of the system fail to survive. Their weakness is only in relation to the system. Transferring this idea to an educational system, summative assessments such as unseen examinations, especially those where detailed feedback is withheld from students, are seldom an effective way to teach students anything. They thrive within the system because (amongst other things) of their perceived strengths as an easy means of assessment from a teacher perspective, a reliable means of ensuring that what is assessed is the students' own work, a powerful extrinsic motivating force (in the absence of intrinsic motivation) and a cost-effective use of centralised resources. These strengths are only in relation to the entire system of which they are a part, not as aids to learning. In a system which does not encourage intrinsic motivation, that certifies learning for other purposes (e.g. helping to get jobs) and that attempts to squeeze as much use as possible out of scarce resources, it is easy to see how summative assessments thrive. None of these features is essential to education, but given their presence in the environment, assessments have a high fitness value. Summative assessments are themselves part of that system and so affect every other part, leading to positive feedback loops which perpetuate the system, much as the trees in a rainforest contribute to the weather patterns that cause the rain which sustains them. This positive feedback is at least one of the factors preventing the successful adoption of systems more conducive to learning.

An example of the weakness of summative assessment

As a means of consolidating learning, a colleague of mine recently attempted to enrich her students' learning experience. As part of a module in systems analysis and design, students were encouraged to implement their designs in the form of a computer program. When the students discovered that this program would not be assessed, for many, work stopped on it. Some students were particularly aggrieved and felt the whole episode to be a waste of time. This transference process which makes secondary goals more important than learning itself is a feature of the summative assessment process. There were two main solutions available to my colleague, either to drop the programming or to make it a part of the assessed work. If it were dropped, then the process of assessment would have defeated a useful learning experience. If it were assessed, then the nature of the exercise would be mutated by the need to meet the assessment criteria, thus preventing the process of discovery and exploration which made the exercise valuable in the first place and defeating a useful learning experience. There are probably other viable solutions such as assessing the process of discovery rather than the products, but whichever method is chosen, the fact of assessment will always shape the process. In this case, like many others in higher education, the issue is complicated further by the nature of the surrounding system. Were my colleague to assess students' programs, the module would be seen to significantly overlap with other modules which some of the students would be enrolled on, which would either be treated as a 'bad thing' (and thus dropped) or provide an unfair advantage to students with modules which overlap. This negative notion of 'fairness' is another by-product of the assessment process, driving the mechanistic model of tuition from the bottom up (students demand it) and the top down (teachers and examining bodies believe it to be right). Again, the summative assessment survives, not because it helps learning, but because it and the system which surrounds it have co-evolved to the point at which their mutual interdependencies stamp out new variations. This is also true of most large natural ecologies. A mutation has to be more successful than its competition within a given system. If it is not, however slight the disadvantage, it will not thrive. Even with a slight advantage, the chances of novel forms succeeding are slender. More often than not, the previously established system will correct any changes within it. This is a problem which concerned Darwin and delighted his critics. What is required is a mechanism to allow speciation to not only occur, but to result in change to the system itself. This leads us to another of the cornerstones of Darwinian thought.

Speciation

The process of evolution leads to species, a fact of such great interest to Darwin that he named his seminal book on the subject “The Origin of Species.” This is of great interest to us if we are to cope with the diversity found in any given group of learners, as well as between different subject matter.

For Darwin, speciation occurs as a natural consequence of descent with modification and competition, hence leading to the survival of the fittest. Contingent occurrences such as continental drift and the isolation of land-masses caused by rising water levels lead to different environments and consequently different adaptations, hence leading to distinct species arising.

Much of what governs the adaptation of biological species occurs as a side-effect of other adaptations, which in their original context are of little consequence but as the environment changes or a species becomes isolated turn out to have the greatest significance. Gould’s analysis of punctuated equilibrium suggests that the pure form of natural selection (strict Darwinism) might be lacking in some respects (Gould 1995; Gould 1978). What sums up a lot of Gould’s argument is the notion of *spandrels*. Spandrels are non-adaptive side-consequences and architectural by-products of what happens when you put a dome on top of a number of arches, They are the spaces that are left (Figure 2-1).

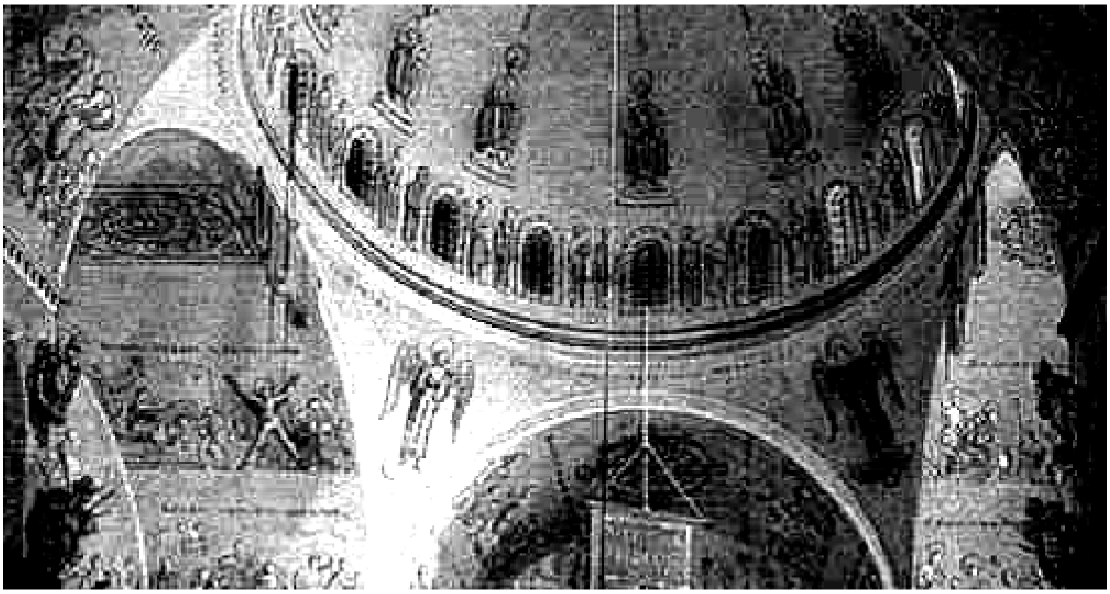

Figure 2-1 – detail of Canaletto's Interior of San Marco showing spandrels

These spaces are not irrelevant:

> Under the spandrel principle, you can have a structure that is fit, that works well, that is apt, but was not built by natural selection for its current utility. It may not have been built by natural selection at all. The spandrels are architectural by-products. They were not built by natural selection, but they are used in a wonderful way — to house the evangelists. But you can't say they were adapted to house evangelists; they weren't.
>
> (Gould & Lewontin 1979)

A similar principle may be seen in the evolution of radiator grills on cars. What started as a purely functional requirement to keep the engine cool soon developed into one of the clearest distinguishing features of a car, with huge marketing benefits to the extent that today, where the functional requirement is no longer there and may even adversely affect the aerodynamic efficiency of a car, many manufacturers (e.g. Jaguar, Alfa Romeo, Rolls Royce) still include a radiator grill as a means of creating a visible individual stamp on their otherwise indistinguishable offerings. There are two particularly interesting things about Gould's analysis in the context of this investigation. Firstly, it emphasises the role of chance in evolving systems. Systems do not necessarily evolve to an optimal condition, but are driven by contingency. The second is that it paves the way for a richer view of self-organisation than that which may be achieved by natural selection alone. Structures can occur for any number of reasons that may or may not join the evolutionary struggle. To distinguish these cases from Darwinian adaptations (which he notes that Darwinians use to represent both the process and the product, as though there were no difference) he has coined the term *exaptions*. Exaptions provide some of the key to flexibility in evolution. Without them it is unlikely that the chasms left when one species or group of species vacates could be filled. If organisms were perfectly adapted to a co-evolved environment then a major disturbance to that environment such as the extinction of the dinosaurs would have an equal effect on other species, such as mammals. Exaptions might therefore be seen as latent capabilities, able to become adaptations if the conditions arise. These chance chunks of surplus capacity allow entities to take advantage of niches as and when they arise, as in the adaptation of the swim bladder into the lungs of the lung fish, or the adoption of used car tyres as sandal soles in Africa (Gabriel 1996). This is a great advantage of evolution over design, especially design for ‘efficiency.’ As Stewart Brand has observed for buildings, *Low Road* freedom or *High Road* flexibility give a much more powerful and efficient way to survive than *No Road* design (Brand 1997, p.52). Low Road, architecturally dull houses which people live in may easily grow and adapt over time, gaining extensions, new facades, being gutted then rebuilt from within, thus surviving changes in use in an almost organic way. Larger, more monumental High Road buildings adapt differently, but still undergo change over many years. On the other hand, elegantly designed buildings which perfectly fit their purpose are in a much more precarious position once that purpose has gone. These are what Brand calls “Magazine Architecture,” or No Road designs, perhaps beautiful but immutable and ultimately disposable.

A spandrel in the works

Returning to our imagined pseudo-history of the university system, it was perhaps a spandrel caused by the centralisation of resources (itself a necessary adaptation caused by the limited availability of those resources) which paved the way for the lecture as an educational tool. The constraints caused by the small number of libraries and the relatively small number of academic experts in a given field made the university an effective form for bringing about learning. In competition with individual tutors the benefits were clear, not only from an economic perspective but also in terms of quality. As many students were drawn together in a small space, despite its inefficiency from a pedagogic perspective, the lecture was perhaps an exaption, a cost-effective adjunct to the business of teaching and learning, a chance to share ideas with other faculty and students. As student numbers increased, universities and colleges able to process larger numbers thrived at the expense of those that did not. The lecture form proved well suited to this need and was sufficiently effective to achieve the aim of imparting knowledge and (occasionally) enthusiasm and understanding. A spandrel became an adaptation. Natural selection did the rest.

Despite the potential hazards of spandrels, they are a primary motive force in the evolution of educational systems. They are not the only ones, however. In a large population spread over a wide area there is little chance that spandrels could drive the massive diversity which we see around us in biological systems. Small changes would occur eventually perhaps, but larger variations would almost inevitably be swamped in the gene pool. The answer lies in the concept of *parcellation*.

Parcellation drives evolution

Gould identifies a useful piece of information regarding evolving systems:

> New species arise in *very small* populations that become isolated from their parental group at the *periphery* of the ancestral range. Speciation in these small isolates is *very rapid* by evolutionary standards....
>
> Major evolutionary change may occur in these small, isolated populations. Favorable genetic variation can quickly spread through them. Moreover, natural selection tends to be intense in geographically marginal areas where the species barely maintains a foothold. In large central populations, on the other hand, favorable conditions spread very slowly, and most change is steadfastly resisted by the well-adapted population. Small changes occur to meet the requirements of slowly altering climates, but major genetic reorganizations almost always take place in small, peripherally isolated populations that form new species.
>
> (Gould 1978, p. 61)

Calvin makes a similar point about the need for parcellation to encourage evolution (Calvin 1997), and is expanded upon greatly by Jones (1999) and Darwin himself, who devotes the whole of Chapter 12 of the Origin of Species to analysing the geographical distribution of species in terms of the formation of niches caused by geological features (Darwin 1872). The logic is compelling and significant for this thesis. If Darwin, Mayr, Gould, Jones and Calvin are correct, then there is a useful lesson to be drawn for the construction of self-organising evolving learning environments. Scale is important. Without the formation of niches and clustering effects, there is little opportunity for speciation and hence for structure to form. This is taken up in an educational context by Price, who cites a large number of authorities as suggesting that “innovation and learning happens most easily in isolated populations.” (Price 1995).

Gould also observes that there is a need to maintain diversity and variability (Gould 1995, pp. 116-117, p 124). This in turn is influenced by the amount of space available- “the larger the island, the greater the number of species.” If we are to see maximum variability then, we are faced with a contradictory state of affairs, where we want to encourage evolution (hence need small and isolated populations) but also wish to encourage variation (hence need large populations and the large areas they require). This combination of scales is achieved over time by such events as the dropping of ocean levels or a collision of continents.

Parcellation in educational systems

In existing educational systems parcellation is not difficult to find, although it is often swamped by its larger scale surroundings. For instance, it is rare to find a teacher who does not at some point experiment with different ways of doing things, although such innovations are generally not sufficiently parcellated to have a significant effect on the larger system. Schools, universities and colleges might be seen as larger islands, but their connectivity through channels such as quality assurance mechanisms, conferences and publications, not to mention league tables, word-of-mouth and so on will generally act as negative feedback mechanisms, keeping them within an overall system. However, it is occasionally possible for a university to provide a sufficiently isolated environment for new forms to develop which may then have larger scale effects on the rest of the higher education community. An example might be the model of the OU. In providing for a segment of the community which (for whatever reason) is denied entry to traditional universities, its systems have developed somewhat separately and without a need for much competition with existing institutions. There is so little overlap between the students of the OU and those of more traditional universities that other institutions have provided resources such as teaching staff and building space to assist its development. In times of change these have become a useful isthmus for the spread of its ideas. The OU’s demonstrable success within its parcellated environment is now feeding back ideas into the mainstream university community as well as being reproduced elsewhere such as IGNOU (The Indira Gandhi National Open University in India). It does this at least partly because the Internet has changed the overall ecosystem in which the University exists to more closely resemble that in which the OU has always existed. Parcellated environments delimited largely by country borders are suddenly facing competition from other systems in other countries. British universities are suddenly coming into direct competition with the large online universities of the United States, not to mention a wide range of private institutions from all around the world. The environment has undergone a change where understanding ways of learning at a distance is becoming a necessity in the struggle for survival, and traditional universities are looking for successful models to emulate. The OU, growing and changing within its relatively isolated environment for many years, with ideas, methods and procedures being developed and tested within its own small evolutionary setting, provides a highly developed model, the principles of which are seeping into the worlds of long-established institutions. This is an example of reproduction of successful systems, which will eventually change the nature of the older systems with which they will compete as the landscape that they inhabit changes.

The lesson for the design of systems which will evolve therefore seems to be to encourage parcellation but to allow the occasional collision of ecosystems or the spreading of their areas. This lesson should be heeded by those who wish to centralise the control of education. Without islands of separate development, those variations which may prove useful when the environment changes (as it inevitably will) will not be in place and there is a potential for a catastrophic breakdown, as seen in the demise of the dinosaurs. In the context of this investigation, the parcellation principle will prove useful when designing educational systems which can self-organise.

Order for free

The degree of parcellation most likely to enable dynamic change may be predictable. Stuart Kauffman has made many contributions to the discipline of plectics. A notable insight is that of “order for free”, order that spontaneously develops at what he describes (after Chris Langton) as the “edge of chaos” (Kauffman 1995). This turns out to be a surprisingly common and predictable phenomenon. Randomly connected networks can achieve self-organised metastasis, although this only happens with certain densities of connection. The best number of connections turns out to average a little more than two for each node of the network.

The edge of chaos

Kauffman has coined the term *antichaos* to represent the limited range of possibilities for complex dynamic systems to fall towards attractors. It appears that any sufficiently connected dynamic system has a tendency to fall into basins of attraction, a sort of metastasis balanced at the edge of chaos. Kauffman warily states that this is as yet merely a strongly supported belief, but it is hugely persuasive. Kauffman gives examples showing the patterns his model predicts in everything from the Cambric explosion to the development of forms of bicycles (Kauffman 1995, p. 202). The key to this metastasis is the notion of *Red Queen* and *Stalinist* regimes of interconnection. Systems which are too rigid (Stalinist) do not adapt to high fitness levels, systems which are too chaotic (the Red Queen effect first noted by Lee Van Valen, always running to stay in the same place) change too much for any stable fitness level to develop. If the landscape is changing constantly then there is no time to adapt. There is an intuitive charm to this. Of all the random ways that connections might happen, it is inevitable that those which survive will reach what Per Bak refers to as a state of "self-organised criticality" (Horgan 1995). Maintaining a state of order in an educational system without central control will mean providing dynamically connected systems and subsystems, capable of developing so that there is some, but not unlimited interconnectivity.

Stigmergy

The word *stigmergy* comes from two Greek words, *stigma* (outstanding sign), and *ergon* (work). It describes instances where agents make behavioural adjustments based on feedback from an emerging pattern caused by that behaviour, mediated through the environment. The word was coined by Grassé in 1959 to refer to systems such as those employed by termites when building mounds. Termites start by dropping mud randomly in a given area, held together with secretions containing pheromones. The presence of a mud heap encourages other termites to drop their lumps of mud nearby, with larger mounds being more attractive than smaller ones (Heylighen 1999). This tendency also means that adjacent mounds tend to grow towards each other, thus forming arch structures. This is a classic example of a CAS in action, resulting in the emergence of interlocking arches of great intricacy. The concept of stigmergy is simple to grasp and can play a large role in self-organised behaviour. It also explains the formation of ant-trails. If an ant finds food, it leaves a trail of pheromones on its way back to the nest. When other ants encounter this trail, they are inclined to follow it. If they too find food, they too leave a trail of pheromones back to the nest. As more ants find food, so the scent grows stronger. Eventually the food runs out, no more ants leave a pheromone trail, and the scent dissipates. The ant trail vanishes (Figure 2-2) .

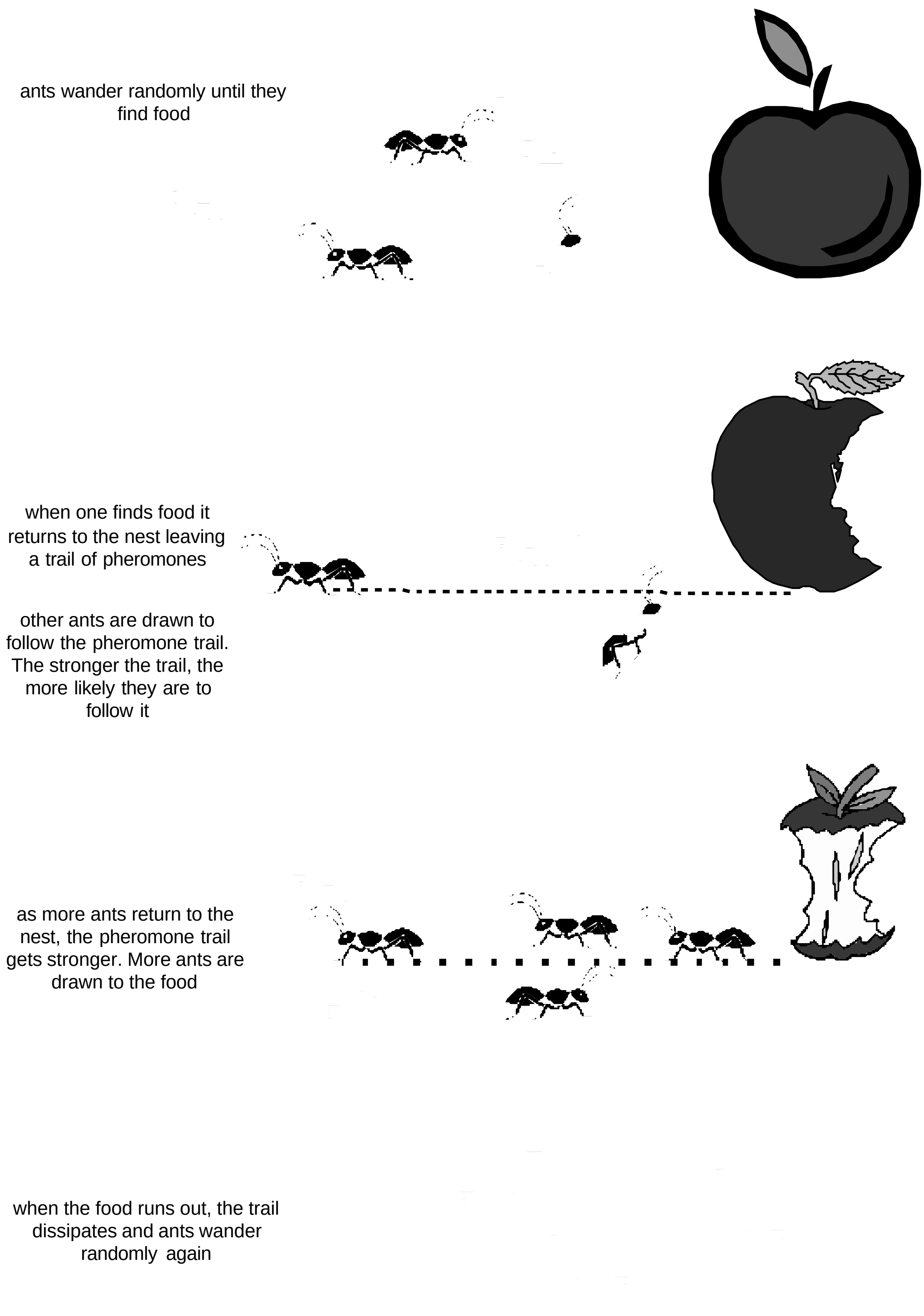

Figure 2-2 – the formation of ant trails through stigmergy

Stigmergy plays a significant role in human dealings. This can be seen in everything from the spontaneous formation of footpaths in a forest, to recessions caused by fluctuations in stock prices, to the large crowds that gather round smaller crowds in a street (an effect well-utilised by professional buskers), to the spread of a piece of software such as a word-processor as a result of the need for compatibility with documents sent by other users of that software. A number of simple individual acts which affect the environment in turn affect other people directly or indirectly. Co-ordinated behaviour arises as a result of indirect communication processes, artefactual communication, if you prefer. In the context of existing educational systems, stigmergic behaviour is rife. For example, the presence of a display of awards in a school hall may encourage those who seek such awards to join the school, as may the publication of exam results. A journal known for publishing high quality papers is more likely to attract high quality submissions. Citations in citation indices lead to more citations. Stigmergy is a powerful concept which is used extensively to drive the CoFIND systems discussed in Chapters six and seven.

Forests and trees

The dynamics of an ecosystem depend most upon its slower moving parts. This is not to suggest that such an explanation will tell the whole story. For example, zebra and lions move in a constant dance of co-evolution, the evolutionary changes in one determining the chances of survival of the other and its consequent evolution. As predators get faster, prey become more agile or better camouflaged. However, both lions and zebra develop in a context of an environment in which running is an advantage. They would not have developed in the ways they have developed were they living in dense jungle. They would certainly not have developed that way had they lived in the sea, or the Arctic Tundra, or the peaks of rocky mountains. The slower moving parts of the system (of which the geographical location is often among the slowest) dictate the changes of the faster moving parts.

A sense of scale

The slowest moving parts of any system really depend upon what kind of scale you are looking at. Brand (1997) talks of a hierarchy of ever faster moving parts from roads and natural features to the structural and exterior walls of houses, to the interior structures through to the decorations on those walls and the fixtures and fittings, the evolution of the faster parts determined by the strictures of the slow. Darwin explains much of evolution in terms of the generally slow moving continents that drift and separate and reform as a relentless slow structure determining the changes in their faster changing inhabitants. At any scale within a given hierarchy there will be dependencies which feed up and down the hierarchy, with the fast often (eventually) affecting the slow but with the slow dominating the nature of change. For a microbe, the gut of a fly is a structural feature, a defining control on its possible forms of existence. For a redwood tree, the make-up of the land itself and the weather systems arising from the movements of the sun and moon play a more important structural role. For the plants that grow around the redwood and the creatures that feed on them, the redwood dominates the landscape, literally and figuratively.

Stewart Brand and hierarchies of layers

Stewart Brand's "How Buildings Learn" (Brand 1997) contains ideas with a much wider application than the world of architecture in which it is situated, inasmuch as they reflect on the ways in which adaptation can occur. Central to the book is his definition of a hierarchy of layers which help to provide a framework for understanding change within a building. These are

? Site (where the building is situated)

? Structure (foundation and load bearing elements)

? Skin (exterior surfaces)

? Services (communications, wiring, pipes etc)

? Space Plan (walls, floors and ceilings) and

? Stuff (furniture etc)

Brand quotes Robert V. O'Neill's *'A Hierarchical Concept of Ecosystems'* as having the insight that "the dynamics of the system will be dominated by the slow components, with the rapid components simply following along" (Brand 1997, p.17). In the context of buildings, this seems clear. Streets and geographical features change more slowly than house sites, which change more slowly than house 'skins' which change more slowly than their interiors and so on. The slower changing parts limit the range of forms that may be exhibited by the faster changing parts. Similarly, trees in forests determine the shape of the ecosystem more than the flowers and humming birds. There are hierarchies of systems and subsystems, with the scope of change for the smaller being dominated by the larger. The point is related to the importance of constraints (Ashby 1957, pp 131-134). In hierarchical systems, slower moving parts act as larger constraints than faster moving parts, thus playing a more formidable role in shaping the systems of which they are a part. A similar observation is made by Bateson, who writes:

> The principle involved here is general and by no means trivial. It obtains in all homeostatic systems in which a given effect can be brought about by means of a homeostatic circuit, which circuit can, in turn, be modified in its characteristics by some higher system of control. In all such systems (ranging from the house thermostat to systems of government and administration) it is important that the higher system of control *lag behind* the even sequences in the peripheral homeostatic circuit.
>
> In evolution two control systems are present: the homeostases of the body which deal with tolerable internal stress, and the action of natural selection upon the (genetically) nonviable members of the population. From an engineering point of view, the problem is to *limit* communication from the lower, reversible somatic system to the higher irreversible genotypic system.
>
> (Bateson 1972, p.355)

A process of fast and slow systems can be seen in current systems of education. The large educational institutions shape the form of the kind of teaching and learning that occurs within. The form of teaching is shaped to an extent by the architecture of the buildings, the form of courses creates a context for the form of teaching within it. A module’s outline dictates individual lessons, lesson plans dictate pedagogic interactions. Indeed, it seems that wherever we see complex evolving systems the forces that shape them are linked in hierarchies. The views espoused by Brand and Bateson show only a single hierarchy, however, whereas an educational ecosystem involves multiple inheritance, and lattice rather than hierarchical structures. For example, the form of courses will be affected by government planning and laws regarding curricula, the input of professional bodies, administrative structures and economics, and many other features which do not follow a strict linear single-inheritance hierarchy but which may certainly be seen as the hierarchical foundation on which the faster moving course will be founded. Interaction between the higher parts of the hierarchy is not necessarily direct. Professional bodies may affect course design, the designers of which may sit on boards with university directors which might sit on government planning committees. As Bateson suggests, there has to remain an interplay between the faster and slower parts, that the fast might eventually influence the slow as the slow must influence the fast. Brand writes, “The slower processes of a building gradually integrate trends of rapid change within them." (Brand 1997). He cites Buzz Holling as indicating that quick processes influence slow processes at times of greatest change. What we define as the slow parts of the system are contextually situated and may be overthrown. For instance, beavers, locusts and humans share the ability to easily shape their environment in ways which can alter an entire ecosystem, despite being more volatile members of that system. The concept of hierarchies of speed of change is powerful. The dynamics of surrounding systems help to determine the dynamics of subsystems. They feed the subsystems with energy. In a majority of ecologies it is the slow that shape the system and we should be aware of this when attempting to build systems that self-organise to achieve particular ends. "The quick processes provide originality and challenge, the slow provide continuity and constraint," writes Brand (ibid.) leading to the maxim:

> An adaptive building has to allow slippage between the differently-paced systems of Site, Structure, Skin, Services, Space Plan and Stuff. Otherwise the slow systems block the flow of the quick ones, and the quick ones tear up the slow ones with their constant change. Embedding the systems together may look efficient at first, but over time it is the opposite, and destructive as well.

This maxim resonates to the roots of this thesis. The concern that inflexible and rigid design leads to ossification and stagnation while its opposite leads to very little of interest at all is the problem facing the builder of environments which can adapt and change to the needs of their users. It reflects the complexity theorists' concept of the edge of chaos, avoiding Kauffman's Stalinist regime and the Red Queen regime with equal emphasis, leading to that point just teetering on the edge, where change and dynamism happens. In designing a system to support the development of evolvable systems of learning and teaching, it will be important to identify the elements of the educational hierarchy which are significant

An educational hierarchy

Unlike the world of buildings and perhaps more in common with biological ecologies, educational hierarchies are not set in stone. It is common to see different areas of granularity in which different specific entities may occupy a variety of hierarchical levels. For instance, 'computing' may be seen in Figure 2-3 as a course, a module, a topic or even a lesson, depending on its context. As with most complex systems, multi-scale descriptions are needed to understand the overall system.

There are distinct differences in the hierarchical structure within institutions. However, Figure 2-3 represents a fairly typical structure which illustrates the transition from low rate of change to high.

As with Brand's hierarchy, dynamism and rate of change increases as we drop down the tree. This helps to provide a broad picture of the shaping influences of our existing educational systems. As with Brand's hierarchy, there is feedback both ways between low and high-stability systems. New resources can shape lesson plans, new lessons can affect modules and so on up the tree. However, the relationship is far looser than Brand's hierarchy. In a modular system we may see the same modules being a part of different courses, courses may be run by more than one institution and institutions may be part of more than one educational system (for instance, the HND and degree level streams run by many universities). In other words, there is a

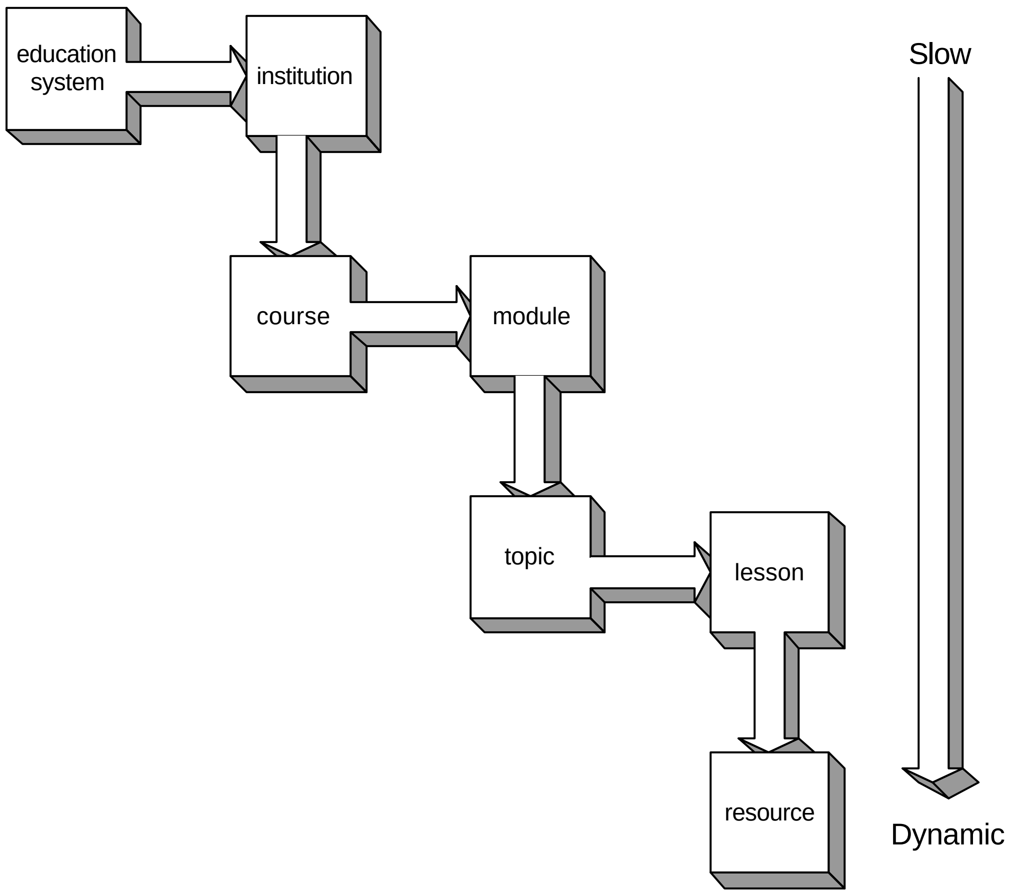

Figure 2-3 – an educational hierarchy

greater degree of multiple inheritance in typical educational systems than might be found in buildings or even biological ecologies. This more flexible hierarchy should in principle allow for greater dynamism within the system. This is the case, but it is not a flexibility which allows the system itself to change, but instead allows it to accommodate all manner of perturbations without disturbing its overall balance. Were there less communication between its constituent parts, it is not improbable that, within separate hierarchies, isolated islands of variegated practice would occur, providing opportunities for new practices to become established as their effects moved up and down the hierarchical trees. It is possible to see a link between our earlier investigation of speciation and our current view of hierarchies. From this perspective, each hierarchy represents a separate ecosystem. With too much connectivity between hierarchies and different hierarchical levels a single system develops rather than several isolated populations, thus preventing the formation of new species of educational system.

An example of the influence of the environment of self-organised systems in education

Goodwin writes of the Peckham experiment (Goodwin 1994), which revolved around 'The Centre' a club set up in 1926 to improve community health in disadvantaged areas. The experimenters set up a swimming bath, a gymnasium and a theatre, then grouped children by age and allocated times in the facilities for each group. The scheme failed, with few children actually turning up. Success only came when the facilities were made available to the children so that they could turn up individually when they wished. The children did not want to use the facilities in a context of teaching and learning like that found in schools, with instructors in control. To prevent drowning, a degree of order was returned by an ad hoc system of chits issued by staff who would verify that a child was a capable swimmer. A system evolved through a cycle of action and response between the staff and the children. This bottom up approach organised itself far more effectively than the designed system imposed from above, through a combination of enlightened staff and fortuitous building design. Goodwin quotes an account by Sean Creighton (a member of staff at the Centre):

> In my work I was freed from the tiresome restrictions of conventional teaching in schools….
>
> The design of the building was a revelation. That alone was, in my opinion, the master key to the liberation I have referred to. Although primarily designed to facilitate the doctors' observations, the open plan and windows through which the main activities could be viewed, gave members the unique opportunity to move about the building, to watch others enjoying themselves, and to be tempted to join in and have a go themselves.
>
> (Goodwin 1994)

Like Gould & Lewontin's spandrels, an incidental feature designed with another purpose in mind entirely had become one of the main features which allowed the perceived evolution to occur. If we are seeking to create online equivalents of self-organised learning, these lessons would be well-learnt. A system should be sufficiently adaptable to allow users' interactions to facilitate change in unstructured ways. The openness described by Creighton is a feature relying on critical mass. If there were no one in the pool, no one would be tempted to "join in and have a go themselves". A suitable environment for learning is a pre-requisite for adaptations which allow that learning to occur.

Kevin Kelly and chunky bottoms

Given that the environment sets the pace of any given system, the development of that system is not *controlled* by the slower moving parts, but instead is formed in relation to them. The notion of *control* has a special meaning in complex systems, as something which is generated by the interactions of its components. Kevin Kelly identifies the importance of developed hierarchies, chunks that coalesce from the bottom up: "no distributed system can survive for long without nested hierarchies of 'bottom-up' control" (Kelly 1994). He likens the problem to the difference between multiplication and division- it is far easier to put chunks together than to divide them. He sums it up:

> The Law is concise: Distributed control has to be grown from simple local control. C*omplexity must be grown from simple systems that already work.*

Margulis's widely accepted theory about the combination of prokaryotic and eukaryotic cells (in the form of mitochondria, Figure 2-4) is a classic example of this, demonstrating how a major factor for enabling evolution has to be the recombination of already working simpler forms (Margulis 1981; Margulis 1998).

George Dyson similarly cites his father's work on the possible ways that molecules capable of replication and entities capable of reproduction might have combined to form the origins of life (Dyson 1997, pp. 28-30). As previously observed, Dyson suggests that this would have resulted in evolution according to Lamarckian principles, a point reiterated by Margulis (Margulis 1998, p.11) who suggests that, like replication, symbiosis also results in Lamarckian evolution, with the inheritance of acquired characteristics.

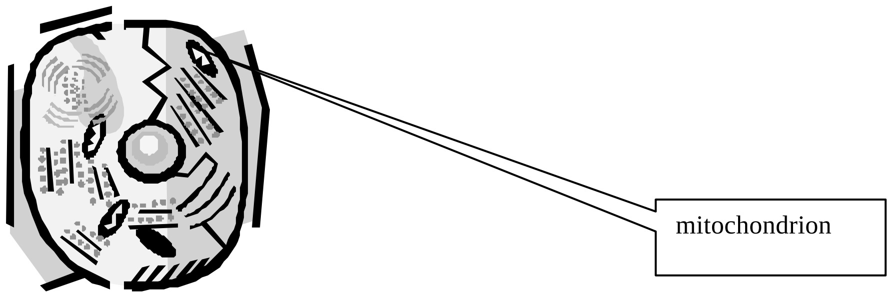

Figure 2-4 - eukaryotic cell with prokaryotic mitochondria

In such systems, we see examples of where the rules for change themselves change as a result of change. Examples of this can be seen in the numerous taxa which split over evolutionary time. Genetic change causes changes in the rules for reproduction. This resonates with the work of Daniel Dennett, whose concept of a *skyhook*, a deus ex machina which is introduced by neo-Darwinists to try to explain what they perceive evolution cannot achieve is resolutely denied any part in an evolving system. Instead, Dennett introduces the concept of the “crane,” “a subprocess or special feature of a design process that can be demonstrated to permit the local speeding up of the basic, slow process of natural selection, and that can be demonstrated to be itself the predictable (or retrospectively explicable) product of the basic process“ (Dennett 1995). Without such processes, chance alone would have been unlikely to create the complexity which we see around us. Replication was a good idea, so was reproduction. If Dyson (1997) was correct, together they provide the mechanism for evolution, each one acting as a crane to lift the other into a new state.

Growth by chunking

Complex systems grow out of small, working systems which in turn work together to form larger systems. Kauffman has shown this in his NK networks. Kauffman created a simple fitness landscape composed of squares, each of which affects and is affected by its neighbours according to a randomly set fitness weighting. Running the system in an attempt to reach a global optimum (defined arbitrarily) is problematic, given that even for a smallish grid of 120 x 120 squares the range of possible configurations is $2^{14,400}$ and there would be insufficient time in the universe to sort out such a problem. However, when the squares are chunked together into patches, each patch having an effect on its neighbour, the smaller patches can evolve to a local optimum which then can affect the global optimum of the system. From what is effectively one large undifferentiated patch to lots of smaller interacting patches, the system is able to develop (Kauffman 1995). There is a similarity in this to the idea that parcellation will speed up evolution. By generating an abstract system, Kauffman is able to show that such an occurrence is largely independent of mechanism- all it takes is parts in a certain relationship with each other. This is in total opposition to the dominant structure which we have observed in most existing educational systems. If we are seeking self-organisation then we need to throw off our preconceptions of how educational systems are organised and instead to consider its constituent parts and their relationships with one another. By so doing, we will begin to lay the groundwork for establishing a new way of creating higher-order structures. To understand this, we therefore need to look at educational systems at a different scale than we have so far encountered.

Finding an appropriate sense of scale

> You certainly can't always look at things from someone else's point of view. For instance, from here that looks like a bucket of water...but from an ant's point of view it's a vast ocean, from an elephant's just a cool drink, and to a fish, of course, it's home. So you see, the way you see things depends a great deal on where you look at them from
>
> (Juster 1962)

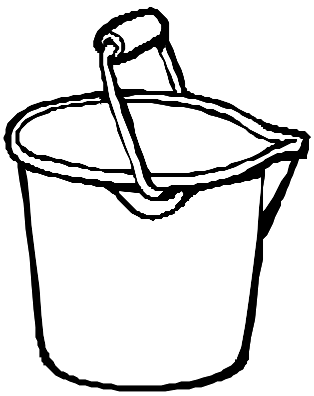

Figure 2-5 – points of view: a bucket of water, an ocean, a cool drink or home?

In examining a system, choice of scale is important, and depends upon which subsystem is of interest, from the global to the microscopic:

> For what is the *Heart*, but a *Spring*; and the *Nerves*, but so many *Strings*; and the *Joyntes* but so many *Wheeles*, giving motion to the whole Body.... *Art* goes yet further, imitating that Rationall and most excellent worke of Nature, *Man*. For by Art is created that great LEVIATHAN called a COMMON-WEALTH or STATE (in latine CIVITAS) which is but an Artificiall Man
>
> (Hobbes 1973, p.1)

The Leviathan described by Thomas Hobbes in his eponymous work is a self-organising system, a group intelligence, a whole which holds together by the complex interactions of its several parts (Dyson 1997). The world is full of such systems, from the formation of clouds to the dynamics of population growth to the spread of memes in a society (Dawkins 1986, p. 194). Hobbes's recognition of the hierarchy of systems of which an individual person is just a component or agent of a larger whole, or an agglomeration of smaller systems, presages an important theme in systems thinking across a wide variety of disciplines: the view of the system is dependent on the observer and that observer's perspective. Whether we choose to treat a forest as a single entity or just a particular conglomeration of organisms occupying a congruent space and time, whether we choose to look at the behaviour of a single bee or the whole hive, or the ecosystem of which it is a part is to an extent a result of the questions we are asking and the kinds of answers we are seeking. In each instance we are less interested in the matter of which the systems consist and are instead more concerned with the connections between its parts and the behaviours they exhibit. Our perspective depends upon our needs and interests. As Steve Jones points out,

> "Any zoology text claims that there are more kinds of insects than of anything else; but squash a fly and thousands of microbes unknown to science will be squeezed from its gut."
>
> (Jones 1999)

Swift put it charmingly:

> Hobbes clearly proves that every creature
> Lives in a state of war by nature.
> So naturalists observe, a flea
> Has smaller fleas that on him prey;
> And these have smaller still to bite 'em,
> And so proceed *ad infinitum*
>
> Swift: Poetry; a Rhapsody

Weinberg is more menacing:

> What is a system? As any poet knows, a system is a way of looking at the world. It is a point of view- natural for the poet but terrifying for the scientist!
>
> (Weinberg 1975)

If we are to guide the development of complex systems, then what is required is an appropriate perspective. As Holland says:

> To build a dynamic model we have to select a level of detail that is useful, and then we have to capture the laws of change at that level of detail
>
> (Holland 1998, p. 45)

We have already seen that most educational systems consist of a hierarchy which can be viewed from a number of different perspectives. As my goal will be to redefine those hierarchies by building from smaller chunks, I shall attempt to identify an appropriate scale to choose when considering how to construct a networked learning environment without too many prior conceptions about current educational systems.

Scale in educational systems

Emergent properties in educational systems occur at a range of scales, from the results of government and social upheavals to the effects of an individual student staying up too late the night before. Educational systems are exactly that, *systems*, interacting with other systems, comprised of subsystems, dependent on a myriad of small interactions and changes, some random, some planned, others the inevitable consequences of the nature of the system itself. Looi (2001) describes it thus:

> learning happens at a rich diversity of levels in the learning environment and can be seen from different perspectives. At the individual level, learning happens at the cognitive level. At the group level when the individual learns with peers, interactions take place at the species level as group, peer or social learning interactions. When different species or populations coexist, there is a thriving community. Different communities form a learning ecosystem in which there is interaction within and between each level giving ecosystems complex behaviour.

The aim of this research is to lay the foundations for the design of an educational system, so it is important to identify the minimal requirements for this to develop. Steiner (cited in Frick, 2000) abstracts these requirements as being *teachers*, *students*, *context* and *contents*. This abstraction is based on a model of education which is descriptive of existing systems rather than derived from any lower level theory. Even so, it provides us with a useful framework on which to base a new system despite the fact that there are other possible means of categorisation. Illich (1971) for example suggests *things, models, peers,* and *elders* as forming the prerequisites of an educational system, though he is not entirely sure about elders. I shall be considering *models* and *things* as subvarieties of resource (available directly or indirectly from the environment) and *peers* and *elders* as subvarieties of teachers. The following then are the four distinctive features of an educational system (Figure 2-6):

1. Learners

   It is *a priori* the case that any educational system contains learners. In an education system, this is most commonly what is referred to by Steiner (Frick 2000) as a 'student,' which is to say one who intends to learn through the guidance of another.

2. Resources

   By *resources* I mean anything external to the student from which learning may occur- source books, text books, films, Web sites, buildings, clouds, machine tools and so on. This equates loosely to what Steiner calls 'content,' which is to say 'that which is to be learned.' Steiner's definition is a little narrow and does not sufficiently allow for those resources which help provide structure and context to what is learned, the spandrels of an educational system, nor does it allow for the possibility that the content may be unknown by any participant at the outset- the process which led to this PhD thesis, for example.

3. Context

   When we remove the contingent features of an educational system, such as its buildings or the infrastructure that supports and is entailed by them, we are freed to adjust what is meant by *context.* Context is what is changed by a networked environment. A major advantage of the use of networked computers to provide support for learning is that many of the traditional slow moving structures which dictate the form of education can be questioned and even by-passed. For example, electronic libraries can sometimes (and increasingly often do) compete successfully with their stone forebears, the need for lectures in large lecture theatres can be forgotten, sometimes time-tabling can be ignored and communication can be controlled by the student, not by the availability of a lecturer. Networked computers thus provide us with an opportunity (albeit seldom fulfilled) to throw away much of the unnecessary chaff of traditional university teaching, leaving us free to concentrate on the central function of education, to facilitate or manage learning. Although the context is by no means entirely dictated by the direct learning environment, it is an aspect of the system over which we, as designers of networked educational systems, may have some control.

4. Managers of learning

   A teacher is not involved in all educational experiences, but we will see in the next chapter that there are strong grounds for finding a space for some mediator of the educational experience. A teacher may be the learner or other learners, or perhaps even a sufficiently intelligent computer program. For the most part, when I use the word *teacher* I will be considering the teacher as a manager of learning, in whatever form that takes. This usage follows Steiner who simply defines a teacher as “one who guides the learning of another,” be this a traditional teacher, a friend or a colleague, peer or elder.

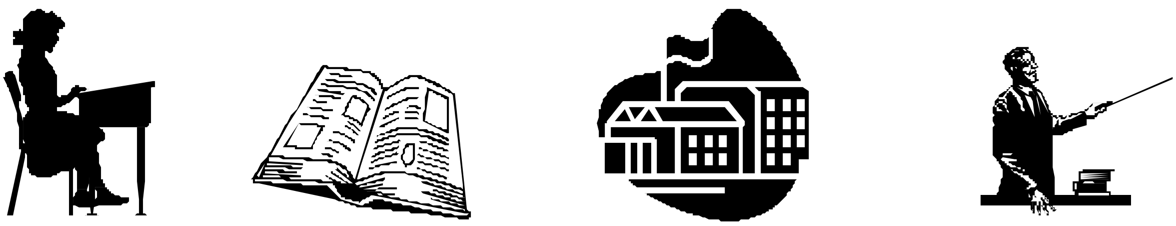

Figure 2-5 – learners, resources, context, managers of learning

Selecting which of these four elements is or should be a slow-moving determiner of structure is not completely straightforward.

Deciding the major determinant of structure

Learners as determinants of structure

Pines (1998) takes the interesting path of inverting the typical top-down faculty-centred view and considering the educational system instead from a student perspective. He notes “Because students naturally cut across departmental lines and make novel connections, student feedback on teaching as well as the direction of research and the internal structure of the university can be especially valuable.” As a student centred perspective opens up a far richer realm of complex interactions it is clear that any system we develop with self-organising tendencies should organise from the bottom-up. However, the most dynamic and fast moving of these elements are without a doubt those very learners, as by definition the teacher is attempting to enable them to change. If we seek bottom-up control, we could well find ourselves faced with a similar problem to Kauffmann's grid of interacting squares. There are simply too many possibilities for interaction. The dynamics of the system may never settle into equilibrium if we allow unlimited interactions between learners to drive the structure of the system.

As we are seeking the slower moving features to identify what shapes the system, we disregard the learner and are therefore left to choose between teachers, context and resources as our main definers of scale.

Resources as determinants of structure

There is a whole spectrum of possible structural roles for resources, from those which are necessarily static because they are the object of study (books, plays, buildings, mountains, rivers and populations) to those which are by nature ephemeral or constantly changing (Usenet newsgroups, events reported in newspapers, students' own work and so on). Depending on the subject and the mode of study, the resources which define learning may be faster changing than the learner or completely static, or anywhere in between.

Teaching may be shaped by resources: it would be hard to teach the history of ideas without a relatively static body of ideas to study. Similarly, most (though by no means all) subject areas consist of a fairly slow-moving body of ideas, arguments and concepts. In the case of, say, the study of a book, content may truly dictate the structure of a learning experience, but even then the manner in which it is approached and assimilated is a variable which is affected by other parts of the system, be they the learners themselves or those who seek to manage that learning.

Resources are promising candidates for key shapers of structure, if not in every situation or context.

Context as the determinant of structure

Context plays a vital central role in determining the course of a learning experience. However, in our virtual world of a networked learning environment it is neither a slow moving nor a fast moving part of the system because it *is* in some sense the system. If we are considering a virtual learning environment, that environment will be made up of the other three constituents, with their relationships to each other determined largely by the way that the environment is constructed and the opportunities that it affords. The context in such an environment is the form that such relationships take, the result of the structuring that has been applied. My goal will be to construct such an environment and in later chapters I will examine the importance of designing that context in far greater detail.

Teachers as determinants of structure

In the majority of existing educational systems the teacher plays the most active role in adapting and shaping the educational experience, mediating between the natural flow of the resources and the educational needs of the learner. Even given the huge system interdependencies of a traditionally taught face-to-face course, the dynamics of the system as it relates to a given individual learner centre primarily around and are controlled by a teacher. In the context of the learner, either teachers or resources might be the dominant shapers of the ecology in which the learner finds him or herself. Finding and selecting suitable resources is, however, one of a number of roles which gives the role of the teacher pre-eminence as the slow moving backdrop to the learner’s changing needs. The role of the teacher (by which I mean the mediation or management of learning) is the central interface between the faster moving systems of learners and the erratically moving body of resources, affected by both. Although I shall be suggesting a position where individual teachers have a less central status in the shaping of learning, it will be instructive to understand the behaviours which constitute their functions in existing learning environments. In the next chapter we turn our attention to the roles of teachers in an attempt to identify the part that they play in systems of education.

Conclusions to this chapter

The previous chapter suggested that education can be fruitfully viewed as a complex adaptive system. This chapter has investigated the character of complex adaptive systems more fully, together with the ways in which structure forms emergently from such systems. Evolutionary theory appears to have some specific applications to educational environments. In particular, the roles of exaptions, stigmergy, parcellated diversity and competition may allow educational environments to adapt to the larger environments of which they are a part and to accommodate change as it occurs. A lot of the answers to questions we might ask depend upon the perspective and above all the sense of scale that we employ when looking at a system.

Once the contingent periphery that shape existing educational systems are stripped away, we are left with the context of interactions between teachers/mediators, learners and the resources of the subject matter itself. Of these, the role of the teacher generally exerts the greatest control over the structure of the process and its content. In later chapters I will be examining systems which manage to act as learning environments without the aid of a teacher. To understand the form that a network-based self-organising learning environment should take, it is therefore likely to be useful to examine the roles of the teacher, a task which will occupy the bulk of the next chapter.

Chapter 3 : The roles of a teacher

> "I cannot teach anybody anything, I can only make them think" Socrates
>
> "You cannot teach a man anything. You can only help him discover it within himself." Galileo Galilei
>
> "I never teach my pupils; I only attempt to provide the conditions in which they can learn." Albert Einstein
>
> "…it's not just learning things that's important. It's learning what to do with what you learn and learning why you learn things at all that matters" (Juster 1962)

About this chapter

Having identified in the previous chapter that the role of the teacher may be seen as central in shaping an educational system, this chapter considers what specific roles teachers actually perform. The chapter starts by considering ways in which learning can occur without an explicit teacher role and the problems that may ensue. It then goes on to consider a small range of instructional theories which provide a framework for understanding the value that teachers add for learners. This is not intended as a comprehensive list of roles, nor is it an unequivocal set of definitions. The intention here is to provide working definitions of how value is added to a system by a teacher, to provide firmer foundations for a self-organising system which takes on some of those roles.

Do we really need teachers?

Self-teaching

It is common to talk of self-educated or self-taught people. These are people who have not just absorbed some knowledge along the way but who have in some sense actively pursued and/or created it, who have performed some actions which have led to learning. Learning is more a state of being than a specific task or set of tasks to be performed. As Senge (1990) puts it: "To practice a discipline is to be a lifelong learner. You 'never arrive'; you spend your life mastering disciplines." If we were to consider the measurement of learning, we might be looking for a demonstrated set of capabilities, not a finite set of tasks that are completed.

A great deal of learning takes place outside of formal settings and institutions. This is an inevitable feature of a rapidly changing world. Papert writes:

> As we face a world of ever-accelerating change, it's no longer possible to have a concept of learning where people in their youth will learn the skills that they will apply through their lives. Learning has to be a continuous matter.
>
> (Papert 1987)

Papert's solution to this concern is that "what you ought to be learning at school is that you don't need to be taught in order to learn." (Papert 1987). This is echoed by Holt, who claims:

> If the child reads only when he wants to, and asks for help only when he feels he needs it, he will work at full capacity, throw himself into the task instead of away from it, and rarely needs help at all
>
> (Holt 1977)

It is a lesson that many of us apparently take to heart, especially Ivan Illich, who observes:

> School is an institution built on the axiom that learning is the result of teaching. And institutional wisdom continues to accept this axiom, despite overwhelming evidence to the contrary.
>
> We have all learned most of what we know outside school. Pupils do most of their learning without, and often despite, their teachers.
>
> (Illich 1971)

Research by Alan Tough on self-initiated learning suggested that the average person (young or old) spends approximately two hundred hours each year on some informal learning activity such as learning to sew, learning a new language etc (Tough 1979). Tough's research was limited to a specific culture, and his definition of self-initiated learning is loose, for instance incorporating occasions where the learner actively seeks a teacher or evening class yet excluding 'learning projects' which take less than seven hours, but it helps to confirm Illich's (1971) assertion that learning outside an academic institution is the norm, not the exception. Not only is it the norm, the inevitable relevance to learners and their high motivation may mean that on many occasions it is better than the alternatives. As Knowles (1975, p.129) writes:

> One of the most significant findings from research about adult learning…is that when adults go about learning something naturally (as contrasted with being taught), they are highly self-directing. Evidence is accumulating that what adults learn on their own initiative they learn more deeply and permanently than what they learn by being taught.

Despite the implications of its name, self-teaching is seldom if ever an isolated activity. If nothing else it will usually be informed by some kind of exemplars which provide goals or starting points for investigation and discovery. More often than not, some element of teaching or training will come from resources such as other people, books, television, audio-cassettes, museums, art galleries or computer-based materials, either in the form of explicit teaching/training material or as primary sources and subject matter from which to learn. Learning is a situated activity, knowledge has a cultural aspect (Grabinger & Dunlap 1995) and all education and learning may be thought of as “generic social processes” (Becker 1998, p. 143). This is made explicit in various forms of peer tutoring.

Peer tutoring

Peer tutoring (or syndicate tutoring), where the process of communication is carried out without direct assistance of a tutor has a long and venerable history in educational literature and has many potential benefits as well as hazards. Looking at it within a traditional academic environment, Goodlad and Hirst (Goodlad & Hirst 1989, pp. 56-57) suggest that peer tutees experience the following benefits:

? receiving individualised instruction

? receiving more teaching

? responding to their peers

? receiving companionship from tutors

The authors cite evidence that peer tutoring is more effective than self-tutoring in both satisfaction and in measurable learning outcomes. However, in order for these benefits to be maximised, they assert that training of tutors is required and learning materials should be highly structured (Goodlad & Hirst 1989, pp 68-69). There are interesting parallels here with Moore’s theory of transactional distance, where the concept of distance is considered as a continuum between dialogue (small transactional distance) and structure, the latter being required when transactional distance is high. In this context it would seem that Goodlad and Hirst’s peer tutors are acting as intermediaries on behalf of the ‘real’ teacher, as vehicles for the transmission of what is effectively distance learning material. It seems therefore that, despite high ideals, their notion of peer tutoring is really just a way of eking out the valuable resource that is the traditional tutor.

Evans (1983) notes that peer to peer interaction is significantly higher in peer-led groups than in those led by a tutor, although the lack of tutor-imposed structure means that there is a 'danger' that some ground will not be covered. Based on an analysis of student interactions in tutor-led vs. student-led groups, Evans says:

> I can state that even if the students end up *knowing* less (which is by no means proven) most of them *understand* more because what they know has been integrated and made meaningful. Their preparation is more diligent; they are far less likely to come to a student-group unprepared than they are to a tutor-led group. In a word they are more *motivated*.
>
> (Evans 1983)

This affirmation of constructivism provides support for the importance of conversation and teachback (Pask 1976) in the pursuit of deep learning. It also reflects issues raised by Muilenburg and Berg (2000) who suggest that the content is not as significant as the ways in which it is put together and constructed by the learner. This results in a deep learning approach with more personal involvement with the learning task, in contrast to the dependant, teacher-led surface learning approach that "arises when the student sees learning as a means to achieve a short term goal which may be simply to do enough work to pass an assessment hurdle" (Johnston 2000). Although moderating this idea by affirming the importance of content, Ramsden too vigorously attacks the surface learning approach based on the transmission and recall of information:

> Surface approaches have nothing to do with wisdom and everything to do with aimless accumulation. They belong to an artificial world of learning, where faithfully reproducing fragments of torpid knowledge to please teachers and pass examinations has replaced understanding
>
> (Ramsden 1992, p. 60)

There are potential hazards with a peer-tutoring approach. Johnston (2000) observes a high dropout rate in students undertaking small-group work, which is related amongst other things to difficulties of recognising the work of individual group members when work is assessed. This is hardly surprising and indicates a systemic failure, not an inherent problem with peer tutoring per se. Were students not in an environment where assessment plays such a prominent role, or were they to be discovering things which related to their interests and not those of curriculum designers then the situation might be quite different. A similar problem occurs due to the difficulties of recent graduates in adjusting to a new mode of teaching. Johnston writes:

> There is a prevailing attitude that if the relatively passive learning approach engendered by a didactic rather than Socratic style of teaching worked for them, insofar as they graduated, this should be sufficient for everyone.
>
> (Johnston 2000)

From a systems perspective this self-reinforcement of a manifestly inappropriate method of teaching demonstrates yet again that systems generate emergent and unpleasant behaviours. Johnston also notes the perception that peer-tutored groups are “a vehicle for sharing ignorance.” This problem is also addressed by Mason, who points out that “working in groups can lead to group transference, to the lowest common denominator’s solution to problems, and to time consuming process discussions”(Mason 1994). A charming explanation of this problem is Alan Kay’s indictment of the ‘chopsticks culture’ which arises when technologies are simply provided, not used in a taught context (Kay 1996).

The perils of a chopsticks culture

Self- and peer- taught learning is often undervalued, and perhaps with some good reasons. Alan Kay attacks the notion of putting computers in the classroom in the hope that they will encourage learning. He claims that it will lead to what he describes as a ‘Chopsticks Culture,’ where he draws an analogy with putting a piano in a classroom and expecting it to cause the learning of music. What results is just the blind leading the blind, with students never progressing past the ability to play Chopsticks (Kay 1996). Providing opportunities for learning does not necessarily mean that anything more than surface learning occurs, unless the learner is given some assistance with where to go and how to get there. A classic example might be Sartre’s Autodidact in *la Nausée* (Sartre 1965) who learnt about the world by reading books in alphabetical order, knowledge divorced from context, its meaning related to its place on a library bookshelf, not its relevance to the learner. When learning how to sew or unblock a drain this is mildly problematic as the goal is near and tangible, but becomes far more of an issue when we enter the world of academic learning, where there is usually a meta-level of learning taking place, what Ryle identifies as *knowing-how* rather than *knowing-that*. Laurillard (1993) similarly draws a distinction between learning *precepts* and learning *percepts*, the former being a form of second-order learning which is a defining characteristic of academic learning, though of course such characteristics may be present in other forms of learning as well. Laurillard believes that our approach to learning academic subjects should be qualitatively different from that by which we gain knowledge from direct experience of the world.

This is not a binary classification without greyness at the edges, however. Learning in what Laurillard describes as ‘natural environments’ may well be experiential, but this is not easy to separate from second order learning. All learning is situated and all learning is articulated to the extent that it is necessarily incorporated into a body of existing knowledge. Our minds are not bundles of perception but are active creators of knowledge. To this extent, all knowledge involves some second-order thinking, some meta-activity which attaches it meaningfully to other knowledge we already possess. The degree to which this occurs is variable and may not always be formalised. Similarly, there is very little pure second-order thinking in the world. Laurillard herself quotes a counter argument from Eysenck and Warren Piper which suggests second-order thinking usually involves giving abstractions some substance, using the example of ping pong balls as a visualisation of molecules. Her response that this merely demonstrates that the process is different from direct experience is flawed and contradicts her own thinking about learning. We do not learn about dogs simply through direct experience. They fit into a world of myriad abstractions (mammal, furry thing, thing to play with, smelly thing and so on), some of which may have been gleaned in an academic setting but all of which are anything but first order experiences. This idea goes back to the likes of Dewey, Piaget, and Bruner as well as most constructivist thinkers since. Constructivism suggests that one who acquires knowledge must apply mental schemes to an environment, a progressive construction incorporating and adjusting previous knowledge as opposed to mere accrual of information. In the same way, Dewey saw the experience and academic learning as being inextricably linked- it is foolhardy to separate first and second order thinking, inasmuch as both are required to construct knowledge:

> As formal teaching and training grow in extent, there is the danger of creating an undesirable split between the experience gained in more direct associations and what is acquired in school. This danger was never greater than at the present time, on account of the rapid growth in the last few centuries of knowledge and technical modes of skill.
>
> (Dewey 1916)

However the argument about first and second order learning turns out, it is not too contentious a claim that much of informally learnt knowledge has many of the characteristics of knowledge achieved through a formal learning experience. Given that this is true, Wilson & Ryder (Wilson & Ryder 1998) recommend that teachers be dropped altogether:

> Rather than being controlled by a teacher or an instructional designer, learners might ‘self-organize’ into functioning communities with a general goal of supporting each other in their learning. That is to say, the function of guidance and control becomes distributed among

> group participants. Specific roles of group members are not assigned but rather emerge from the interaction of the whole.

Wilson & Ryder do not take this much further, but they provide a very good summary of what I shall be attempting to enable in the design of the CoFIND system, discussed later. For the moment, it is interesting to note that, although Wilson & Ryder are suggesting that teachers are unnecessary, they do not attempt to suggest that the role (at least of structure and guidance) is not useful. There is at least one thing distinctive about the process of formal education, be it a means to structure and guide, explore second-order thinking or an opportunity to observe good practice. This is reasonably good news for those who have invested large amounts of time and money into becoming educated or in facilitating the process for those who do.

So what *do* teachersdo?

> Learning something with the aid of an instructor should, if instruction is effective, be less dangerous or risky or painful than learning on one's own.
>
> (Bruner 1966)

Bruner's central requirement of a teacher provides us with a useful baseline by which to identify whether or not teaching is taking place, as well as a potential criterion for excellence, but does not provide us with a generative theory. This section will be dealing with theories of instruction which identify what is required for teaching to occur. By abstracting the roles of a teacher I hope to identify requirements for systems which might take on those roles. This section therefore looks at some instructional theories and attempts to extract some common themes.

What is a theory of instruction?

There are many theories which relate more or less explicitly to the nature of instruction, most of which are tied up with a view of learning that acts as a counterpoint to it. As the aim of this thesis is to produce a better midwife, it will be less concerned with learning theories but will instead concentrate on the extra value provided by teachers.

Bruner (1966) identifies four major elements to a theory of instruction:

? it should specify the experiences which implant a predisposition toward learning

? it should specify ways a body of instruction should be structured for easy assimilation by the learner

? it should specify the most effective sequences to present materials to be learned

? it should specify the nature and pacing of rewards and punishments in the service of learning and teaching.

As they are elegant and provide an historical context which other instructional theories either confirm or deny, I shall use these elements to provide a framework around which to string a number of instructional theories. These elements provide a meta-theory which identifies the form that a theory of instruction should take, rather than the specific content of such a theory.

Theories of instruction come in many forms. For example, the instructional design proponents pay little attention to prescriptions of what tasks should be performed and far more to the process of achieving them, whilst other models such as elaboration theory take an opposite stance, suggesting that effective tuition should follow a specific stipulated path. This thesis is not particularly concerned with the underlying process models and project management methodologies of how to go about designing instruction. These are very important to a flesh and blood teacher, but the purpose of this chapter is to abstract the functionality of a teacher, not to tell teachers how to go about teaching.

Gagné's nine instructional events

Among the most influential of theories of instruction is that provided by Robert Gagné (1985). Based on theory developed from experimental studies in cognitive psychology and information theory, Gagné developed initially eight and then extended these to a set of nine instructional events which should be performed by a teacher. Although originally based on a behaviourist world view, his later revisions incorporated a wider perspective. I am going to take some liberties with Gagné's events and match them to Bruner's requirements for a theory of instruction. Although Gagné's events offer a more refined perspective, from this matching it can be seen that they do not add to Bruner's initial precepts, but provide extra detail and clarity to Bruner's fuzzier concepts turning a meta-theory into a theory of learning. In brief, Gagné's nine events, matched to Bruner's, are shown in Table 3.1.

Table 3.1 – Bruner and Gagné juxtaposed

Bruner	*Gagné*
? It should specify the experiences which implant a predisposition toward learning	? **Gaining attention**, or activating motivation. This is to do with signalling that learning is about to occur. ? **Informing learners of the objective**. This is to do with setting the goals of a specific learning event. ? **Providing feedback**. Here the teacher tells the student how it is all going.
? It should specify ways a body of instruction should be structured for easy assimilation by the learner	? **Stimulating recall of prior learning** . Here the teacher sets the work in a context of what the learner already knows. ? **Providing learning guidance**. Here the teacher might show how it should be done, give examples, simplify representations and so on. ? **Enhancing and promoting retention and transfer**. The teacher might provide a range of different tasks or present other examples. ? **Presenting the stimulus** or directing attention. For example the teacher might select a book or a film to be studied.
? It should specify the most effective sequences to present materials to be learned	? The events of Gaining attention, Presenting the stimulus and Providing learning guidance are relevant to this precept.
? It should specify the nature and pacing of rewards and punishments in the	? **Eliciting performance**. This is concerned with providing tasks for the learners to perform. ? **Assessing performance**. In the context of the initial goals, the teacher identifies whether learning

Bruner	*Gagné*
service of learning and teaching	has been successful ? **Providing feedback.** This role is significant here as well as in specifying experiences which implant a predisposition towards learning.

Although based on a theoretical model that some have difficulty in accepting and which does not spring from what actually happens when students are taught but from what may be inferred from its theoretical basis (Laurillard 1993, pp. 74-75), the instructional roles which Gagné identifies are persuasive and (if not complete) hard to fault. They are a high level abstraction of the general functions, not a prescription of how they should be performed. For the purposes of this thesis, this is useful. However, it will also be instructive to look further into what is or should be involved in the processes surrounding these roles.

Marton and Ramsden

Laurillard basis (Laurillard 1993, pp. 74-75) does not like the lack of grounding in experience and practice represented by Gagné's views, but is far more positive about the instructional design theory promoted by Marton and Ramsden. Marton and Ramsden use a phenomenographic analysis of teaching practice to identify the following eight roles for teachers:

1. Present the learner with new ways of seeing.

2. Focus on a few critical issues and show how they relate.

3. Integrate substantive and syntactic structures.

4. Make the learners' conceptions explicit to them.

5. Highlight the inconsistencies within and the consequences of the learners' conceptions.

6. Create situations where learners centre attention on relevant aspects

7. Test understanding of phenomena; use the results for diagnostic assessment and curriculum design.

8. Use reflective teaching strategies

(Marton & Ramsden 1988, pp 277-280)

The essence of the view expressed here is one which is defined in terms of student thinking and communication rather than in the ordering of material, a reflective and iterative process where the teacher learns from the students. The principle of using reflective teaching strategies is a prescription for an attitude towards learning and teaching which places it in a context of particular learners and a particular subject matter being approached. Therefore the bulk of these roles act as a counterpoint to those identified by Gagné, with a focus on communication and interactions between teacher and learner and subject sharply delineated. The roles here address the structuring of learning based upon a systemic view of learning and teaching, where the effects of one role impact the form of another and where communication plays a central part in determining the form that instruction takes. In this way it is a model for an adaptive system, one which responds to the changing and growing needs of the learners within it. Though couched in another perspective, several of the concerns of Marton & Ramsden are very similar to those of Gagné. In particular, providing feedback, testing understanding, structuring/simplifying and providing goals are common to both theories as well as to that of Bruner. In a sense, Marton & Ramsden are looking at a slightly different system, drawing the boundaries in different places. Maturana addresses a similar problem when considering the relationship of internal organisation to its environment, showing that it is our perception of what constitutes a system which dictates our point of view:

> As observers we can see unity in *different* domains, depending on the distinctions we make.
> (Maturana & Varela 1987).

We are looking more at an issue of perspective than at a fundamental disagreement between ways of seeing the world. There is no fundamental discontinuity between this and other theories, it is merely where one chooses to delineate the boundaries and concerns of the system.

It is important to abstract those roles which are to do with formative processes and those which prescribe specific actions. Marton & Ramsden are concerned with approaches to becoming a better teacher which are firmly grounded in reflective practice. This is an interesting issue if we are seeking to build systems which somehow replace the teacher. It is going to be important to build in feedback loops that allow our systems to adapt to the needs of the learners and the subject matter being taught. Whether our system will be able to assume a similar reflective role to that of the teacher is to an extent irrelevant. The strength of the phenomenological approach taken by Marton & Ramsden is that it grounds theory in practice, but this is also its weakness if we wish to abstract these roles into some non-human system as it changes the systemic nature of what we are observing.

Abstracting the roles of a teacher

This thesis will use the elements of Bruner's theory of instruction as a framework on which to hang a range of more specific theories, notably those of Gagné, whose nine events provide a prescription for the kinds of activity which may be identified as contributors to instruction.

Behind the framework prescribed by Bruner there lie two large assumptions:

1. that a teacher should have some modicum of subject expertise, otherwise goals could not be identified nor success recognised
2. that a teacher should communicate and enable communication between learners

I shall discuss these issues before going on to discuss my understanding of Bruner's precepts in greater detail.

A teacher is a subject expert

> A merely well- informed man is the most useless bore on God's earth.
>
> (Whitehead 1929)

The belief that subject expertise is central to the role of a teacher of adults is pervasive. This is carried through to the extent that lecturers are often hired on the basis of their knowledge, not their ability to impart that knowledge. Laurillard rightly pours scorn on this self-defeating strategy (Laurillard 1993), which persists by removing from the teacher the responsibility of student failure. Although perhaps not as central as tradition would have it, subject expertise is none-the-less a significant feature of successful teaching, if only as a means of enabling more central functions, including three out of the four requirements identified by Bruner. Structure, sequence and feedback are all much simpler tasks if the teacher understands the subject matter.

> Teachers do know more of the subject matter and teachers do have responsibility for assisting their students to learn. This means, among other things, not only directing students' attention to their learning challenge and giving them tools with which to learn on their own, but also helping to remove obstacles that interfere with their learning. And it means understanding that nobody can learn without making mistakes. Your presence and the way you relate to their mistakes can contribute to, or free, your students from fear.
>
> (Larsen-Freeman 1997)

Larsen-Freeman's suggestion that a teacher is a remover of obstacles and freer from fear is an interesting perspective which echoes Bruner's justification of instructors as a means to reduce the discomfort of learning which starts this section.

Similarly, Ramsden (1992) has a firm conviction that teaching must be situated firmly in a strong grasp of the subject matter, without which it will not be at all clear how best to structure the subject effectively. In fact, he sees it as a subsuming factor:

> In good teaching the method used is always secondary to the teacher's aims for student learning and the extent to which the particular strategy actualises the principles of effective instruction within a certain context.
>
> (Ramsden 1992)

The themes of direction, organisation and goal-setting will arise again in this analysis, but there is no doubt that at some point in the learning experience a learner will have to confront the subject matter, whether through the teacher (the facilitator of the learning) or through some other teaching resource.

A teacher is concerned with communication and the mediation of communication

There is a strong and well founded belief in the world of pedagogic theory that learning is enabled by communication. This is not a new idea. In 1916, Dewey wrote a definitive passage on the subject:

> Not only is social life identical with communication, but all communication (and hence all genuine social life) is educative. To be a recipient of a communication is to have an enlarged and changed experience. One shares in what another has thought and felt and in so far,

> meagrely or amply, has his own attitude modified. Nor is the one who communicates left unaffected. Try the experiment of communicating, with fullness and accuracy, some experience to another, especially if it be somewhat complicated, and you will find your own attitude toward your experience changing; otherwise you resort to expletives and ejaculations. The experience has to be formulated in order to be communicated. To formulate requires getting outside of it, seeing it as another would see it, considering what points of contact it has with the life of another so that it may be got into such form that he can appreciate its meaning. Except in dealing with commonplaces and catch phrases one has to assimilate, imaginatively, something of another's experience in order to tell him intelligently of one's own experience. All communication is like art. It may fairly be said, therefore, that any social arrangement that remains vitally social, or vitally shared, is educative to those who participate in it. Only when it becomes cast in a mold and runs in a routine way does it lose its educative power.
>
> (Dewey 1916, pp.8-9)

As Bruner says, “the instructional process is essentially social,” (Bruner 1966, p 42) and is to do with developing ways of understanding through communication. However, communication alone is not the answer to learning. We communicate every day without necessarily learning a great deal in the process, for a variety of reasons such as: we are at the level of expletive, we are making performative utterances, we are repeating platitudes and conventional greetings and so on. For communication to have pedagogical value it needs to be focussed and structured with at least an implicit goal of bringing about learning. A useful framework for that process is provided by constructivism, where the learner is actively involved in the construction of knowledge. Communication is never far from the heart of the constructivist ethos, enabling the interplay of mind and content that is needed to construct knowledge and meaning in the world. For many authors it may be seen that communication plays a pivotal role in allowing learning to take place at all. Pask, for instance, in his theory of teachback establishes that the act of communicating is what brings about learning (Pask 1976). Vygotsky’s dialectical structuralism is founded on the interactions with other students and adults who socialise them into the culture (Doolittle 2000). A similar point of view is expanded upon by Muilenberg & Berg (2000), who see the classroom discussion as being capable of promoting thinking of four hierarchically organised and interconnected varieties: critical, higher-order, distributed and constructive thinking. There is little doubt, then, that conversation plays a central role in teaching and learning.

Teachers may be guides of conversation, perhaps in a seminar, tutorial or even in a lecture. In distance learning this role becomes abstracted somewhat. Moore & Kearsley cite Mason as identifying the teacher’s responsibility as falling into three main roles, organisational, social and intellectual:

> The organizational role involves managing the conference and providing leadership,. The social role entails establishing and maintaining good relationships and a positive learning

> environment. The intellectual role involves getting all students to participate and weaving their contributions together
>
> (Moore & Kearsley 1996, p. 142)

Teachers may themselves be the main source of dialogue. At its most extreme it leads to forms such as Socratic dialogues, where the teacher seeks to persuade the student of a fact or relations between facts by a process of argument. Collins & Berge (1996) quote Rohfield and Hiemstra as describing this process as “the responsibility of keeping discussions on track, contribute special knowledge and insights, weave together various discussion threads and course components, and maintaining group harmony.” This is an interesting set of roles, especially (pace Moore & Kearsley) those that are involved in ‘weaving, ’ the structuring of discussions and the crossing of borders between discussions. This flexible movement between areas of interest will be seen as crucial to the development of flexible, self-organising systems.

Subsuming the role of discussion facilitator is the role of community builder, connecting learners not only with each other but with the wider community, be it intellectual or social (Corrigan 1995). It is not possible to divorce the practice of teaching from its wider context, as a subsystem in a hugely interconnected array of subsystems. A teacher is one of the primary conduits through which connections are made.

A theory of instruction should specify the experiences which implant a predisposition toward learning

Implanting a predisposition toward learning is a complicated feature of teaching, involving not only the more obvious aspects of motivation, but also, following Marton & Ramsden (1988), in an active involvement with the learner, an understanding of what makes a learner curious.

Motivation (and demotivation)

As Laurillard (1993) points out, one of the few justifications for continuing the traditional lecture format is that it can be inspirational, albeit not very often.

> Academics will always defend the value of the ‘inspirational’ lecture, as though this could clinch the argument. But how many inspirational lectures could you reasonably give in a

> week? How many could a student reasonably absorb? Inspirational lectures are likely to be occasional events.
>
> (Laurillard 1993)

This view is perhaps a little jaundiced. Few professional performers (actors, musicians, dancers etc) would make a living if they did not fairly consistently inspire their audience, usually on a daily basis. However, we can agree that the consistently inspirational lecturer is a rare beast. Perhaps the most detailed of theories of motivation as it directly relates to a theory of instruction come from Keller (Keller 2000) and his ARCS model of motivation. Keller bases an entire theory around Attention (need for stimulation & variety), Relevance (desire to satisfy basic motives), Confidence (desire to feel competent and in control), and Satisfaction (desire to feel good about oneself) as the prime motivators in learning. He provides the interesting insight that motivation is not always a good thing:

> Motivation follows a curvilinear relationship with performance. As motivation increases, performance increases, but only to an optimal point. Afterward, performance decreases as motivation increases to levels where excessive stress leads to performance decrements.
>
> (Keller 2000)

The word *motivation* in this context is clearly referring to extrinsic rather than intrinsic stimuli, for it is only in a failure to achieve such goals that stress might arise. Following this theme, it is possible to take the position that every now and then the teacher has to play the role of demotivator. Papert describes a situation where children were so enthused by a project that they were coming in to work during their recreation time and the teacher “had to become a conservative brake to stop them from overdoing” (Papert 1987). Although it is likely that the need to stem learning indicates a failure in the system, Papert does draw attention to a potential danger: if we are looking towards self-organising systems then learners may be drawn to the areas which enthuse them at the expense of (perhaps vital) other areas, such as those which provide a theoretical foundation for later discoveries. Without a teacher to provide guidance, enthusiasm for parts of the learning experience may result in important foundations being missed.

Motivation is central to many theories of instruction. Bruner states that an instructional theory should specify the experiences which implant a predisposition toward learning (Bruner 1966). A similar theme can be found in Knowles’s need to foster a co-operative learning climate (Carlson 1989), Gagné’s requirement to elicit performance (Gagne 1985) and Collins et al’s stipulation that a teacher should “involve” students in learning as apprentices (Collins, Brown & Newman 1989).

The need to provide extrinsic motivation may not always be that strong. Alan Tough's research in the late seventies suggests that around seventy percent of learning takes place outside of an institutional framework and, of the remaining thirty percent, only about five percent occurs with the aid of professional helpers such as teachers, trainers and counsellors (Tough 1979). The strong implication is that, where there is a desire to learn, external motivation provided by a teacher is not required.

Teachers have many ways of motivating students, from the threat of exams to the lure of transmitted excitement. McKeachie, quoted in (Hill 1999), claims that "one of the major tasks in teaching is not to scare students but rather to nurture their curiosity and use curiosity as a motive for learning." This is reflected in the QAA handout, for UCoSDA- "enthusiasm is a powerful motivator of learning." (UCoSDA 1997). When we remember great teachers they tend to be those who enthused us. It is inevitable that in a traditional teaching environment motivation will be low. In a university, class sizes can easily be in the hundreds and the chances of all those students wanting to learn exactly the same things at the same time are very very low. Even with smaller class sizes, the requirements of demonstrating knowledge of a fixed set of facts (and perhaps their relationships and meaning, if the teachers are a bit enlightened) means that it is again certain that some students will be trying to learn about things of no interest to them. It requires a much lower ability to enthuse an audience with an interest in the subject (although the number of boringly delivered papers at most conferences stretches this observation beyond breaking point at times). The lesson to be learnt here is that teaching should cater for the interests of the students.

A theory of instruction should specify ways a body of instruction should be structured for easy assimilation by the learner

Resource maker and distiller

Closely allied to the role of subject expert is that of resource maker. From the creation of lesson plans, to accompanying notes, to examination questions, to lectures, to informal discussions, to notes on the board, to whole teach-yourself books, teachers from time immemorial have been seen as sources, condensers and purveyors of knowledge. The mediated transfer of knowledge to the learner cannot be under-rated as a role, and this mediation necessarily involves some creative input. Even in a world where educators as a profession were to disappear, if learning is to continue then there will always be a need for resources from which to learn.

Resource gatherer

Whether a teacher is a guide on the side or a sage on the stage, we can infer that a central role he or she plays is the discovery of useful resources for the learner. The teacher acts as a filter, an editor mediating between the tangled complexity of the real world and (by definition) the simpler understanding of the learner. As McKenzie writes:

> Good lecturers do tons of extra reading and research into the topic before us. They save us the trouble of doing our own exploration, having 'turned down the corners' on the best pages. They synthesize, summarize and report the 'best parts.' Knowing their audience, they are able to translate what might otherwise seem foreign, confusing, boring, or overly abstract into a half hour of explanation and illumination. They act somewhat as tour guides.
>
> (McKenzie 1997)

McKenzie may be a little over optimistic about what a lecturer can achieve in terms of knowing an audience. This may be true in certain cases where the audience is small or of a known state of ignorance (perhaps with no previous experience), but many audiences faced by a typical lecturer are large and diverse. However, in a perfect world the teacher would be an adaptive filter, shaped by the needs of the learner. When combined with the next role of resource organiser, the gathering of resources can become a central role for a teacher.

Resource organiser

One significant part of the role resembling that of a filter is that of a simplifier for representation. For instance, a lecturer may draw a diagram of relationships rather than relying on an original textual description. A diagram of this nature might be found in a textbook, but the lecturer is drawing it for a specific group of learners, adapting resources to be more useful to the cohort.

A theory of instruction should specify the most effective sequences to present materials to be learned

Definer of boundaries, structurer and sequencer learning

A student may have a desire to study philosophy but may not know even the names of the great philosophers. There are plenty of ways of finding this information, hundreds of books, articles, people who know, Internet discussion fora and so on. The value added by the teacher is to point out the landmarks that are of interest, filter the unnecessary ones and match objectives to the known abilities and understanding of the student. At least, this is what the ideal teacher does. In real life, a teacher with a large group of students provides pointers for an ideal student, an average student or some other general indicator of what a student should be. This may be far removed from the needs of a given individual learner. Knowing the goals is part of the way to knowing how to get there, but it is a lot easier to do this if a structured path is provided.

Collins et al's theory of cognitive apprenticeship makes great use of the concept of 'scaffolding' as a means of abstracting problems and providing a stepped approach to a problem (Collins, Brown & Newman 1989). Elaboration theory is almost entirely based on the structuring and sequencing of learning, based on conceptual, procedural or theoretical grounds (Wilson & Cole 1992). In *The Conditions of Learning* (1985), Gagné requires that the teacher identifies objectives and guides learning. Two of Bruner's four stipulations for a theory of instruction are that it should specify ways a body of instruction should be structured for easy assimilation by the learner and specify the most effective sequences to present materials to be learned (Bruner 1966). Even Malcolm Knowles, whose theory of andragogy requires explicitly self-directed enquiry with teachers, fellow students and materials available but not imposed, is extremely clear that the teacher is there to manage the process, guide the interactions and design sequential activities (Carlson 1989). He writes:

> Many students enter into a new learning situation feeling a deep need for the security of a clear structural plan- an outline, course syllabus, time schedule, and the like. They want teachers who know what they are doing, who are in charge.
>
> [Knowles, 1975 #212, p.37]

Similarly, Saba identifies teacher roles as including "informing the learner of the objectives required by the course" and "developing study plans for achieving objectives agreed upon between the learner and instructor in the learning contract." (Saba 1999a). However, he also notes that "some students require more structure for learning and others demand to be left alone to work at their own pace." This harks back to Marton and Ramsden's requirement for reflective teaching, based on feedback loops from students. Teaching strategies should adapt to learners according to their needs (Marton & Ramsden 1988). A course may progress through a group of set texts, each one building on the last. Especially but not exclusively in an online environment, this may be extended to providing a more flexibly structured list of resources, such as a hierarchical or web structure, perhaps giving more information about the relationships between resources. For example:

- document B provides a counter-argument to document A
- document A provides the foundation for document B
- document B follows document A in temporal sequence
- document A is one of the sources for Document B

The teacher is providing not only a sequence but also a rationale behind that sequence, or semantic linking between them. This link may or may not be explicit. The sequence of texts may simply arise out of the topics as they are presented on a day by day or week by week basis. Alternatively, groups of texts may be clumped together into loose agglomerations, leaving the learner to sort out the relationships between them. Even then, the choice of texts will usually imply that the teacher sees connections. The process of organisation lies at the heart of gestalt approaches to understanding learning and teaching, the identification of wholes of related parts (Wertheimer 1938). Like most attempts to abstract the specific nature of a complex and diverse activity, the organisation of resources is not an essential prerequisite of teaching. As Moore & Kearsley (1996) separate structure and communication, so it is possible to find instances of teaching without such structure being planned, or perhaps planned so generally that it does not merit the word 'organisation.' For example, a research thesis by its nature has no prior organisation, save in generalities and the shape that evolves out of the process. Plans can and do develop within the overall shape, but the teacher is only a participant in this process, not necessarily the organiser of it. A similar sort of process accompanies some aspects of the teaching of fine art or other transcendent skills such as creative writing. Once the means have been learnt to produce artefacts in the first place, the teacher acts as a critic, a guide, a sounding board, a setter of goals, but not necessarily an organiser of resources.

If organisation of resources is important then it would be helpful to distinguish the ways in which organisation of resources might be approached. Whelan (1988) provides a useful distinction in the form of structuring and ordering approaches to problem solving employed by students. In an ordering (or atomistic) approach, individual parts of a problem are ordered and grouped, but the facts are not fitted into an holistic understanding of the whole, which can only be achieved using a structuring approach. In the structuring approach, relationships between facts are understood and inter-related. The distinction brings into sharp relief an issue that will arise later when I look at ways in which self-organisation might arise in learning. It is not enough for there to be emergent order. Relationships between subjects and problems and facts have to be structured in a manner that is meaningful.

A theory of instruction should specify the nature and pacing of rewards and punishments in the service of learning and teaching.

Provider of feedback, assessment and evaluation

Self-directed learners often have difficulties deciding whether learning objectives have been successfully met, and it is an abiding (if often frustrating) part of the role of most teachers to mark work and provide formative and summative assessment. Bruner states that a theory of instruction should specify the nature and pacing of rewards and punishments in the service of learning and teaching (Bruner 1966). A similar point is recognised by Gagné, Collins et al, Knowles, Laurillard and many other instructional theorists. I have already observed that extrinsic rewards are a poor substitute for self-motivated learning, but the need for feedback (if not rewards and punishments) is a vital element of directed learning.

Assessment can be summative or formative: Formative assessment is generally seen as being preferable from the point of view of the educational system as a whole. From a systems perspective it can act in two distinct ways. In a traditional setting there is a danger that the feedback mechanism is applied like a thermostat. It is feeding back without feeding forward. To work effectively, formative feedback forms not only the student's view but also that of the assessor. It becomes a part of the evaluation process leading to adaptations in teaching style and content (Pask 1976).

Purely summative assessment provides a limited feedback mechanism to the student, but provides an interface between the institution and the world beyond, the rubber-stamping validation that confirms learning has been achieved to those (other than the student) who wish to know. Its role in the system is one that acts as a channel between the educational system and the world in which it resides. In principle, if those who are qualified are poorly adapted to the world of employment then feedback from the employers will affect potential students which will in turn affect intake figures to the awarding institution. In practice, the world is a slightly different place. The relationship between learning, assessment success, employability and institution status is richly interwoven with other factors. Choice of institution may be affected by location or history, student success related to prior ability and so on. Employers may have preconceptions about institutions and may themselves be uncritical former students, so that the complex whole achieves a kind of solonic wave of stability. At the University of Delhi, for example, computer courses are developed in conjunction with a large local employer, but the representatives of that employer are themselves former students, whose preconceptions of what constitutes a useful course is based upon their own schooling. Thus, it remains an entry requirement to know about the Brownian motion of gases and nuclear fission, despite their apparent minimal relevance to the subject of computing.

The evaluative process does not end with assessment. Evaluation of learning resources, of learners, of the learning of learners, of teaching, of environments, of learning technologies and so on is a major role played by the teacher. Moore and Kearsley identify direct questions, assignments, quizzes, polls and questionnaires as being effective means of getting this kind of feedback (Moore & Kearsley 1996). It is also reflected in the principles of reflective teaching espoused by Marton and Ramsden (1988).

An holistic view

Collins & Berge represent design of the student learning experience as something to be striven for in contrast to just the provision of content (Collins & Berge 1996). The objective is to provide scaffolding to allow students sufficient latitude and freedom to refine questions and search for their own answers from multiple perspectives. This role cuts across or straddles many others and is so non-specific that it could largely be construed as being synonymous with ‘teaching’ itself. However, I would like to retain a sense of the phrase inasmuch as it provides an holistic view of the activities. Although this process of analysis has considered a group of more or less distinct roles, like most complex adaptive systems teaching appears to be more than the sum of its parts, not a simple agglomeration but a system of interacting elements.

Other things a teacher might do

This thesis began by observing that educational systems should always be seen as systems. Abstracting teaching roles like this seems a little improper except that, in doing so, the systems themselves may be reinvented from the ground up. However, there are some other roles which, though not as a rule performed by teachers, are a vital part of the process even in its reconstructed form. For example, if we accept the need for communication then there may still be a need for scheduling, although asynchronous network technologies may render this less important. Means are needed to bring people with an interest in learning together in the first place. Without formal institutions, what mechanisms will there be to support the basic functions that we take for granted? Similarly, an infrastructure that allows and indeed positively encourages interactions to take place is vital.

Conclusions to this chapter

It is probable that the majority of learning in life is accomplished without the aid of a teacher, and that there are very good reasons that learners themselves should tutor each other. Despite this, there are good reasons for teachers' continued existence, many of which have been considered in this chapter. Having identified and abstracted various roles of the teacher which are not dependent on contingencies (like the nature of institutions) we have seen a variety of features that constitute the act of teaching. This approach may have missed some important features and, in limiting its perspective, has avoided many interesting ways of looking at the subject. The process of teaching is one filled with phenomenally rich, interlocking systems and subtle adjustments to a myriad of stimuli on a constant basis. None of these should be undervalued but, as I have already argued, the choice of perspective is part of the nature of how we view systems. In this chapter the perspective has been determined by the desire to build networked computer systems which, through the actions of their users, emergently exhibit teacher-like characteristics.

When looking at the development of CoFIND in Chapters six and seven I will be referring back to the ways that a teacher has been defined here. In so doing I will ignore most of those issues which relate to the psychological and social process of becoming a good teacher and instead concentrate on the aspects that relate to being a teacher at all. For this purpose I will be drawing far more heavily on Bruner and Gagné than others I have discussed, as their abstracted roles are less dependent on contingencies than most other theories. Having said that, in order to enable learning it is also clear that subject expertise and (taking the post-Vygotskian constructivist ethos to heart) communication are an essential part of the process. Following from

Moore & Kearsley and Marton & Ramsden there is also a need for some feedback mechanism to enable what might be seen as reflective practice, or a process that can lead to improvement of the act of teaching.

The next chapter will look at some of the ways in which some aspects of the roles identified in this chapter might emerge as a result of user interactions within existing networked computer environments which have not been built with self-organisation in mind. By identifying the limitations of some general purpose tools to support self-organisation I will be in a better position to identify what strengths are needed in the design of tools built for the purpose.

Chapter 4 : The emergence of teacher-like qualities in existing networked learning environments

About this chapter

The previous chapters have discussed the interconnected nature of educational systems, identified a fair selection of the features which distinguish guided learning from unguided learning and considered some of the ways in which emergent behaviour can arise in complex systems. This chapter looks at ways in which emergent guidance might arise as well as how it might be hindered within network-supported learning. It is an investigation of ways in which self-organisation takes place in networked learning environments without explicit support from software. To begin with I look at some of the ways that the Internet (especially the Web) may assist in the discovery of resources. I will address some of the problems of searching and ways in which structure emerges when seeking resources on the Web. I then report in some detail on a few small-scale instances of asynchronous discussion groups that have been used in my teaching, with the aim of discovering their strengths and shortcomings in allowing self-organisation to occur.

Teachers are bad for learning

In the first two chapters of this thesis I suggested that the nature of educational systems affects their subjects, sometimes negatively. In many cases, this occurs because of the hierarchical structures that pervade educational systems, leading to rigidity, lack of adaptation to learners' needs and unwanted artefacts which are antithetical to effective learning, such as examinations and lectures. I suggested that the most significant layer in this hierarchy is filled by those who teach. Despite teachers' roles in perpetuating potentially harmful systems, it became clear in the previous chapter that they are important enhancers of the learning process.

We are faced with the potential quandary that teachers, whilst apparently a boon to the process of learning, are typically major contributors to systems which are detrimental to learning.

There are a few possible solutions to this problem. For example, a significant amount of educational literature is concerned with ways in which teachers can and should become “guides on the side,” thus reducing their hierarchical roles. With sufficient care, these roles might genuinely shift to the side within the hierarchy. One-to-one tuition, which at least allows the possibility that a less hierarchical relationship might develop, is almost universally hailed as a most effective way to assist learning, but economic realities make this the exception rather than the rule. An alternative that will be explored for most of the rest of this thesis is to consider ways that the roles of teachers might be replaced, or at least extensively modified, by making use of the combined intelligence and knowledge of a group of learners. This is not a particularly radical suggestion. We can see the process in many conventional learning settings, such as the traditional seminar or the academic conference, where peers share their research and learning and, through a process of discussion and debate, help each other to learn.

The concept of a teacher-less future will be presented as an alternative option, not as a cure. It is not necessarily a better idea than the status quo, and may itself lead to unexpected emergent unpleasantness. We are in the world of complex adaptive systems, where it is often hard to predict behaviour based on simple rules.

The growth of the Internet allows a range of different forms of interaction and means of information retrieval and knowledge sharing not afforded by traditional situated methods of education. Many of these forms make explicit their utility as systems to aid collaboration. Network-based learning is therefore a fruitful area of investigation when considering the potential for self-organisation in learners.

Finding good stuff

> First, what's there is stuff: partly information, partly pure nonsense--and it's not always easy to distinguish the two. Second, it's not a superhighway, it's a swamp, albeit a swamp with many remarkable hillocks of well-organized, first-rate data and information.
>
> (Crawford 1999)

In universities the hiring policy for lecturers has often been far more concerned with their perceived knowledge than with their teaching abilities. It is assumed that those who possess knowledge will somehow be able to transmit it to their students. If equivalent knowledge could somehow be transmitted in another way, then it is tempting to speculate that, at least from the point of view of those who specify such selection criteria, little would be lost if lecturers were removed entirely from the system. This is, of course, silly. I have already gone to some lengths to dispel the notion that knowledge transmission is the sole function of a teacher, but the passing on of knowledge together with the ability to respond to questions of subject matter are important roles which might in principle be achieved without a traditional lecturer. It must be re-emphasised that these roles are only a part of what a teacher should do to enable learning to occur, but they are an important part.

Resource-based learning

To reduce the knowledge imparting role of a lecturer and increase the emphasis on student construction of knowledge, a range of approaches have been developed over the last few decades which may be characterised as resource-based learning (RBL). RBL is a learner centred approach which is based on the principle of fostering learning by encouraging learners to explore and discover a body of resources. An underlying theme of RBL is that learners become empowered in their own learning by allowing them to take their own paths through provided or found content. A further theme is that the teacher has a major role in this process, as all or some of a resource maker, resource distiller, resource gatherer or resource organiser. As Rakes (1996) puts it:

> In a resource-based environment, teachers encourage students to
>
> ? be active, not passive in learning.
> ? engage in an inquiry approach to learning.
> ? accept responsibility for their own learning.
> ? be original and creative.
> ? develop problem-solving, decision-making, and evaluation skills.
> ? develop a broad outlook on the world.

Although this is a steadfastly student-centred approach, it is notable that Rakes begins her list emphasising that it is the teacher which is the means by which this process is achieved. RBL is still very much a guided process. The next part of this chapter is concerned with investigating the problems and issues which affect learners seeking knowledge from the Internet without the aid of that explicit guide.

Information overload

The Internet provides massive diversity and a huge range of people and resources. There is no shortage of information, with most subjects being served by thousands, sometimes millions of pages, discussion groups and so on. The main problems of utilising this plethora of knowledge revolve around discovery and structuring of relevant and reliable resources and people (Looi 2001, p. 14). These problems divide into a number of distinct areas, including those of lack of shared categories and values, inconsistent ontologies (in the computer-science rather than philosophical sense of the word), inadequate indexing, lack of semantic metadata, and the sheer volume of the web, currently estimated at several billion pages on around seventy-one million Web sites and growing (Thompson 2001). This is not including the indefinitely large number of dynamically generated pages and the hundreds of constantly changing messages on a large percentage of around fifty thousand newsgroups and an even more enormous number of mailing lists and ezines.

Learning is about change

Even were all of these problems to be solved, learners would still be faced with major difficulties in identifying appropriate resources for specific learning needs. It is the nature of learners that they are unlikely to know where to go next and indeed it is a logical outcome of learning that prevents this from ever being an easy problem to solve. Learning changes the learner. This is a necessary feature of any system that learns. As Kosko puts it, “learning changes an information medium” (Kosko 1994, p.214). Future needs are generally hard to predict prior to that learning taking place.

Problems of Categorisation

Metadata standards

Should we all agree to describe our resources to an agreed standard then we might be able to use search engines or other automated tools to find the kinds of things we are looking for. Murray (1998) writes:

> We are interested in situations where there is an instructional goal....and the resource for achieving that goal is not explicitly known. In a sense, we would like information (called meta-content or metadata...) attached to tutorials which describes what and how they teach so that a search engine can locate an appropriate tutorial on the Web.

Murray believes that such metadata can be specified and codified in a consistent manner. However, there are problems with such a model, as Murray himself recognises when he identifies *term ambiguity* as a thorny problem. His solutions are pragmatic and interesting, to implement topics (the metadata he is interested in) within controlled or local contexts (interestingly thus reflecting issues of parcellation, scale and growth by chunking discussed in Chapter two), to use metadata standards such as the IMS (Instructional Management Systems) and Dublin Core schemas, and to semi-automate rather than fully automate the system. Murray's solutions skirt around the problem but do not attack it at its core, probably because the problem is essentially irresolvable. I will look at this rather bold assertion in a little more detail.

Dynamism and stability

Solomon states:

> Even though we often act as if the world were static in the information field, it is in motion and without adaptive mechanisms our knowledge organization schemes are likely to become less and less appropriate over time....knowledge organization schemes need to be seen as living things.

(Solomon 2000)

Traditional classification schemas are not as fluid as the world that they model. Classification schema such as the Dewey (DDC), Library of Congress (LCC) and UDC (Universal Decimal Classification) are extremely popular with librarians, forming as they do a theoretically based and somewhat flexible categorisation schema. Developments such as Ranganathan's facets allow structured classification to be applied to the subtlest nuances of meaning. DDC, LCC and UDC constantly develop but each requires a substantial intellectual investment to be used effectively and modifications and extensions to the schema are the stuff of academic conferences, not arising from the day-to-day usage of them. Pejtersen and Albrechtsen suggest a more flexible view of categorisation as arising within information ecologies and themselves being ecological in nature (Pejtersen & Albrechtsen 2000). Their system is based around empirical analysis of invariant structures within a given information ecology at different levels, which may then be used as a framework on which to hang the more dynamic categories. There are similarities between this understanding and the point noted in Chapter two that ecosystems are shaped most strongly by their slower moving parts. Invariant structures are by their nature slow moving. They only appear invariant within a given context; as Pejtersen & Albrechtsen observe, principles of universality have to give way to principles of use and context dependency. Even dynamic and system-based approaches like this are rooted in the world of the knowledge professional, however, and do not necessarily relate closely to the usage of classifications within a given context.

Context dependency

Lakoff is a luminary in his own field of linguistics, but his influence has extended further, at least partly due to the intriguing title of his book, “Women, Fire and Dangerous Things” (Lakoff 1987). Lakoff’s is concerned with categorisation. He sees the ways in which we categorise as central to understanding how we conceptualise the world. The process of categorisation is one that can be represented using metadata, so his interest coincides with ours. The significant feature of categorisation is that it is situated within a cultural context. Given our analysis which shows learning and knowledge in the same light this should not be surprising. However, it does lead to a range of conclusions that are problematic:

? we may not agree about our classifications and it would be surprising if we did. Macskassy et al performed an interesting experiment to identify how closely different people agreed on the clustering (or classification) of Web documents, to answer the question whether it is in principle possible to meaningfully cluster Web pages. Although the study only looked at a group of ten subjects, there was an extremely notable lack of correlation between the clustering of any two individuals. Indeed, the low correlation achieved when subjects only had access to URLs and titles dropped further when subjects were given access to the full text of the documents referred to (Macskassy et al 1998). This is a startling result to anyone wishing to achieve meaningful classifications as it implies significant differences between individuals (let alone groups) when making classifications. What is remarkable then is our ability to understand and use the classifications of others

? ambiguity, homonymy, synonymy and related issues make it seem unlikely that consensus will ever be reached about categories of any sort. Within a given field, a community of practice can usually come to a fairly high level of agreement about terminology, although there are potential dangers. Lakoff’s eponymous example of women, fire and dangerous things provides an interesting example. In the Dyribal language, everything is classified into one of four divisions, Bayi, Balan, Balam and Bala. The only one of these that most of us might recognise is Balam, which is essentially non-flesh food, fruit or vegetables. Bayi includes men, most fishes, some birds, the moon and some spears. Balan includes women, dogs, some fishes, most birds, some spears, scorpions, anything connected with water or fire. Bala includes parts of the body, meat, bees, some spears, most trees, grasses and so on. Even after years of analysis, researchers found it difficult to apply these categorisations, although eventually it was possible to discern consistency in most applications of them, much of it relating to the mythologies that surround them. What is significant is that, even when an ostensive definition can be provided, it is not necessarily clear what it is that makes a classification apply for a given community. If we are to think about ways of building systems, it probably makes sense to look at relatively small and tightly focussed communities rather than attempting to embrace the entire Web, an approach that will be utilised in the CoFIND system discussed in Chapters six and seven.

Information Retrieval issues

With the advent of the web, traditional methods of finding resources using classification and cataloguing to aid information retrieval (IR) have either been forgotten or discarded. Consequently we see a wide range of classification schema, many of which are clearly not produced by knowledge professionals. Yahoo, for example, uses top level categories that are disorganised and barely meaningful:

> The librarians at Yahoo! Divide the world of knowledge into fourteen broad classes of unequal status (Education, stands next to Entertainment) and variable types (Arts & humanities, Reference, Regional).
>
> An expansion to the second level in the organization of the discipline Education shows more of the same absence of distinction between various categories of resources, and lack of direction as to what aspect of a complex subject...has been given priority in the classification of the resources.
>
> (Hudon 2000)

Faced with such disorder, free-text searching has become the order of the day, despite its known shortcomings (Crawford 1999). Search engines are growing in sophistication from the simple content-based systems such as Alta Vista (http://www.altavista.com) to second generation systems such as Google (http://www.google.com) and Clever (http://www.almaden.ibm.com/cs/k53/clever.html), yet all are floored by the wealth of information hiding in a mass of dross.

Google is amongst the best and most relevant of all current search engines due to its second-generation collaborative filtering engine and vast collection of resources. A search using Google on August 7th 2000 for “Ethernet” revealed 1,780,000 results. Narrowing the field by trying “Ethernet tutorial” reduced the number of results to

39,700. This is still an unfeasibly large number of results to wade through. Although many of the results were clearly not relevant, there was a sufficiently large number to make the task of sorting through them fiendish if not impossible. Narrowing the search helped to bring some useful sites to the top, but it is impossible to tell how many useful sites were lost in the farther reaches of the search results. Random browsing through many pages still revealed potentially useful resources up to the point at which Google automatically cut off, 794 results into the search. Adding the word “beginners” reduced the response to 3,200. Unfortunately there is no clue as to what else might have been lost along the way by narrowing down the search query, leading to the loss of “Ethernet 101”, “Ethernet Getting-Started” and so on. Also, there are many aspects of Ethernet that we might wish to find out about- there is a big difference between a training manual on how to implement the technology as opposed to a theoretical model explaining the concepts behind how it works. There is a strong case for teaching the skills of searching, but even the best professionals may fail to find the most relevant and useful resources. Part of this problem relates to being able to phrase the right question. When seeking information in a new problem domain, the learner may have insufficient knowledge to enter relevant keywords, a point noted by Heylighen: “in order to select relevant keywords, the user already needs to have a clear idea of how a potential solution would be formulated " (Heylighen 1999). The need for effective IR systems on the Web is a pressing concern.

Quality of Information

When considering the needs of education, a significant issue is that of the quality of the information returned by a search. Valovic (1994) provides a useful framework for identifying the quality of information (QOI) which he breaks down into:

? time value of information- information half-life

? scope of information- how many people it affects

? authenticity of source – how verifiable is this

? dissemination value- if information has been widely disseminated it may be less useful to an individual or organisation, at least in a business context. Of course, in a broader sense, the wide dissemination of hurricane warnings is probably a good thing and the effects of bad news on stock prices may have at least some beneficiaries.

A theme that will be returned to later is that there are many other potential dimensions of quality and that these are hugely context dependent. Valovic makes it clear that information is not simply 'good' or 'bad' but instead may be categorised and evaluated using many different criteria. This point is taken considerably further by the DESIRE (Development of a European Service for Information on Research and Education) Project which identifies scope policy, content criteria, form criteria, process criteria and collection management criteria as critical factors affecting judgements of quality in a given Web-based resource. Within each category they list a variety of important criteria for the evaluation of resources, as indicated below:

1 Scope Policy: Considering your Users

? Information Coverage

? Access

? Cataloguing Policy

? Geographical Issues

2 Content Criteria: Evaluating the Information

? Validity

? Authority and Reputation of Source

? Substantiveness

? Accuracy

? Comprehensiveness

? Uniqueness

? Composition and Organisation

? Currency, and adequacy of Maintenance

3 Form Criteria: Evaluating the Medium

? Ease of Navigation

? Provision of User Support

? Use of Recognised Standards

? Appropriate use of Technology

? Aesthetics

4 Process Criteria: Evaluating the System

? Information Integrity (Work of the Information Provider)

? Site Integrity (Work of the Web-Master/Site Manager)

? System Integrity (Work of the Systems Administrator)

5 Collection Management Policy: Considering your Service

? Collection Coverage and Balance

? Availability of Internet Resources

? Availability of Library Resources

(Hofman & Worsfield 1996)

This is an excellent piece of research based on many correlated studies (including six in-depth user surveys and twenty-two sources listing Web-site quality criteria), which gives a strong indication of the kinds of issues which are going to be important to users seeking resources. The categorisations provide a useful framework, but they do not begin to scratch the surface of any given user's potential specific evaluation criteria for a given set of search needs. Hofman & Worsfield implicitly acknowledge this by giving further sets of subdivisions and examples of use, but DESIRE is just a framework. It is easy to think of examples of useful value criteria (e.g. "cuddly," "funny," "reflective") which may be shoehorned into these quality selection criteria but where the framework has little obvious relevance to the searcher.

Novelty

Karamuftuoglu provides us with a useful analysis of the forms and uses of information retrieval (IR). He identifies two distinctive uses of IR, the transmission of knowledge and the production of new knowledge, the latter of which tends to be under-represented in the literature and daily practice of IR professionals and amateurs. He correctly points out that a great deal of the purpose of IR is to do with identifying often-unforeseen connections between retrieved items (Karamuftuoglu 1999). In such cases where connections are to be invented, the information required does not exist (or there would be no need for invention). Learners exist in a context where, for them, all knowledge is new, but if we can capture the connections others have made, then the productions of some can become the transmitters to others.

Approaches to resource discovery

In a traditional educational system, resources are usually discovered and explored with help from a teacher, but the example of self-taught learners shows that this need not be so. Learners may make use of self-teaching books, for example, or each other to discover a subject. Networks provide a potential to share the burden of discovery efficiently. One individual may discover or create a small number of resources. Many users will be more likely to discover or create many resources. Computer networks allow these discoveries and creations to be shared. Diversity and conflict between ideas that arise generate a knowledge ecology. Malhotra writes:

> Just as natural ecologies thrive based on species diversity, knowledge ecology thrives on diversity of knowledge. Such diversity rests in co-operative competition: the various knowledge nodes collaborate *as well as* compete based on their differentiating characteristics.
>
> Knowledge ecology treats knowledge creation as a dynamic *evolutionary* process in which knowledge gets created and recreated in various contexts and at various points in time
>
> (Malhotra 1998)

Systems which allow this 'co-operative competition' will incorporate methods for communication and sharing, as well as providing a rich diversity of knowledge to be drawn upon. Networks, especially large ones like the Internet, provide these special opportunities for mediated communication and resource sharing. They allow the creation of various different 'landscapes' for interactions to occur, as a means of structuring and controlling the ways in which users react with other users and learning resources. In the next chapter I will explore many fascinating examples of systems which make use of and enhance this effect, but there are plenty of instances where these landscapes are quite perceptible with minimal assistance. The rest of this chapter looks at how such landscapes occur and the limitations of a relatively 'raw' approach to identifying them.

The Small World Web

Brown and Duguid (1995) have observed that all documents are in some sense related, whether on the Internet or not:

> From turned down pages, to notes on a dust jacket, to academic essays, to fan zines, to direct quotations and indirect allusions, to stories lifted for future retelling without attribution, we are always commenting on texts, which continually intertwine in a process grandly known as "intertextuality." Documents are not, then, independent. Like biological organisms, every document is always related to some other.

The connected nature of the Internet reifies these connections and multiplies them inordinately. The notion of a "small world" topology refers to a network with highly clustered nodes. The classic example is the "Six Degrees of Kevin Bacon" game, wherein the object is to find the shortest path from any actor to Kevin Bacon. An actor with a Bacon Number of one has appeared in a film with Kevin Bacon, an actor with a Bacon Number of two has appeared in a film with an actor who has appeared in a film with Kevin Bacon and so on. It turns out that it is extremely difficult to find actors who have appeared in films with a Bacon Number of more than four (Adamic 1999). Adamic has analysed the Web to find that it too has a small world topology. It is this feature that gives the Google search engine its power, as it identifies the degree of linking to a given page from other pages. Giles reports on research at the

University of Notre-Dame which suggests that, of the billion or so pages available on the web, the average distance between two randomly selected pages is in the region of only nineteen clicks apart (Giles 1999). This clustering phenomenon suggests that even without the aid of adaptive hypertext there is at least a certain amount of self-organisation occurring on the web. Adamic reports on a strongly connected group of sites relating to the pro life and pro choice communities by examining cross-links within them and is able to conclude that the community of pro lifers is more tightly knit and better organised than that of the pro choicers. Lempel & Moran (2000, pp. 387-409) also investigate and confirm the same range of clusters which exhibit the TKC (Tightly Knit Community) effect as a means of proving their own LHA (Latent Human Annotation) algorithms. Simply through the independent linking of pages, the Web in its 'raw' state might provide at least the beginnings of the organisation required to structure knowledge.

Web visualisation systems

Kleinberg and others have capitalised on the inherent patterns within the web, leading to systems such as CLEVER (Kleinberg 1998), SALSA (Lempel & Moran 2000, pp. 387-409) and Google (http://www.google.com). These systems iteratively mine the Web for clusters, based on an analysis of in-degree and out-degree in hubs and authorities. Information that Kleinberg describes as latent human annotation (LHA) is condensed and purified, resulting in emergent patterns indicating popular and probably relevant sites of interest, given a few keywords. Although such sites may be authoritative and even good, LHA- and citation-based systems are not particularly likely to be helpful to learners. This is because the kind of structures which are found are not of a form which corresponds to the kinds of structure I have identified as being generated by teachers. Although a system such as Google will provide us with implicit metadata (discovered resources are displayed in order of relevance, hence we are looking at implicit metadata describing degree of relevance) it does not capture the context in which the data are to be used. It does not tell us whether what we visit will be useful to us at our present stage of development, whether we should look at something else first, even whether the information we are presented with is within our frame of reference. Unlike a teacher, the only significant value criterion used by such a system to describe a resource is its popularity. In a sense, we might treat this as a single dimensional system, where value is plotted on a straight line.

An extension of the principle of clustering by indegree and outdegree as used by search engines such as Google and Raging is taken further by visualisation systems based on data mining, such as Document Explorer, Harmony and Narcissus (Fowler, Fowler & Williams 1996). These systems provide a visual indication of the relative popularity of a resource and the degree of linking to other such resources, thus identifying emergent structure based on the principle of LHA. By providing a visual representation of these links, the inherent structure of clustering in a group of Web pages is highlighted, allowing the identification of emergent order based upon the independent decisions of individual authors to provide links from their Web pages. This is a powerful example of self-organisation, although it does not provide a path through the resources nor give any clue as to why the pages might be considered popular: there is no semantic linking here. It is possible that such authorities will turn out to be sites that have been advertised for money rather than placed there because of their intrinsic value. Even if means of avoiding such hubs are implemented (and Google uses a variety of strategies to do so), there is still no indication of the pedagogic value to a learner. We can identify self-organisation but not to instructional ends. A closer approximation of a pedagogically useful system is provided by the newcomer WiseNut, which also employs an LHA algorithm but makes use of clusters of keywords in referring as well as referred documents to mine an extra dimension of categorisation metadata (WiseNut 2001). This only helps with identifying broad topics, however.

It appears that Web resources exhibit some self-organising characteristics. We now turn to ways that self-organisation of some sort can also be seen in communication media such as the interactions of a simple discussion forum.

Discussion fora, flora and fauna

In looking at the ways that networks can assist the development of self-organising learning environments we do not have to stray into the realms of the exotic or unusual. Take for example this extract from the late Tom Creed’s seminal article *Extending the Classroom Walls Electronically*:

> ... my students E-mail me their written homework assignments two hours before class. Not only does this allow for incubation for them, but it provides a unique and invaluable classroom assessment technique for me. I can read my students' submissions before class, which allows me to assess what they know BEFORE class begins--I go to class having a good idea what they know and where the problems with their understanding are. This allows me to skip

> material that they seem to know well already, and concentrate on the areas where there are widespread weaknesses. In addition, I read their Make Up Your Own questions, so I can address the topics that they have already identified as being of interest to them. Similarly, the ongoing discussion on our electronic conference gives me vast insight into how they are viewing the more controversial areas of the course. Our discussions are enhanced since we all have an enlarged shared cognitive set--we all know what each other is thinking about the topic.
>
> (Creed 1996)

In this simple system we see many of the hallmarks of a classic self-organising system. One agent (the student) affects another (the teacher) which adapts its behaviour and thereby affects the original agent and so on in a rich cycle of adaptation and self-adjustment. In this example the teacher is an important part of this system and plays a significantly different role from that of the students. Given our goal of self-organised learning, this is too hierarchical, relying on a single agent to provide structure. What I will be aiming for is to see such significant roles of the teacher either as an emergent property of a system or as a set of roles that form from the randomly differentiated learners who make up the system.

A self-organised learning environment is not unusual, as least in part. The concept of the seminar, with its structured presentation/discussion approach encourages the development of learning simply as a result of the interactions of students, perhaps but by no means always with some teacher-mediation.

Murphy et al (1999) discuss a number of uses of CMC (Computer-Mediated Communication) technology to provide support for self-organising groups of learners. Technologies used varied from BSCW (Basic Support for Co-operative Working, at http://www.bscw.de) to MOOs to FirstClass, providing a variety of integrated and less-integrated tools for asynchronous and synchronous discussion. In each of the instances reported, the students were not exclusively taught using CMC and (more significantly from the perspective of this thesis) teachers played a strong role in providing a structure for self-organised learning to occur. Teachers provided tasks, split students into groups, gave them roles to perform, and scheduled opportunities for meetings. However, there were clearly some aspects of the various systems which were organised by the students, if not self-organising in the strong sense that I am seeking. Students moderated discussions, performed some scheduling tasks, designed evaluation criteria and went through an iterative process of design and evaluation to produce project outputs. Murphy et al describe the advantages and disadvantages in terms of collaboration, relevance, learner control and technological preparation (Murphy et al. 1999). Although some of their conclusions are a little trite (“adds realism to the working process”, “synergy results from two minds working together”) there are some important insights. They note the problems experienced by some students with leadership roles and (conversely) the problems of ‘too many chiefs, not enough Indians.’ A related problem is identified as the intimidation of the less well informed or skilled. Social roles such as defusing such intimidation and providing some form to discussions are usually performed by teachers and are important to the smooth running of a designed system. If we are to build a self-organising system then these issues need to be taken into account. On the positive side, Murphy et al talk of the benefits of shared workloads, multiple approaches and diversity, control of time and pace and advantages of students learning from each other. They conclude that “group formation and group dynamics are critical to the success of collaborative learning and peer-directed activities.” Establishing the means to allow social networks to develop without losing the periphery is definitely a concern, although it is hard to tell from this study the extent to which the teacher’s control and need to retrofit the results into an existing system causes the need for the particular kind of roles that Murphy et al see. A similar problem affects my own studies. Subsystems of learning cannot be divorced from the systems of which they are a part. It is quite difficult to identify the effects of other parts of the system on the development of new subsystems.

My own studies

> Messages are themselves a form of pattern and organization. Indeed, it is possible to treat sets of messages as having entropy like sets of states in the external world. Just as entropy is a measure of disorganization, the information carried by a set of messages is a measure of organization. In fact, it is possible to interpret the information carried by a message as essentially the negative of its entropy, and the negative logarithm of its probability. That is, the more probable the message, the less information it gives. Clichés, for example, are less illuminating than great poems.
>
> (Wiener 1950, p.39)

Weiner’s description of messages as a form of pattern suggests that we may be able to treat messages and their interactions as elements in a self-organised hierarchy. It might be possible to consider the interactions of a newsgroup in support of a set of learning objectives as a self-organising evolving system. The following section builds on work first described in (Dron, Mitchell & Siviter 1998).

One of the most useful types of resource for groups of learners with shared interests is the asynchronous discussion forum, exemplified by Usenet News and Webboards

(Web-based discussion fora). This study looks at ways that self-organisation might arise within them.

Methodology

The three cases that are about to be described make use of the students' own comments either in the forum or in reflective documents about the exercises. No structure to these comments was imposed and no questions were asked to elicit the responses, which may thus be seen as fairly freely given. The purpose of this study is to interpret, not quantify. This is not an objective study, as (for example) the various agendas of the students themselves may well have influenced their behaviour, perhaps perceiving that they might achieve better marks if they pleased the tutor with meta-comments on the process, or maybe merely wishing to better organise their thoughts on the learning achieved. The comments are reproduced as originally written, without any corrections to spelling, punctuation or grammar.

The first study: raw fora

To investigate the power of newsgroups to facilitate self-organised learning, I created an exercise for a group of level one computing students of very mixed abilities (Dron, Mitchell & Siviter 1998). The students were set the task of exploring a topical subject at the time, that of net computers (NCs) versus personal computers (PCs). This was selected as being not only topical but also a 'wicked' problem. Wicked problems are a "class of social systems problems which are ill-formulated, where the information is confusing, where there are many clients and decision-makers with conflicting values, and where the ramifications in the whole system are thoroughly confusing " (cited in Buchanan 1995, p.14). The great advantage of setting such a problem is that there is unlimited scope for argument and discussion, thus fully enabling the process of conversational learning via teachback proposed by Pask and discussed in Chapter one (Pask 1976). The students were required to use this newsgroup for discussions and asked not to discuss the issues using other means.

The group of 102 students on a basic computer skills module known as Personal Computer Concepts were given no background information and none had any significant prior knowledge of this topic, although some were a lot more experienced with and capable of using computers than others. The exercise took the form of an assessed assignment and was set to last for two weeks. I explicitly avoided participation in the discussion myself, so that the students knew that they were on their own. Thirty percent of the marks for the assignment were given for level of participation in the discussion, with the remainder going to reflective summaries of the discussion presented as Web pages. None of the students were expert news users, though all had taken part in a simple introductory tutorial.

Results

An average of around 2.5 messages per student were posted, with a maximum of twenty from one student and five students not contributing at all. Two hundred and fifty messages were posted in total.

Most of the students believed that they learnt something and it was clear that the newsgroup had played an important positive role in this learning experience. The students' reflective summaries were mostly very positive with regard to the conversational processes of learning engendered through the use of the newsgroup. For example, these comments from various students demonstrate their growing awareness aided by others:

> "I found the newsgroup to be beneficial in both learning facts and gaining a wide variety of views that I had not considered. This is the first time that I have participated in a discussion of this sort and I was pleased to find how well it worked in providing fact and opinions and then prompting relevant discussion."
>
> "There are various opinions on this Newsgroup, some of which I agree with and others that I do not. The main benefit of this group, to me, was how items have been discussed that I hadn't realised or thought of."
>
> "I felt that using the newsgroup for this exercise was a good idea as it was very useful to see volumes of opinions on such things as NET PCs, Web TV etc. Before forming one of my own."

Coming from the students themselves, the level of technical knowledge was well adapted to their own level of understanding, as demonstrated by these two comments:

> "The discussions that have occurred as a result of the ... newsgroup have been very productive. To begin with those students who had difficulty defining the topics involved have been able to seek the help of their peers. This has been beneficial to everybody mainly because the explanations that have been posted have been in the answerer's own words, not jargon from a book or magazine."
>
> "The discussion was good because it made it easier for people to understand what was going on as it was in people's own words."

Movement from a lesser to greater knowledge was apparent with the passage of time, with a limited amount of structure to that knowledge imposed by the hierarchical threading of messages. Broadly speaking, messages towards the end of the thread conveyed more refined knowledge than those at the beginning, although this was not always clear nor consistently the case.

Although there was a modicum of evidence supporting the self-organisation of learning, there were some notable problems that show a failure of the newsgroup discussion to adequately organise itself to improve the learning experience of the students. In particular, I identified *trust & reliability, losing the thread, lack of differentiation between messages* and *hostile postings* as being particular issues, which I discuss at length below.

Trust and reliability

In keeping with Powell's comments on tutorless groups (Powell 1974) there was some uncertainty expressed about the reliability of messages posted. Several students commented on the problem of trust in the authority of their peers. One student noted:

> "Having scanned through the messages 'posted' on the newsgroup – I realised that there were a great number of people, like me, with very little knowledge on the subject in question- but there were a few prolific 'posters' who seemed to have a good technical understanding of what was going on. Unfortunately, despite the latter group, a lot of basic questions posed by students remained unanswered. Hence, I found it difficult to build up a solid picture from all the little snippets."

Several interesting issues are raised by these comments. Although a lack of trust is indicated, there is also a suggestion that some students became recognised authorities very quickly. This is self-reinforcing mechanism, as Heylighen (Heylighen 1999) observes, pointing to simulations performed by Gaines where "individuals who were successful in solving a particular type of problem are more likely to get problems of that type delegated to them, and thus will develop a growing expertise in the domain." This view is strengthened by the fact that those perceived as having authority were also the more prolific posters of the group. This feature can often be seen in mailing lists and newsgroups alike. It is reminiscent of the notion of 'key species' alluded to by Watson (1999), those "irreplaceable species and functional types" Watson claims are analysed by Grimes as being more important to a functioning ecosystem than simple diversity. Whether or not this notion is correct, it is clear that a few posters had a disproportionate effect on the functioning of the group as a whole and that this is a pattern seen in most online discussions. Without the incentive provided by marks it is highly improbable that more than a few of the students would have participated at all. In large, public groups, this is endemic.

> "A recent survey by a computer consulting firm in Chicago found that 98 per cent of the visitors to large sites with open forums - from AOL and MSN to sites like Slashdot - never submit ideas or articles and never post opinions or participate in arguments. "
>
> (Katz 1998)

The amount of lurking (reading without posting) within an online discussion varies from group to group. For example, Preece (2000) reports that in health support groups lurkers may comprise less than half the total of "participants" in a discussion group. It is far from clear that lurking is necessarily an evil practice, and there is some doubt about research methodologies which have tended to look at groups over a limited period to identify lurkers. I am a subscriber to some mailing lists to which I contribute once or twice a year, which I judge to be more than adequate in those contexts, but I would be considered a lurker in studies such as that of Sproull & Faraj (1977, cited by Preece 2000) which looked at contributions to a discussion over a single month to find that 80% of people subscribed to the discussion were lurkers. In my quiet periods I am still actively immersed in discussions which I follow closely.

The problem of building up a picture from small snippets is a more pernicious danger than lack of trust or (worse still) inappropriately placed trust. One of the key roles that I have identified for a teacher is that of an organiser of information. To recap, this organisation involves (in an ideal world) selection and sequencing of material appropriate to a learner's needs. Without this role, the snippets of information to which the student refers may remain disjointed and incomplete, at least in relation to the topic as defined by the teacher. If the choice of learnt material were in the hands of the learners, there would perhaps be a very different definition of incompleteness, in terms of the needs of the learners rather than the prescriptions of the perceived 'expert'. Within the context of the exercise, however, there was an apparent movement from a state of little knowledge to a state of greater knowledge throughout the study, but that knowledge belonged mainly to individuals. From a broader systems perspective there was a lot of barely differentiated information but little consensual group knowledge[1].

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[1] . An extreme example of the same sort of phenomenon occurred to the article just cited (Katz, 1998) which, after its original publication which when printed fitted into a neat six A4 pages, gained comments totalling around 80 pages over the following two days. These comments ranged from the completely puerile to the truly profound, but the latter style of message was hard to find, especially as that particular discussion was not threaded

Losing the thread

There was a certain amount of drift from the set topic, which might be seen as an indicator that the guiding role of a teacher is valuable. In particular, a whole thread formed about the future of the floppy disk that was at best tangential to the main discussion. As an evolving method of learning this seems appropriate and potentially rewarding, with the possibility of allowing students to follow their own interests. However, the main reason for this occurrence seemed to be the students' limited knowledge of the subject, leading them to feel their way into adjacent territories. The species did not survive for long, self-organisation setting in when it was noted that this was not a fruitful line of discussion. That said, this provides some evidence that mutation and variation can occur quite unexpectedly and it was perhaps just bad luck that this particular variation was unsuccessful.

Undifferentiated volume of messages

Mostly through the students' lack of experience, few threads developed further than three or four levels deep, with a fair number of posted replies being sent as the start of new threads. The lesson here seems to be mainly that any technology has a learning curve. Given time, learners would probably come to grips with the possibilities afforded by the technology, but two weeks was apparently not long enough for this to happen, even for a low-threshold application like news. The lesson we need to draw from this when building our own self-organising environments is that the technical hurdles of using it should be kept to a minimum. Perhaps Kelly's maxim that systems should grow by chunking (Kelly 1994), building larger from smaller systems might be appropriate. Revolutionary systems are inherently harder to master than those with which learners are familiar.

A further issue relating to this undifferentiated volume of messages was the massive interconnectedness of it all. Completely at odds with Kauffman's prescription for limited connectivity to drive a self-organising system, there was maximal connectivity between all parts of this system. It is possible that all that saved it from total chaos was the previously mentioned emergence of recognised experts, who provided some focus to discussions and recognisable stability in the form of reliable postings.

Hostile postings

One student became quite aggressive in his postings. Within the controlled environment of this exercise I was able to stop this with a single email message, but it could become a significant problem in a self-organised environment. Flaming (the posting of aggressive messages) is a common problem in newsgroups and mailing lists in general and eventually, like a forest fire, will usually die out of its own accord without destroying an entire newsgroup. Indeed, in moderation it probably provides a useful means of feedback control, preventing careless or unintelligent/uninformed postings. However, the casualties along the way are those who are dissuaded from posting for fear of reprisal. This is a clear instance of a self-organising evolutionary environment, but it does not adapt to better suit the learners. Instead, it sets up a predator/prey relationship in which only the mean or resilient survive. There is a lesson to be drawn about the role of a teacher as moderator, which needs to be incorporated into any self-organising environment that we may build. It might also be worthwhile to investigate ways of making the effects of flaming less traumatic to its victims.

Technical problems

The students mostly used Netscape News (version 3) which had a number of ‘features’ thankfully removed in version 4 and above. In particular, the default settings limited the number of messages downloaded to one hundred at a time. This meant that some students posted messages then thought that they were lost.

Due to security restrictions on the University of Brighton News server, students attempting to gain access from home were limited to using Pine or Tin via Telnet, which were universally detested to the point that no one used them. Technical and interface problems are a feature of any interaction with a computer system. A system with the soundest theoretical basis will fail if it cannot be used. Even a well-designed and reliable system requires users to learn different ways of seeing and behaving.

Conclusions to the first study

Although many useful lessons were learnt (in at least two senses of the word) the newsgroup showed itself to provide at best limited support for self-organisation. My own involvement was a major factor in shaping, but I was not seeking autopoiesis (the system pulling itself up by its own bootstraps), merely for signs of self-organisation within the strictures of the environment. As Churchill put it in a speech made in the House of Commons on October 28, 1944, “we shape our dwellings and afterwards our dwellings shape us.” (Grothe 1999). The biggest obvious problems were lack of experience with the medium, trust & reliability, and losing the thread due to the myriad of entangled interactions.

The second study: Adding structure.

Lessons learnt

I identified a range of issues arising from the first study. Some of these could be traced to lack of knowledge or experience on the part of the students, especially technical problems, inadequate use of threads and lack of knowledge of netiquette. These problems could be solved by providing experience and traditional tuition to students in the use of the medium. Reliability and losing the thread could not easily be resolved this way, however. Reliability was an issue that I was not yet ready to deal with, but I devised a further system to enable students to learn which attempted to deal with the organisation problem by imposing a structure on the discussion.

The second study took place some five months later than the first. It involved a group of 32 students enrolled on a one year MSc Information Systems conversion course, studying network technologies. The students were similarly lacking in familiarity with computers as the first group, although in other ways (especially in terms of commitment and prior education) they were quite different. The task was also significantly different, though again involved the discussion of wicked problems. For the purposes of this piece of research these differences did not seem significant as its purpose, like all the research I have carried out for this thesis, was to identify potential avenues of development, not to answer questions which had already been posed.

I had ensured that the group was much more familiar with the technology than the earlier group, to which end the students were given a tutorial at the beginning of the course, followed by a two-hour tutorial with exercises just before the assignment. From the start of the year they had been repeatedly encouraged to use the newsgroup for course-related communication and it had been well used by around half of the group, with evidence that nearly all the remainder spent time lurking. This was strongly encouraged as last minute changes to timetables and other such announcements were posted to the newsgroup, sometimes as the only source of such information. As it was also being used to aid administration (events and new timetables were posted there throughout the course) most of the students were familiar with reading Usenet news and many had used it to seek assistance.

The assignment

The assignment involved producing a report for a semi-fictitious company called Fax-Vobiscum, specifying a network for the company as it moved into new premises. The students were familiar with the company, as I had been using it as an ongoing case study in conventional tutorials for some months. To make it more realistic, I used Web pages to give a lot of information about the company, its employees and current infrastructure as well as its plans for the future. I included biographical data, a photograph of the building and a sample of the work produced by the company. The pages contained links to sites containing technical information and tutorials to help complete the assignment, but as there was a lot of written material I also issued the notes in paper form to minimise the effort required for tasks unrelated to learning.

In consultation with the students (although I was explicitly intending to intervene as a sky-hook, in the spirit of self-organisation the students' contributions to the environment were as important as my own), I created the structure of threads shown in table 4-1.

Table 4.1 – thread structure in the MSc networking assignment newsgroup

Thread	Purpose
Networking assignment-	All messages were sent as part of this root thread
-Ask Jenny...	This thread was used to post messages to the managing director of the company. Messages appeared to be replied to by 'Jenny' (with the students' knowledge, a role played by me).

Thread	Purpose
-Post useful URLs here	This thread allowed the students to share relevant information they had found on the web. This provided a mechanism for the students themselves to act as resource filters for each other, without reliance upon a teacher.
-Post URLs of finished work here	This thread required students to place pointers to their finished reports, all of which were accessible via a Web browser. This allowed a feedback mechanism to develop whereby the students could reflect on each-others' approaches to the assignment.
-Assessed	Each sub-thread here represented a seeding message designed to provoke discussion. Participation in the discussion was assessed together with the technical content of the messages.
--Fast Ethernet	Seeding message: "Fax Vobiscum need a fast Ethernet solution for their LAN. There is no other rational alternative."
--Firewall	Seeding message: "Assuming that they need a firewall, what sort of firewall should Fax Vobiscum use?"
--NT everywhere	Seeding message: "What are the pros and cons of dropping the Novell fax server and making every server run Windows NT?"
--Windows 95	Seeding message:

Thread	Purpose
	“Everyone in the company should be using PCs running Windows 95”
--Reliability	Seeding message: “What steps should Fax Vobiscum take to ensure continuous uptime for their clients' servers?”
-Ask Jon...	I answered questions posted here in my role as a subject expert.
-Meta discussion	I encouraged students to post messages here on the pros and cons of the process.

The report was completed as group work by groups of five to six students and accounted for 50% of the marks for the assignment. The remaining 50% was given for individuals’ contributions to the assessed threads of the newsgroup.

The exercise differed from the earlier model in several ways:

? It was more structured. Jones et al (2000) have characterised approaches to the design of discussion environments as ranging on a continuum from tight to loose. From the previous study it was apparent that structure did not arise to any great extent. Also, given that I was always going to be a deus ex machina in setting the exercise in the first place, I wished to provide as many niches as possible in which development could occur, rather like the parcellations which evolutionary theorists suggest might lead to accelerated evolution (see Chapter two). The different elements of the exercise were clearly differentiated and signposted, so it was easier to keep the ‘jungle’ (a wild and untamed area containing the students’ reflective postings) to be kept from the ‘garden’ (nurtured space, areas where I wished to contribute). Of course, from a systems view everything was interconnected anyway, but I was attempting to build hillocks in the stuff swamp.

? I tried to minimise technical problems. Most of the work was accomplished during three scheduled two-hour sessions so that there was less need to work from home and machines could be booked for the students. As a result of the experiences of the earlier group, the students were given more guidance on the potential problems they would face and were given three weeks in which to complete the assignment.

? It was more solidly informed by educational theory. I wished to preserve a problem-based approach and to retain teachback, as the first exercise had proved these to be successful in providing a variety of perspectives and helping students come to terms with the issues. Much of the justification for structuring the threads was to provide ways to cover different areas of the Kolb learning cycle of experimentation, reflective observation, abstract conceptualisation and concrete experience:

Experimentation- a virtual persona (Jenny), was introduced as the managing director of the company and answered messages relating to the company under a thread called 'Ask Jenny...' Although not a substitute for real interviews, this gave everyone in the group the opportunity to benefit from each others' questions and suggestions and to try out ideas. Even those who did not ask Jenny questions could feel involvement simply by knowing that they could do so if they wished.

Reflective observation- I posted 'seeding' questions relating to the problem-based exercise, but otherwise these threads were allowed to grow as a jungle. I was hoping that the process of argumentation and reflection required to answer these questions would not only lead to a good knowledge base and all the advantages of teachback, but also would accentuate key issues for the report. To ensure participation, these threads were assessed. Other opportunities for reflection arose as a result of the way in which work was collected (it was publicly available for perusal so that students could critically reflect on each others' work) and in the meta discussion, a thread created so that the students and I could discuss the process of using the newsgroup as a learning tool.

Abstract conceptualisation - the thread called "Ask Jon..." gave the students the opportunity to ask questions relating to theory, good practice and particular technologies. This proved helpful in clarifying issues and making sure that the students had a solid grounding on which to base their solutions, and created a powerful student-led teaching method.

Concrete experience - I created a thread where each group left a message pointing to the location of their finished report. The report gave them an opportunity to consolidate all that they had learnt through other channels (electronic and traditional) as a final product.

Results

The "post useful URLs here" thread received eight postings, with a range of useful sites mentioned in each. If nothing else, this demonstrates that, despite no obvious personal benefit, there are learners who are willing to contribute to the group's overall learning. Most of the prolific posters appeared to be those who were in the more capable segment of the group, which suggests they might bring something closer to the subject expertise of the teacher to the system. This reinforces the results seen in the first study.

Perhaps because of applying a good deal of structure to the system, threads in all strands of the discussion grew rapidly and fairly chaotically. The meta-discussion provided an excellent tool for reflections on the learning process. One of the students commented:

> "with 32 people being forced to engage in this enterprise the quantity of information produced and the inadequacy of the display medium, I am afraid I can no longer tell what is interesting and what is not."

This is reflected by another, who wrote:

> "The medium of these strands and answering to them is getting over complicated. I wonder whether this is due to my unfamiliarity with the medium or to the impoverished nature of communication over it?"

Despite my experience in this medium I too was finding it increasingly difficult to follow the discussions. The level of the threads was far deeper than those that developed in the earlier study, sometimes reaching ten levels of replies. The phenomenon was observable even in the "Ask Jenny…" section, where I had expected no more than two or three levels of replies, given that most postings would be requests for information and not invitations to chat. Although this allowed the system to retain a semblance of organisation, the number of messages at different depths was surprisingly confusing and it was often difficult to work out which message was in reply to what. Turoff writes:

> The hierarchical classification system for comments (i.e. the content independent meta ‘comment and reply to any level’ structure) breaks down because the classification of comments into what is, in essence, a hierarchical index is impossible to keep consistent when done collaboratively by a large group.
>
> (Turoff et al. 1999)

Even within a suitably structured hierarchy, systems break down because of the inclusion of multiple subjects within single messages. Turoff et al note the use of professional indexer and editor roles in the TOPIC system as one incomplete answer to the problem but it seems that the basic hierarchical mechanism found in most discussion fora is not up to the task of organising messages effectively. There are several related problems here.

? the interface to a hierarchy is visually confusing and not friendly, even when good use is made of expansion and contraction of branches of the tree

? like Nachmias et al (2000) I observed a change in transactional patterns from those of the earlier group, moving from the simple root-based shallow hierarchy of the earlier group to a more sophisticated set of relationships between documents

? perhaps because of the greater sophistication of the group, the narrow confines of a hierarchy proved inadequate for many students. Here is a small sample of postings illustrating the students’ efforts to overcome the hierarchy by referring to postings elsewhere:

> “ On the issue of using an existing staff member to double up as network manager, Jenny responded to Zoe by saying that all her staff are either too busy, not sufficiently qualified or not in the office enough. The answer is clearly to appoint a new member of staff. He/She could also provide training for existing and new staff (as they arrive) and general PC support.“
>
> “I would like to support Pip's suggestion that we get back to basics -and would like to quote Dan in support of this suggestion! “
>
> “I think this would be done by routing those without passwords using the dual-homed gateway Pip was refering to”
>
> “This takes me on to a point Jonathan made
> > ...It doesn't matter whats the best technically”

There were many more examples of references to messages at some other branch in the hierarchy, which suggests strongly that, were a mechanism available, a more flexible networked means of discussion might be helpful and lead to emergent organisation. Of course, with too many connections it might lead to chaos. There is room for innovation here, but the single connection provided by the threading mechanism is reminiscent of the kind of connectivity in NK networks which Kauffman identifies as leading to a Stalinist regime (Kauffman 1995).

Structure and guidance

By creating a distinct structure and explaining what I considered to be good practice, I had placed a number of constraints, some of which were clearly stultifying. One student wrote:

> "We receive guidance in how we are expected to contribute to the exercise which could be seen to have shaped the way we went about it. Could we not have collectively decided that there was another way we wished to go with this ?"

Despite trying to take a back seat and to enable self-organisation to occur as far as possible, I had already made my mark by imposing the structure and criteria for excellence of the exercise. One of the previously identified roles of a teacher is to establish the scope and then allow students to explore the realms that lie within that scope, but it was difficult to decide the boundaries between interference and appropriate guidance. It is important to make work as relevant to the students' experience as possible and to teach them what they need to learn when they need to learn it, or at least to make it clear why they are doing something. A student wrote:

> "How about some more spontaneous threads that really reflect our real interests/concerns? "

This is an important issue, relevant to William Glasser's Control Theory, of which On Scope Associates write, "If students are not motivated to do schoolwork, it is because they understand schoolwork as unconnected to their basic needs" (*Funderstanding-About Learning* 1998). This view of intrinsic motivation arising from a genuine interest in the subject is a vindication of my quest for emergent education, based on learners, not the demands of teachers and the systems that surround them.

Perhaps the neatest summary of the (not quite fulfilled) potential of this system comes from a student who wrote:

> "One of the potential advantages of this form of exercise is that it brings the possibility (for the first time on this course? with the possible exception of self-organised pre-exam revision

> workshops) for the group to take charge of an exercise and pool its not inconsiderable collective intellect."

It is clear that an unadulterated newsgroup, particularly where the footprints of the teacher are so visible, only provides partial support for this process. There is a strong need for more support for structure and control emanating from the participants themselves.

The outside world intrudes

The students had worked together for seven months or more and knew each other as well by email address as by name. One student wrote:

> "if we were posting using aliases then maybe people would be more comfortable adding their point-of-view. 'Real' Newsgroups are usually global with the participants having no personal knowledge of each other which makes this exercise slightly artifical"

This opinion was confirmed by a personal mail message I received from a student, which started:

> " Before I reveal my question to the newsgroup (these things worry me somewhat as I feel that my question might be obvious or irrelevant) what... "

I replied that he had a sensible question and even if it were not, others would share his confusion. After my response he became one of the most prolific posters, a clear indication of a continuing important role for the teacher as guide and motivator in an increasingly student-led environment. If this role is to be supplanted by a self-organising system, some method of avoiding the embarrassment of getting it wrong in public (and persistently) must be created. Perhaps one method for achieving this would be to follow Creed's example and to allow anonymous contributions (Creed 1996). However, without a controlling mechanism, such a technique might open up a system to potential abuse- the problems of flaming are a particular worry.

The artificiality of the exercise is a concern that is reflected somewhat differently by a student who wrote:

> "Sometimes I am impressed by the absurdity of this excercise. To find Dan and Graham writing to each other when they sit side by side in class is bizarre".

Graham himself had a ready response to this with which I agree:

> "It would be wouldn't it? Except of course that we're writing to no-one in particular and everyone in general."

News is a medium that provides a new means of interaction. As Andrew Feenberg writes, “the difference between retrieval and repetition no longer correlates neatly with the distinction between writing and speech” (Feenberg 1987). News is more than just a way of discussing issues, it becomes a kind of Answer Garden (or Jungle) (Ackerman 1994) by its very nature, formalising and making public the informal processes of discussion. However, the degree of self-organisation is limited by a combination of the inherent structure and (perversely) of the lack of structure that relates to the organisational needs of the students.

The third study: adding stigmergy

The imposition of structure seemed to have had a moderately positive effect on the growth of discussions, but the issue of trust still remained and it was clear that the basic hierarchies of the discussions were not adequate to provide the kinds of self-organisation based on students’ needs rather than the structural Stalinism of the environment itself.

When setting the same exercise for the following year’s intake of forty-four MSc students, I dropped the use of the newsgroup in favour of a home-grown solution, largely to examine the effects of a simple form of collaborative filtering on the ability of the system to self-organise. A subsidiary goal was to improve accessibility to students working from home, an option available to over ninety percent of the cohort. The system I created was a Web application written in Microsoft’s ASP. It incorporated most of the features found in newsgroups, with the addition of a search mechanism and a simple rating system- a button at the foot of each message saying, “I found this useful.” The results of pressing this button were fed back to the users by a simple numerical indicator showing the number of votes for each message in the message listings (Figure 4-1).

In this way I was attempting to provide a form of positive feedback which would lead to stigmergy. The forum was also divided more firmly into themes, selectable via a drop-down list, within which threads were allowed to develop. There was not enough time to develop a more sophisticated structure than the simple hierarchy.

In most other ways the exercise was similar to that of the previous year, with the significant change that instead of a “post useful URLs here” thread I provided a fullblown collaboratively filtered bookmark mechanism which was also used to post finished work (CoFIND 1) which is discussed in Chapters 6 and 7.

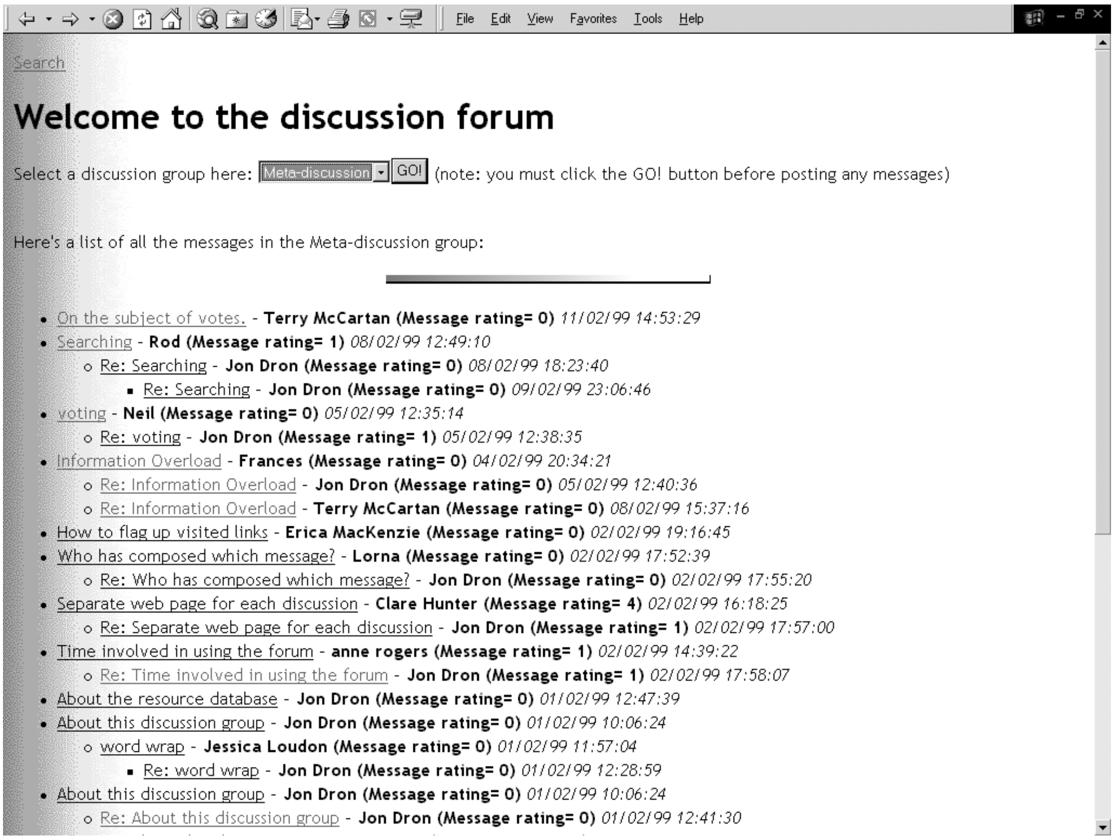


Figure 4-1 – messages with stigmergic ratings

The meta-discussion

As with the previous year's news discussion, information overload was cited as a significant problem, though only by two group members and then almost frivolously:

> "On 04-02-99 8:34:21 PM, Frances wrote:
>
> > Any one else feel like their drowning under too much information?
>
> >Yes!!! "

The voting mechanism clearly had some effect. One student wrote:

> "I ain't got no votes. Anybody that votes for any of my messages gets double back from me!
>
> How can anyone resist an offer like that? And don't worry I'm sure it's well within the rules."

The student did not get any votes this way, although it demonstrates how self-organisation might lead to a structure that achieves a non-educational goal, unless that educational goal is to understand political processes.

It is possible that the voting mechanism was helping to sort out the useful from the less useful, although this was not a controlled study and no firm conclusions should be drawn. Certainly there was a significantly greater depth of threads than for the previous year's exercise, regularly extending to fifteen levels deep. The 'Ask Jenny' thread only attracted six levels of threads as opposed to the previous year's ten, which suggests either that the replies were more appropriate or that it was easier to identify those which were useful. There is unfortunately no easy way to identify from the results whether the causal factors for the differences in thread depth were due to voting, the interface or the nature/prior learning of the group. A controlled experiment would need to be carried out to test this further.

The maximum number of votes for usefulness given to any message was twelve, with one hundred and thirty five of four hundred and thirty-eight messages receiving at least one vote and sixty three of those receiving two or more.

A large number of rated messages (sixty-nine of one hundred and thirty five) related to the 'Ask-Jon' and 'Ask-Jenny' threads, but that left a significant remainder of messages (sixty-six) posted by students in the *assessed* sections and found useful by other students, which provided some indication of the level of trust in the responses as well as their usefulness. This seems to demonstrate some potential for self-organisation.

In total, eighty-seven messages posted by thirty-three students were rated (the remainder of ratings being for my messages), a sizeable proportion of the total. However, there was a strong bias towards messages posted by a small subset of students. Again, this is clear evidence that a small community of trusted experts was emerging from the crowd. The system did not give any clear indication of who these experts were apart from on a per-message basis. If this system were to develop further it would be interesting to explicitly draw attention to well-rated experts, perhaps with a 'see other messages posted by this user' button, or with a 'top posters' list. Such a system might help to encourage a higher level of competition amongst posters, giving some sort of reward (peer-approval) for success.

Thirty-one of the one hundred and thirty five rated messages were posted at the top level of the hierarchy, and twenty-five of these were questions in the ‘Ask-Jenny’ or ‘Ask-Jon’ themes. Although none of these was highly rated (a maximum of two ratings) it is interesting that questions should be rated at all. It seems that the rating system was being used as a reinforcement mechanism, drawing attention to the significance of the question. This is borne out by four ratings being given to a message in the meta-discussion asking for separate themes for each seeding question (see next paragraph). A system designed merely to make identification of relevant information easier was adapted to further uses, rather like Gould’s spandrels (Gould & Lewontin 1979). This is clearly the kind of mechanism that needs to be encouraged when designing evolvable learning environments.

When the discussion started a single assessed theme was divided into threads. This proved unpopular with a number of students who also felt that there was insufficient range in the topics addressed. Based on their feedback, a further five themes were added. This proved popular, and prompted the following message to the meta-discussion from one user, which also provides some evidence of crossing boundaries:

> “I think the discussion groups and the resource database are an excellent method for interactive learning and better understanding of the networking issues. The discussion group was improved by dividing into themes. Some of the links in the Resource database have been very useful for gathering material for my dissertation "Wireless data transmission". “

The fact that I had to play the role of the theme designer was a limitation of the design of this exercise. However, it is easy to see how students themselves could create such themes collaboratively. To make such a system fair and effective, a means of pruning and collaborative identification of good themes would need to be devised, perhaps using a simple rating system, perhaps even through the discussion mechanism itself.

Given that the students were using an experimental system, there were a number of technical problems that were addressed via the meta-discussion. However, there was no evidence that the technology posed any greater difficulties to the users than the previous year’s use of the newsgroup.

Some conclusions to the third study

Throwing an unknown but tightly focussed task at a group of students and hoping that they will produce an organised body of learning as a result of their interactions via a hierarchical discussion mechanism has proven at most partially successful. Focus seems important, with a higher level of interaction evident given a tighter set of foci. Given that the focus was supplied by the tutor (an important teacher-role) what was hoped for was the emergence of structure within the dialogues in each of these studies. Even when assistance in the form of ratings was provided, the structural Stalinism provided by the hierarchical form proved inadequate to the task, leading to confused threads and calls for greater structure. This is at least partially in keeping with the predictions of Moore (1996), Saba (1999b) and others, with a clear interplay between levels of structure and communication. However, it seems that a certain amount of structure leads to more effective communication, which is perhaps a little unexpected. The implication seems to be that a teacher provides structure through the process of communication and, in the absence of the teacher, this structure is not readily supplied by peer interactions. The hierarchical structure of newsgroup messages is inadequate to the task. To achieve better self-organisation, more effective mechanisms are needed to provide the possibility of the emergence of structure without the aid of the tutor. The following chapter considers some potential candidates for such a role.

Creating useful learning experiences through the process of discussion and guiding learners to a meaningful learning experience through the conversation process is a complex process. Salmon, for instance, discusses a five-stage model to assist moderators of online discussions (Salmon 1998). In this model, the teacher takes on different roles at each stage. At stage one, the main roles are help with getting online and motivating students to use the system, mostly through private email responses. Stage two still involves personal emails for support and direction as the learner discovers online socialisation. Stage three involves the learner in information giving and receiving, at which point the moderator becomes a research leader, assisting the learner in finding information. Stage four is to do with knowledge construction, wherein moderator and learner work together to construct knowledge. The moderator's role at this point becomes that of a facilitator, stimulating and facilitating interaction. Stage five is the development stage, at which point the learner is becoming independent, with the moderator role mainly involved in encouraging this growth. The question therefore arises as to whether such a process might occur in a self-organising environment and, if not, why not. In my studies with newsgroups and fora, these processes were clearly present in at least the early stages. Learners needed help in tackling the technology (stage one) and some intervention at stage two when messages prevented socialisation (the flame wars). In the first newsgroup study, the intervention stopped here, at which point it seemed that the remaining three stages were achieved by at least some of the students, although it is not clear how much more effective the learning might have been had I intervened. During the second and third studies I remained involved to some extent at stage three and beyond, although the absolute segmentation of threads in which I made no contribution allowed learning conversations to proceed fairly unimpeded. We must ask what it is that the teacher adds, especially at these later stages. Salmon uses a range of somewhat imprecise terms such as “leader and supporter” and “the usual face-to-face facilitation techniques” to characterise the teacher’s roles at these points, roles which may develop in the learners themselves and are not necessarily fixed within an individual. Properties such as leadership and facilitation seem to develop more flexibly and within more limited contexts than in physically collocated groups. The early stages that Salmon identifies are problematic: encouraging and facilitating participation in novice users, especially in groups of disparate skills and knowledge, remains a problem and it is hard to see a technical solution to it. Reluctance to participate might be somewhat alleviated by the option for anonymity and by developing small groups and multiple channels of communication.

Conclusions to this chapter

This chapter has looked at ways in which self organisation can occur without much assistance from the network environment. In discussion fora in general, despite the odd encouraging sign, I can say that the answer is ‘not very satisfactorily.’ The rigid hierarchies of threaded fora provide an element of structure, but at a basic and not very helpful level. The extra layer of metadata added in the final study (the ‘I found this useful’ button) appears to have been helpful in sorting out some further layers of structure as well as to help to identify leadership and support roles, but the kinds of structure which develop are not as sophisticated as those which Salmon (1998) suggests might be needed to encourage the successful development of a learning community. The next chapter will investigate other systems that allow structure to develop in a less rigid manner.

Chapter 5 : Networked environments to encourage emergent behaviour

About this chapter

I have already identified some of the features that typify complex learning environments and we have seen how principles of self-organisation might apply in existing networked learning environments. This chapter is concerned with network-based systems that actively assist groups of learners to self-organise. It will largely take the form of a review of a range of tools which, to a greater or lesser extent, enhance the interactions of their users to bring out form or structure. The discussion will include reference to a number of systems which are not intended as learning environments but which none-the-less might assist learners and are to some extent self-organising. Houghton observes that “the qualities and durability of the system depends heavily on the systems of communication and information transfer” (Houghton 1989). I am seeking ways of bringing about communication and information transfer which will tend towards qualities that will benefit learners.

Although it will sometimes be difficult to identify the degree of self-organisation in a system, I will apply a simple heuristic to provide a coarse level of sorting. A self-organising learning environment will be one that achieves some level of organisation as a result of the interactions of its users, that organisation being unpredictable in advance by designers of the system. It is predictable that a newsgroup will exhibit organisation in the form of hierarchies, but it is unpredictable how those hierarchies will be used and the effects of feedback within the group. If there are further patterns of organisation discernible within the newsgroup, it will therefore be a candidate to be considered somewhat self-organising. To this end, positive and negative feedback loops will be sought where these seem relevant.

Lessons learnt from the systems examined in this chapter feed into the design of the CoFIND system, discussed and described in Chapters six and seven.

Structuring of content

The combination of existing knowledge with learning expertise, communication with others and the resources available on the Internet can result in all of the necessary parts being available to adult learners to constitute the educational experience provided by a teacher. However, unless these components are properly connected (structured), they may be of little use.

Teachers' roles might be duplicated by emergent patterns of user behaviour, but in most existing frameworks there is little selection pressure to ensure that structures such as these which do arise will have any sort of stability, coherence or educational value.

Structure is an abstraction of patterns that may be extracted and/or imposed. We may consider all systems thinking, all notions of structure as being explicable using metadata, data about data. We are physiologically and logically incapable of experiencing anything but abstracted data, being dwellers of Kant's phenomenal rather than noumenal world. As soon as we start to distinguish one thing from another, we are looking at an abstraction of the world, Plato's shadows on cave walls. This abstraction looks at relationships between things: A is bigger than B, A is next to B, B happened after A, B is better than A, A entails B and so on. Other abstractions we make are less obviously relational, and are more concerned with describing, evaluating or categorising content- for example, B tastes good, B is yellow, B is a fruit, B is curved. These are the kind of terms which describe structure. Structure is thus explicable in terms of metadata. Largely these metadata will be verbal, but they may also be logical/mathematical, visual, aural or even tactile.

Many of the roles I have identified for teachers in Chapter four (including selection, sequencing, mediation of communication and feedback) are largely explicable in terms of abstraction and the provision of structure.

In a traditionally taught course, structure and metadata may be implicit. Teachers may present materials in a certain order because that is what their instincts and years of practice tell them to do. They may present resources which they consider good, implicitly avoiding those which they consider bad. There is no special abstraction of metadata, because none is necessary. The metadata are implicit in the way that the materials are presented. Similarly, there is no need for a teacher to explicitly tell the students that the work they are doing is chosen because it is expected that it will be useful to them in their current state of knowing. However, if asked to describe the process, and the events and resources which are involved, it will only be possible in terms of metadata. Similarly a teacher might look at a student's work and provide feedback such as 'this is good,' 'this is bad,' 'this would be better if you learnt to spell properly.' If we seek to abstract the nature of teaching, then one way we might approach it is in terms of the metadata which characterise the educational process.

Although metadata might be abstracted by some form of data mining from the raw data, teachers are concerned with shaping, not just describing patterns in data. Based on subject expertise and (one hopes) pedagogical principles of some sort, teachers generate an educational experience. The kinds of shaping will be fairly specific to the needs of teaching a given subject, but metadata about resources will mostly fall into one of three broad categories:

1. Those which describe the subject matter (what are we looking at? What are its attributes?)

2. Those which describe its utility (why are we looking at that?) and its qualities (why is it worth looking at that and what might I get out of it?)

3. Those which describe its relationships with other subject matter and its users (when should we look at that, how does it relate to what we already know or need to know?)

Communication

At least some duplication of the functionality of a teacher could be accomplished by generating metadata that fit the three general forms characterised above. However, as we have seen, teachers do more than structure resources. They are involved in mediating communication, in responding, answering questions, assessing work and so on. Conversations, especially in groups, may be seen from a systems perspective as individual systems, each of which will be describable in terms of the same kind of metadata that would be used to describe any resource. However, within those conversations are relationships and meanings which themselves constitute a subsystem or set of subsystems, and which are generally far more dynamic than those of other resources. Metadata that relate to communication may be seen in terms of what, why and (especially) how is it related to other communication, but the potential complexity of interactions makes it a special case. This is exactly the distinction which is drawn by Michael Moore (Moore 1993) with his theory of transactional distance, where structure struggles with dialogue- as one goes up, the other goes down and vice versa. The problems with communication are quite distinct, therefore, from those that relate to the structuring of resources and, in a large networked environment like the Internet, are to do with disentangling the threads and reducing the noise of the parts of the conversations which are irrelevant. Although this may seem superficially similar to the problem of dealing with more static resources it is not. Conversational processes are always situated, with statements, expletives, performative utterances, civilities, replies and replies to replies and so on all contextual and barely meaningful outside that context. I will therefore look at systems that organise communication separately from those which organise other resources. Sometimes the distinctions will blur and there will be many instances of systems to do with the organisation of information, which are also communication systems. Indeed, they would not be included in this thesis if they were not, although often that communication will be artefactual, as abstract as stamping a chad out of a voting slip to communicate a vote for a president. In fact, some might disagree that this is communication at all. Franklin, for example, is quite specific in his use of the word:

> Communication, in the sense of the word I intend, requires the sending and receiving of signals. Is the bobcat signaling when he leaves tracks in the snow? I think not. How about the tigress marking the boundary of her territory with urine? I think so. And the difference? Intention, in the folk psychology sense, not the philosophical sense.
>
> (Franklin 1996)

As Franklin himself admits, there are some very grey areas. For example, animals' use of pheromones, flowers' displays for insects and, for that matter, ant trails all seem to communicate a message where the intention to communicate is not apparent. Accepting that the use of the word *communication* is not always unproblematic, it will be used here to refer to any occasion when a message (however unintentional) is passed from one person to another or to a group. Other forms of communication such as machine-to-machine communication are not relevant to the themes of this thesis.

Communication via electronic means can be categorised into synchronous or asynchronous modes. Such a distinction recognises that the forms that each mode takes may exhibit very distinct structures. I will therefore be looking at each mode separately.

Synchronous communication tools

Many Internet-based synchronous communication environments have been enlisted in the cause of learning, including simple Internet Relay Chat (IRC), instant messaging systems such as ICQ and MSN Messenger, MUDs (Multi-User Dungeons) and MOOs (object oriented MUDs), and video conferencing systems such as NetMeeting and CuSeeMe. Many are interesting in the context of self-organisation inasmuch as they allow individuals to create electronic gathering places which can be more or less attractive depending on the number of visitors to them. Preece observes the self-organising nature of this:

> Too few people, and there will not be sufficient discussion to retain people's interest and draw them back; too many participants, and the community may become chaotic, and people will start to leave.
>
> (Preece 2000, p. 171)

Like the well-trodden footpath, success breeds more success and a form of stigmergy can take place. However, multi-user synchronous communication mechanisms are noted for their chaotic nature, with chats often tending towards the surreal as users type in their messages in (not quite) real time. One or two systems assist in bringing some sense of order to this chaos, through processes of self-organisation.

Example: Odigo

Odigo is a client-side real-time chat application that allows annotations and discussions to centre around Web sites but with the added sophistication that it indicates who is visiting the site now. This allows stigmergic clustering to occur as users congregate on busier sites. It also incorporates a '"What's hot" mechanism to identify topics of current interest to those online, based on popularity, another subsystem which allows emergent behaviour to occur (Figure 5-1).

Figure 5-1 – Odigo community formed around Yahoo Web site

Example: ChatCircles

A particularly elegant system for real-time chatting is represented by ChatCircles (Donath, Karahalios & Vi gas 1999), a real-time chat system akin to IRC (Internet Relay Chat). It provides a graphical interface to a text-based chat system, which represents every user as a coloured circle on the screen. Those who are actively chatting are represented by bigger circles, whilst those who have not contributed fade away to small dots to represent their online presence (Figure 5-2) . Users may move their circles around the screen. They are likely to move to areas where there are larger circles because of stigmergy, a positive feedback loop where success breeds more success. The need to move is encouraged by the fact that users cannot ‘hear’ what is being discussed unless they are nearby, within the ‘zone of hearing’ of a given circle.

Histories of chats may be recorded and played back through another interface which represents individuals as vertical time lines, the messages they send shown as horizontal lines of varying length bifurcating their timelines. This graphical representation shows the shape of particular conversations, hence,

> The sequence of growing and shrinking circles creates a pulsating rhythm on the screen that reflects the turn taking of regular conversations.

(Donath, Karahalios & Vi gas 1999)

Figure 5-2 - ChatCircles

The system is designed without central control, and yet encourages and graphically depicts the emergence of order within it. Though not explicitly stating the goal of self-organisation, the authors are very keen to avoid anything that smacks of a skyhook,

> Color in ChatCircles is purely discriminate. Indeed, it is one of the challenges in this project to find a palette of colors that will not inadvertently suggest meaningful interpretation.
>
> (Donath, Karahalios & Vi gas 1999)

As a tool for mediating conversation in a learning environment without the aid of a moderator or teacher, ChatCircles has many strengths. By encouraging self-organised clustering, particular areas of interest might be formed. However, there is no clue as to the nature of a given discussion. It is as likely to be about visits to the pub as it is to be about a learning topic. As so often happens, this is a system which self-organises but which does not necessarily (nor even probably) do so for the educational benefit of its users. It would none-the-less be interesting to use this in an educational environment as a focussed group of learners might well achieve a form of self-organisation related to learning goals as much as social needs.

Asynchronous communication tools

Asynchronous communication tools are certainly the most widely used means of communication on the Internet, inasmuch as they include all varieties of bulletin boards (including Usenet News and web-boards) as well as email. As discussed in the previous chapter, a basic bulletin board offers limited automated support for self-organisation. However, a variety of systems have been developed which, to a greater or lesser extent, allow mechanisms such as stigmergy to provide structures which extend beyond conventional hierarchies.

As previously observed, Turoff et al (1999) provide a damning criticism of traditional hierarchically structured discussion fora such as newsgroups, pointing out that there is no support for the semantic links between messages, leading to confusion and obfuscation. They suggest that alternative representations of the relationships of one message with another should be created:

> CMC systems with tailored content oriented discourse and visualization structures can become the foundation to support large scale 'electronic community systems.' This has been defined as 'a computer system that encodes the knowledge of a community and provides an environment that supports manipulation of that knowledge.'
>
> (Turoff et al. 1999)

Essentially, Turoff et al are suggesting the creation of metadata that represent semantic information about messages and their relationships with other messages. They are explicit about the contextually situated nature of these metadata, requiring that they be generated according to the needs of the group to "evolve discourse structures." The use of the word 'evolve' in this context appears to be the weaker more general sense of the word than that of Darwinian evolution, but the idea sounds promising in principle. The production of systems that are actually usable by the thousands of people Turoff et al imagine might be involved in discussions is still some way off. There is a need for intuitive and simple-to-use systems that embody the kind of metadata Turoff et al are asking for.

Computer Supported Collaborative Argumentation tools (CSCA) – e.g. D3E and POW!

The concept of Computer Supported Collaborative Argumentation applies to any of a wide range of technologies designed to support the argumentation process. In particular, they offer assistance with a range of problems defined by Rittel as ‘wicked’ (Buckingham-Shum, Motta & Domingue 1999). CSCA tools seek to provide mechanisms for structured discussion and argumentation to help organise discussions and avoid the problem of losing the thread identified earlier in the analysis of newsgroups.

Example: Journal of Interactive Media in Education (JIME)

JIME uses the D3E engine developed by the Open University. Discourse is centred on a document, immediately providing a level of structure not found in a free-form forum. Messages are posted much like those in a traditional discussion, but with the option to add icons which represent the relationship of a given message to its predecessor, especially in terms of agreement/disagreement (Figure 5-3). Thus, a further layer of metadata helps to distinguish the form of an argument, without that form being explicitly imposed from above.

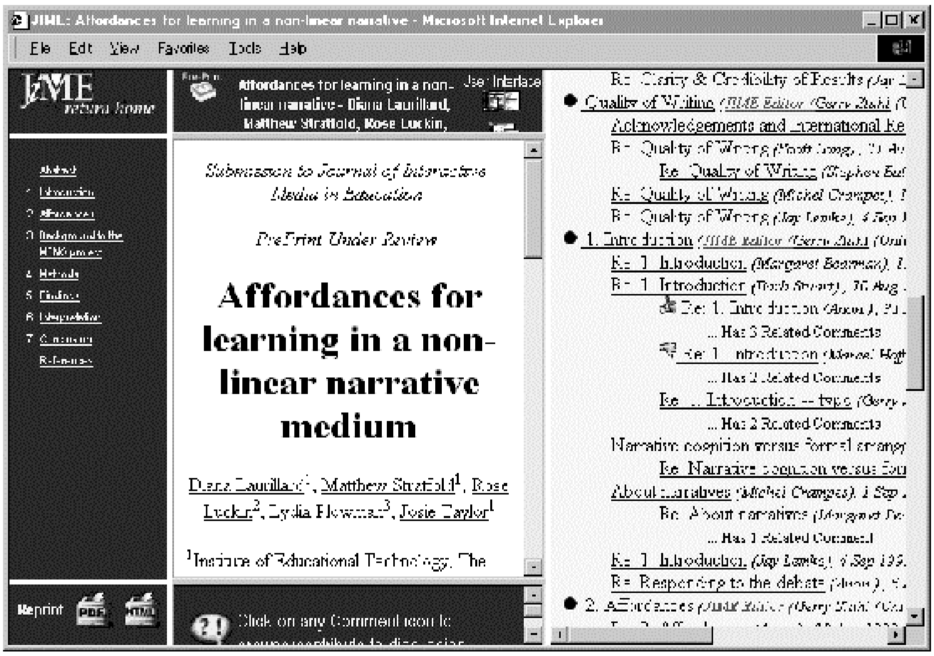


Figure 5-3 – JIME

A similar principle may be found in a large number of Web-boards, where visual cues (usually icons) give some indication of the content of a message. Icons demonstrate the intended uses of each message, and cross-hierarchy clusters are often apparent at a glance. An example of this may be seen in Figure 5-4. Again, these clusters arise as a result of individual postings, not through design.

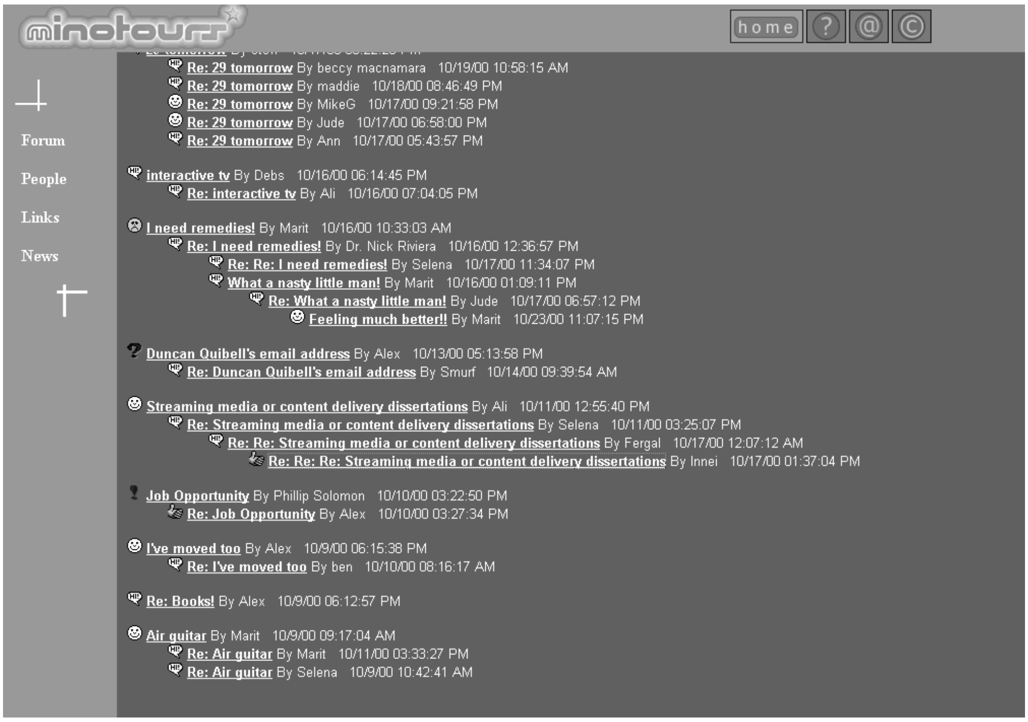


Figure 5-4 – a typical web-board

Example: POW!

Like D3E, POW! (Perspectives on the Web) is designed as a collaborative argumentation tool (Stahl 1999). Users of POW access information via ‘perspectives’. Perspectives can be personal or shared, and may exist in hierarchies, including notions of inheritance and multiple inheritance. Personal perspectives are constructed through inheritance from team or class perspectives. A perspective will contain a variety of electronic information sources, such as emails, Web pages, annotations and notes. Individuals add linking structures, but as individuals can browse and incorporate other linking structures from other users within groups, different perspectives may be collaboratively constructed. The potential for such a system is large, but Stahl has commented (in a personal discussion) that the students do not always find it easy to use. The combination of complex metaphors and a rich environment requiring a certain amount of learning makes it less self-organising than we would wish. The issue clearly arising out of this is the need for simple metaphors and easy-to-use, adaptable interfaces.

Annotation systems – e.g. uTok, Comentor, CoNote

When Tim Berners-Lee first designed the protocols and tools which now make up the Web it was in some ways a more sophisticated beast than that with which we are now familiar. In particular, it was not a simple publishing medium, as it allowed for groups working together to collaboratively annotate and link items. The most common implementations of the system lost this ability, but several tools have been created to restore such a mechanism. Typically these tools allow a user to share annotations with other users, although they often have other powerful mechanisms to enable group working, such as chat programs and presence indicators (*who else is here*?), helping to provide a stronger sense of community. This is particularly important in the anonymous world of the Internet, where it is often difficult to gauge the reliability of a particular user. The ability to interact is a step towards building trust.

Annotation systems work on a similar principle to that of D3E, whereby communication occurs within the context of a document, which in these cases can be any web page. Virtually all annotation systems make some use of stigmergy as a means of self-organisation. Visiting an annotated page will give a fairly instant clue to its popularity, based on the number of contributors and quantity of annotations. Like a footpath in a forest, use encourages more use.

Example: uTOK

As well as providing annotations, uTOK (http://www.utok.com) incorporates a voting mechanism of some sophistication, which allows users to set up their own polls (Figure 5-5) on their notes, which can relate to the Web sites they were viewing when the poll was created if they wish. Users seem to use this to discover consensus opinions on everything from interface issues to opinions of movie characters.

The ability to vote provides a particularly powerful mechanism which results in low-rated notes being actually removed from view. This is an evolutionary struggle which organises itself to remove poor messages, thus leading to messages well adapted to the communities that use them. A more basic form of collaborative filtering also applies to the selection of groups in the first place. If there are too many topics of insufficient interest, then a user will leave a group. This works stigmergically, and like nesting birds or termite mounds, the groups will centre themselves to form a self-organised community.

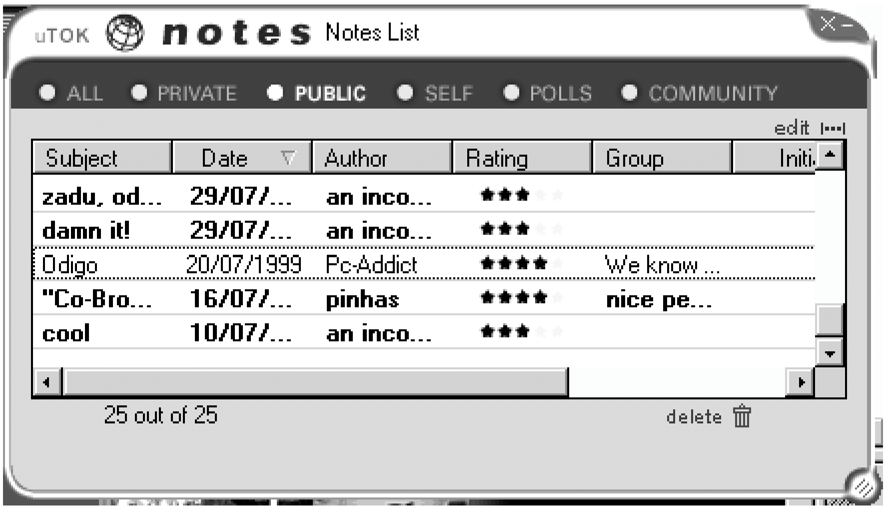


Figure 5-5 – uTOK

Examples: CoNote, Critlink, Third Voice

The CoNote system (Davis & Huttenlocher 1995) is a shared annotation tool with the specific goal of allowing Web pages to provide a context for discussion. Based on a proxy system that intercepts calls to specific servers and adds appropriate annotations, CoNote allows the structure of the Web document to shape and give structure to the discussion that surrounds it. CritLink Mediator (http://www.crit.org/) operates in a similar fashion to CoNote. Making use of a proxy server it redirects users through its own site to redisplay pages with annotations. A similar application, Third Voice (http://www.thirdvoice.com) controversially allows annotations to be added to any Web site, although instead of using a proxy it acts as an add-in to the client's Web browser. In each system, annotations act stigmergically, like the mud piles of termites: more annotations attract visitors to wonder what all the fuss is about.

Example: Annotea

The future of annotation systems now seems assured with the development of the Annotea project (Koivunen 2001), a product of the W3 Consortium which makes use of XML standards such as RDF (Resource Description Framework) to store annotations relating to any given document and Xpointer to indicate exactly where in the document the annotation should be placed (Figure 5-6). Experience suggests that many of the annotations on public sites are trite or malicious, but it is certainly true that the more annotations are available, the longer one is likely to linger and the more one will be drawn to a given page.

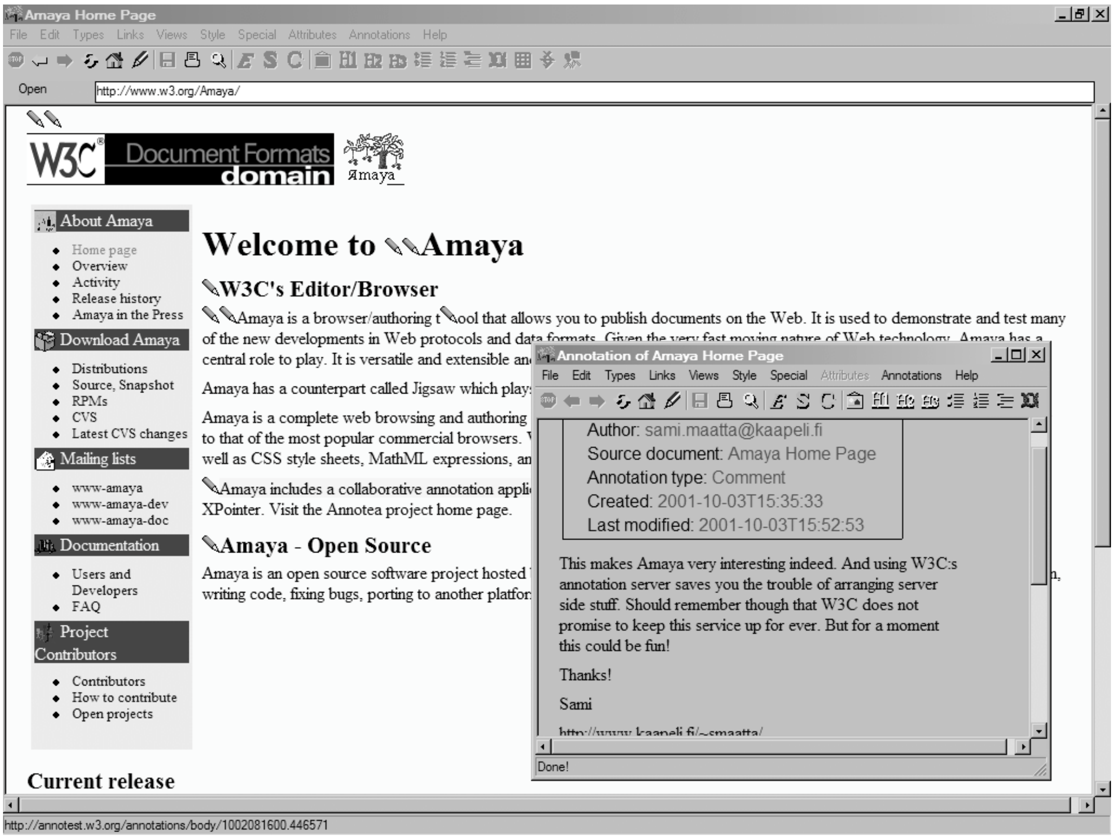


Figure 5-6 – Annotea annotations

Due to its integration with RDF, Annotea systems will be searchable across a distributed network, providing potential for large-scale collaborative efforts, such as virtual distributed peer-reviewed journals of the sort proposed by Edmons (Edmons 2000b). However, as we shall see when discussing collaborative trails, the nature of the Web can make annotations held separately from documents become disconnected and out of date if the document is not edited with great care.

Knowledge bases – e.g. the Answer Garden, Knowledge Garden, Mecpol, Q&A sites

A collaborative knowledge base lies somewhere between a discussion forum and a set of static, published web pages. Collaborative knowledge bases grow, hence leading to a proliferation of garden and evolutionary metaphors in their names and descriptions. The original Answer Garden was the PhD work of Mark Ackerman (Ackerman 1994). Like many good ideas, the concept was essentially simple. A database of answers to questions was created by a group of experts. As users of the system asked questions they were given a list of possible answers in return. If none of these answers gave them the help they needed, they pressed an “I’m not happy” button, which redirected the question to an appropriate expert. The expert’s answer was then incorporated into the database, making it more likely that the next time somebody asked a similar question that the answer would be found. In this way the system grew and adapted to the needs of its users. However, this was a garden which never stopped growing, lacking much in the way of negative feedback, leading to a potentially tangled and overwhelming amount of available knowledge. In particular, Ackerman and McDonald (Ackerman & McDonald 1996) draw attention to the need for contextual information to identify the relevance of the answers. This context dependency in learning has already been noted several times and comes back to haunt us in most attempts to provide automation of structured knowledge. Another issue which I have observed in my own experiments and which is raised by Creed (Creed 1996) is that of the need for anonymity. This is closely linked to the notion of trust and the social nature of any interactions.

Answer Garden 2 sought to address these problems (Ackerman & McDonald 1996). The main mechanism for organisation is a structured escalation mechanism, allowing messages to be posed to known or trusted sources before being passed on to the next level of help. From a self-organising point of view the elegance of this system is that any user of the system, not just an accredited expert, might give an answer at the first level. Thus, learners are able to take full advantage of teachback, providing a feedback cycle that benefits both the helper and the helped, increasing the knowledge of each. Answer Garden 2 allows for the insertion of rule-based or other systems to find appropriate experts, allowing for the possibility of a collaborative mechanism for identifying such experts, which would help to introduce the cycles of feedback needed for self-organisation. The system also allows for information culling, organising and distilling. These processes are user-controlled, thus affording a more interesting dynamic of collective gardeners. However, a garden is not like a jungle. At its heart is a Stalinist regime that dictates the forms that interaction will take. Although content springs from the users, organisation occurs due to the intelligent algorithms provided by the programmer. It is possible to consider that, with its open structure, it might one day itself be able to evolve.

One notable lack in the original Answer Garden was an effective means of pruning, although this was somewhat improved in Answer Garden 2. This problem is being interestingly addressed by a group of BT projects, which started with a system called the Knowledge Garden (recently renamed to "Information Garden", presumably due to the prior existence of a far less interesting product of the same name) which is currently wrapped around a system called Jasper. Jasper incorporates a VRML interface to an information garden. In the Information Garden, clusters of associated URLs are visualised as flowers growing (Crossley et al. 1999). Leaves that are little used wither on the stem and eventually fall off. The colour of flowers codes for document status (updated, unchanged, dead) and, when selected, the flower stems wave for a while like real flowers that have been touched. A visitor seeking interesting information is thus drawn by colour and movement created by other users of the system. Each user has an avatar, the position of which records users' perceived availability based on mouse clicks, keyboard presses and the last time their emails were read. Users can prune the stems that are not wanted and even take cuttings to grow in their own private gardens. An interactive space is created where the environment is formed out of the active participation of its users, a place where knowledge can be shared independently of physical space and formal organisational groupings. As a tool to assist organisational learning this is powerful and could easily be adapted to groups of like-minded learners.

The concept that underlies both answer and knowledge garden is that of an organic yet tamed system. These are not jungles, although they are subject to the rigours of evolutionary selection. However, nothing unexpected is ever going to grow here. The Answer Garden will generate better or worse answers; the Knowledge Garden will provide access to resources in a fairly constrained way. If there were an ecological niche of, say, users seeking documents that were published in a given year, then the system would not evolve a new colour or height of flower. This would still be in the hands of the designer, the head gardener who controls the available variations. In our search for systems that evolve we have taken an interesting step in the right direction, but we are not there yet. The teachers have gone but they have left footprints and strictures in the way of a maximally self-organised learning environment. When the gardeners leave the weeds should grow and strangle the delicate flowers, but this garden is too well managed. It would at least be nice to see something more like a Capability Brown design than a formal arrangement.

Information flocking

In a related BT project to the information garden, a metaphor of schools of fish is used to indicate similar clusters (Tateson 2001). This system is based upon the observation that similar fish tend to swim together. Different coloured fish represent interests of groups of users, and their clustering behaviour indicates similarities between individuals and of different groups (Figure 5-7). This harks back to the work of Reynolds, who demonstrated that emergent flocking behaviour can be created by the interactions of three simple rules- collision avoidance, velocity matching and lock centring (Kelly 1994, pp. 13-14), demonstrating yet again the complex systems that can be generated by simple rules acting on many inter-related parts. By tuning the weighting of the three rules, different flocking behaviours may be produced, like those of bats, sparrows or fish for example. Although the information flocking experiments are a form of data mining, intended primarily as a way of visualising existing relationships, if they are successful then the results will affect the actions of those whose relationships are being modelled, allowing the emergence of connections where none existed before. This is another example of the operation of stigmergy in the service of self-organisation.

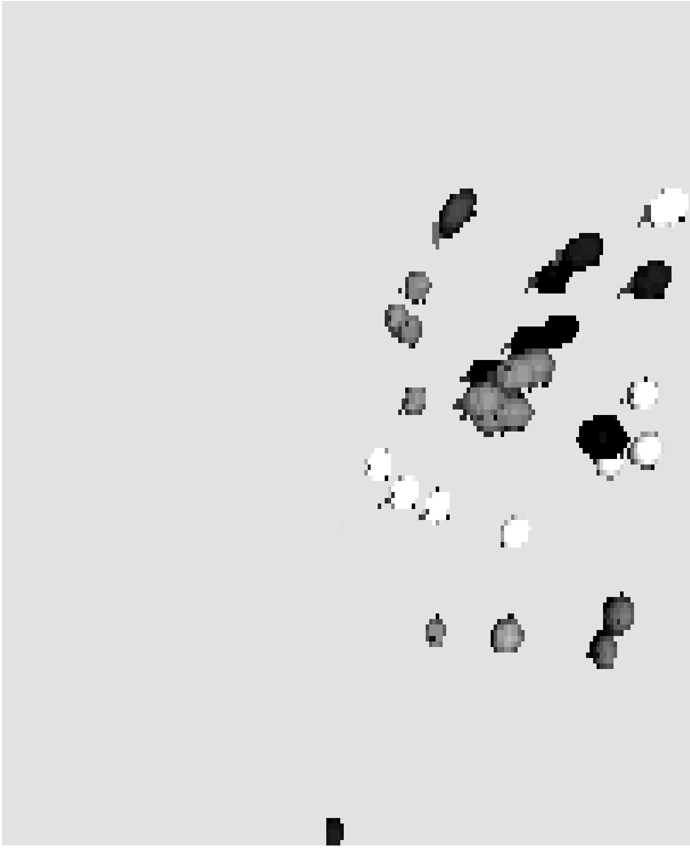


Figure 5-7 – information flocking

JITOL & MECPOL

JITOL (Just In Time Online Learning) was a visionary project designed to assist collaborative learning by allowing people to interact and (more interestingly) to reify their interactions to generate knowledge from debate (Boder 1992). A knowledge base served as the reference for interactions and was itself updated by the outcome of those interactions in an iterative, recursive process that was somewhat self-organising as a result, albeit with a certain amount of effort on the part of those involved. The system provided a framework but not very much conceptual support. This was partly remedied in the MECPOL (Models for European Collaboration and Pedagogy in Open Learning) project, which might be characterised as JITOL TNG. At the centre of the MECPOL project is the concept of the “evolving knowledge base” (EKB). The EKB stores information about foreground resource (online resources directly available), background resources (off-line resources) and meta-resources (aids to finding background and foreground resources such as bibliographic databases, information about other JITOL users, on-line reviews etc). The EKB sees everything in the system as a resource, including the interactions between them, for instance an exchange of messages between tutor and student. In the words of its authors:

> The key feature of the EKB, then, is that it reflects and embodies the changing beliefs, needs and activities of the community of practice which it supports. It represents a growing, self-improving resource, created through the collaboration of knowledgeable learners and tutors. It stands in sharp contrast to alternative forms of IT-based learning resource, which at their worst are expensive ossifications of tutors' interpretations of the world.
>
> (The partners of MECPOL 1998)

The authors of MECPOL present a variety of models for the continuing development of open and distance learning (ODL). They warn against uncritical use of the simple prototyping model on the grounds that the needs of each cohort of learners will be different from those of all others. Lessons learnt which would improve the experience for one cohort might be actively harmful to the next. This is a significant insight into the situated nature of learning. Any systems that we allow to evolve should not be considered as universal panaceas. Every cohort of learners represents another ecology.

The notion of making everything on the system a resource, including user interactions, is an interesting one, which would be problematic were it not for the structure which is imposed by the system's metadata framework. It is interesting to note, however, that the framework itself is fixed and does not evolve. Although we see evolution in the knowledge and how it is presented, the underlying framework cannot be affected by changes within the knowledge itself. It thus breaks Kelly's law of chunky bottoms (Kelly 1994) and will always dictate the forms that knowledge can take.

Q & A sites

There are many question and answer (Q & A) sites on the web, which can be rich watering holes for self-teaching learners.

A particularly effective use of a Q & A site is HelpShare (http://www.helpshare.com). This is marketed as the "Micro-Consulting Marketplace". Questions are posed and answered by experts for a price, which is supplied with the question. This makes excellent use of the power of the web, bringing many and disparate people together to do business- in this case to learn and to provide the source of that learning.

HelpShare is particularly aimed at solving IT-related problems, an area where, due to the rapid rate of change, education and training opportunities inevitably lag behind the need for them. It incorporates what are described as Trust Algorithms, to allow questioners to assess the reliability of answerers' responses and for answerers to assess the questioners' ability and willingness to pay promptly- a self-organising feedback mechanism. However, it suffers from a problem that besets all such systems, the cold start phenomenon. John Harney writes:

> A virtual community like this can only succeed if three things happen- the number of members is sufficiently large, the content is sufficiently rich and the relationships that members form are sufficiently nurtured. Obviously the three phenomena are interdependent- lots of members contribute more content which in turn makes it harder for members to give up the relationships they form with various experts and defect to another community.
>
> (Harney 2000)

Harney's analysis succinctly explains how this system, though self-organising to a large extent, is not autopoietic (i.e. it cannot pull itself up by its own bootstraps). The system clearly has to reach a point at which it becomes useful but prior to which it is close to useless and may be positively harmful, requiring a much larger investment than the immediate return. This investment is inevitably compounded by the need to provide information to feed the Trust Algorithm. It is just this sort of complexity that continues to make people search for a grand designer to life the universe and everything. Evolution almost certainly managed it in small steps, each of which was self-sustaining (Dyson 1997). There were none of Dennett's skyhooks along the way (Dennett 1995). It is hard to see how such a system could start from scratch in the chaotic jumble of the Internet.

The missing steps needed by HelpShare have been taken by Yahoo (http://www.yahoo.com). Yahoo's Q & A site does not cost its users anything, although the answers are probably not as valuable as those found on HelpShare (yet). It is organised by Yahoo staff, the only chaotic element being the stream of questions flowing by. It none-the-less shows a route through which the likes of HelpShare could be successful, through a symbiotic existence with something already valuable enough to visit, with a readily available mass of visitors in sufficient numbers to make it self-sustaining. In this sense it might come to resemble Margulis's account of the role of symbiosis in evolution (Margulis 1981; Margulis 1998), joining two already successful entities to make a third, more successful species.

Recommendersystems

Looking for the good stuff- descriptions of utility

Finding useful resources and structuring the students' approaches to them is central to the process of learning and is one of the key roles of a teacher, be they virtual or otherwise. We have already looked at some ways in which structure can evolve within interactions with the support of computer-based tools as an aid to communication. I now turn to ways in which computer support can provide mechanisms to assist the structuring of content through the interactions of groups of users. It is worth noting that we have not altogether left the world of communication, inasmuch as any collaborative process implies some form of exchange of information.

Seals of approval

While researching for this PhD I have spent some time browsing through library books. In some, the notes in the margin dominate the text, often with inane or baffling comments that, once they have become the focus of attention are very difficult to ignore. Sometimes they are useful, either suggesting useful insights or being so blatantly wrong that they encourage a closer appraisal of what the text is really saying. The kinds of problems that relate to margin notes and underlined bits of text are magnified when formalised. How do we know whether a comment is reliable, how does it fit with our way of seeing the world? The seal of approval (SOAP) has been a time-honoured way of seeking useful resources. Typically these have taken the form of recommendations by teachers, colleagues and friends, or the more formal peer review exercised in journals or the published reviews of critics in the press. However, such systems are unwieldy and labour-intensive. Buckingham-Shum et al note that:

> We can think of conventional scholarly publication and debate as a document-centred, text-based process. Text is a rich medium in which to publish and discuss ideas in detail and with subtle nuances, but the corresponding disadvantage is that it takes a long time to read, and is hard to analyse computationally.
>
> (Buckingham-Shum, Motta & Domingue 1999)

Stretching the definition further, we may also consider that a citation might provide a tacit SOAP- an oft-cited document is likely to be of a higher quality than one that is not. However, papers, books and so on are often cited in the context of disagreement or dislike. Just because Lamarck is heavily cited in literature on evolution does not make his theories correct or even useful to us as learners. This is a theme that will be pursued further in the forthcoming discussion on collaborative filtering.

A number of Web sites provide mechanisms for users to comment on and review their own or other resources, with these comments and reviews being fed back to other visitors to the sites. A good example of this would be epinions.com (http://www.epinions.com), which provides user-generated commentary on a wide range of resources and objects such as shops, toys and records. Piller (1999) cites the example of M.J. Rose, author of a phone-sex novel 'Lip Service.' Unable to interest publishers, the author published the book herself then offered it through Amazon.com. Piller writes, "On the strength of rave reviews posted on Amazon by ordinary readers, and similar plaudits posted on other Web sites to which she had sent review copies, the novel began to sell." Before long, the author was in receipt of a high-five-figure sum from Pocket Books to publish her novel.

There are several problems with a textual recommendations however, including:

? information overload

? trust

? diversity

Information overload

Reading reviews requires a good deal of effort, time and commitment. Although a review can provide subtle and meaningful indications of the value of a resource, there is a relatively high level of interpretation needed, especially if one review is to be evaluated in juxtaposition with others.

Trust

The most obvious difficulty with a SOAP of any kind is in establishing trust. For example, it is apparent that the authors, publishers or some other partial reviewers have added many of the reviews of books supplied at the Amazon site. Even where the reviewer is neutral, there is no guarantee of the quality of the review. This problem might be solved by only looking at reviews by reviewers with a good reputation either by hearsay or perhaps by some reputation brokering service of the sort suggested by Chislenko (Chislenko 1997) or a more formal system of vetted experts as suggested by Zellouf (Zellouf 1999) or the ReferralWeb, a means of “restructuring, visualising, and searching social networks on the web” (Kautz, Selman & Shah 1997).

Diversity

Even when the quality of the reviewer is assured, there is still only a relatively small probability that the reviewer and the searcher share the same tastes and needs. The reviewer may be able to supply information as to the content and veracity of a given resource, but any value statements are likely to differ from one individual to another. If this were not so then there would be no market for film critics, for instance. We value the diversity of taste in critics and it is a rare movie that is loved by all or hated by all.

Collaborative filtering

We have already seen how the Web provides us with numerous ways of communication that were simply impossible before the advent of a large, public network. Collaborative filtering is a particularly powerful example of one of these ways.

The concept of the collaborative filter dates from the Tapestry system, a product (like so much of importance in the world of computing) of Xerox PARC in the early 1990s (Resnick & Varian 1997, pp 56-58). Tapestry allowed users to add annotations and ratings to messages, thus enabling a community of users to filter messages using a system based on the intelligence of human beings and the raw processing power of computers (Borchers et al. 1998). This system and its offspring, sometimes termed ‘recommender systems’ or ‘social filters’ come in many different forms but all are based on a simple premise – that the recommendations (explicit or implicit) of others can help us to find what we are looking for. Collaborative filters are organisers of knowledge, with a classification scheme based on the preferences of others. Typically, such systems are used to recommend resources based on a matching of users’ interests, but the visionary Sasha Chislenko noted that they could be used in a much wider context, of particular interest to us being the idea that “educators would pay special attention to things that students find too difficult or boring” (Chislenko 1997).

Forms of collaborative filter

There are several ways to classify collaborative filters, based on how ratings are discovered, the forms these take, the algorithms they use. For our purposes, they can broadly be split into those which use implicit ratings (tacitly expressed metadata) and those which use explicit ratings. Between these two extremes there are many partial and hybrid systems.

Some examples of collaborative filtering approaches to the discovery of resources and their value

The classic explicit rating system was probably Firefly, largely the brainchild of the late Sasha Chislenko, and prior to its purchase and subsequent abandonment by Microsoft among the most successful recommenders of movies on the Internet. Users entered ratings for a number of movies they had already seen until there were sufficient ratings to be able to match them with those of other users. It was an early instance of an *Automated* Collaborative Filter (ACF). An ACF explicitly seeks patterns of matching rating behaviours between individuals, not relying upon a simple cumulative vote but instead extracting mined similarities.

Beehive was a tacit rating system designed to discover communities of interest, based on how it recorded the behaviour and interactions of members of communities of practice (Huberman & Kaminsky 1996).

GroupLens (Konstan, Miller & Maltz 1997) is a system designed to assist users to cope with the large amount of information carried in Usenet Newsgroups. Its strengths lie in the hybrid approach it adopts to collaborative filtering, taking explicit ratings, implicit information such as time spent reading articles and content-based information extracted from the messages themselves (Lueg 1999). The underlying principles of the system have since become transformed into the Net Perceptions product (http://www.netperceptions.com/) widely used commercially.

General knowledge retrieval with recommender systems

Recommendersystems lend themselves well to identifying personal preferences, but have often been less successful when applied to problems of general knowledge discovery. A sophisticated approach that lends itself well to focussed groups of learners is WebTagger (Keller et al. 1997). This is an explicit collaborative bookmarking system designed to address various identified problems with existing bookmarking systems, particularly those of a monolithic or hierarchical structure, lack of facilities for sharing, inability to rank and a clumsy navigational access model. It incorporates a storage system based on a lattice structure, where URLs are stored at different category nodes with a weighting applied to their utility. Users can select one or more categories and rank URLs within them, thereby providing a feedback mechanism that can help refine further searches. The system incorporates a genetic algorithm that purges nodes when their frequency of access drops below a specified level.

WebTagger provides unique views for each retrieval context, the views being generated by the combined ratings of all the system's users. It is an adaptive system with a powerful set of mechanisms for self-organisation. There are many similarities between this system and CoFIND, the experimental system I shall report on later.

Some of the team responsible for WebTagger went on to produce DIAMS, a Java-based system integrating knowledge-bases, neural networks and genetic algorithms "to develop an ecology of users and agents that evolve over time" (Mathe, Chen & Wolfe 1998). This system is essentially an enhanced version of WebTagger with added rule-based intelligence, which in a sense dilutes the ability of the system to self-organise, instead introducing a designer, albeit an adaptable and flexible one.

Recommender systems explicitly designed for learners

PHOAKS

The PHOAKS (People Helping One Another Know Stuff) system (http://www.phoaks.com) employs an ingenious form of implicit collaborative filtering. It sorts through news groups looking for URLs. It works on the assumption that the more often a resource is mentioned the more useful it is likely to be, as people seldom refer to URLs of no use. The results of a search on a given term are displayed in order of popularity or reference. This idea has been taken up with a vengeance by the extraordinarily powerful Google (http://www.google.com) search engine, which rates the popularity of a given resource by the number of times it has been referred to in other Web pages. Such systems embody self-organising principles by combining the actions of individuals to create a pattern not envisaged by those individuals. CiteSeer (http://www.citeseer.com) works in a similar fashion to PHOAKS in that it performs a citation analysis of academic papers.

LON-CAPA

The LearningOnline network is an attempt to create a market-driven infrastructure for resource sharing in learning systems. This incorporates a large number of mechanisms with a greater or lesser amount of centralised control, from course management tools to communication and collaboration mechanisms. Its most interesting component from our perspective is the use of genetic algorithms in the provision of the student interface to the system. A form of adaptive hypertext, the system will learn from learners' previous selections to automatically customise courses to their needs. The authors hypothesise that it should be possible to cross-compare different students' preferences and learning outcomes.

> By offering the resources that were deemed 'better' to the students and encouraging the instructors to supersede the ineffective resources, the human-computer interaction could lead to more effective virtual university classes. In system science, this type of creation of structure via selection rules and feedback loops is known as 'self-organized criticality.'
>
> (Laboratory for Instructional Technology in Education 2000)

The explicit attempt to produce a system which self-organises is interesting and reflects many of my concerns that I attempt to address with the CoFIND system. In particular, this is not a simple feedback loop, inasmuch as the control mechanism is itself able to adapt. Good resources result in successful selection; bad resources are forced to adapt. The effect of this adaptation has the potential to change the way in which resources are rated, because the learners have learnt as a result of the rating process. It is easy to see how such a system could approach self-organised criticality, although it would be interesting to see how successful this system turns out to be. For the feedback to be effective it requires active participation on the part of the assessors and the producers, something which is far from guaranteed. In addition, the mechanism of feedback gives little indication of the sources of the learners' displeasure. Knowing that something is bad is part of the way there, but knowing why it is considered bad is probably more important. This system does not provide sufficient meta-information about itself, so the self-organisation is only going to occur along a linear plane, with a restricted number of connections between nodes.

Capturing knowledge

Tacit knowledge is notably tricky to capture, as by Polanyi's definition it is inexpressible. The notion of inexpressible knowledge is perhaps contentious (Boyne 1999), but it is certainly true that some knowledge is extremely hard to capture and express. Stenmark (1999) has built a system which seeks to externalise tacit knowledge by capturing patterns of behaviour, the documents we read, the Web sites we visit, the people we contact and so on. His system makes use of agents that capture such information into profiles and allow it to be shared amongst other users of the system. Hence, it is possible to discover users across an organisation with similar profiles and matching interests, not through any explicitly stated similarities but through matching tacit knowledge. As with most recommender systems, the system suffers from a cold start problem, with the need for agents to be trained before useful results could be returned. Despite this, such an approach is promising, inasmuch as it captures behaviours that are not explicitly stated. In terms of complex adaptation however the system is just a means of automating the process of bringing people together and does not exhibit much particularly emergent behaviour per se, although it is easy to see how it could generate clusters based on the habits of its users.

Problems with recommender systems

Collaborative filters and other recommender systems provide excellent candidate methods for replacing the role of the teacher in a self-organising learning environment, but a number of problems present themselves.

The cold-start phenomenon

> One of the major problems with collaborative filtering seems to be that it typically imposes additional burden to the debit of users supplying recommendations in one form or another. The so-called cold-start problem has frequently been discussed in the literature but is as yet unresolved
>
> (Lueg 1999)

For a system to be of any use, there must be a certain body of resources and associated recommendations. However, until the system has been used, there will not be any recommendations and often (if users are adding the resources themselves) no resources. Implicit recommender systems suffer less from this phenomenon, but it is still a major barrier to their successful uptake.

There is seldom a strong incentive to actively recommend a resource. In general, once a resource has been found most users are happy to stay with it, given the time and effort involved in even a simple process of clicking a button. Avery & Zeckhauser describe the avoidance of evaluation as 'free-riding,' identifying the core problem that "evaluations will be provided by an unrepresentative group – those who most enjoy the evaluation process" (Avery & Zeckhauser 1997). They apply a little basic games theory to prove that no matter what strategy is adopted (rating or waiting for ratings) the results will be non-optimal for at least one class of participant, usually those who apply ratings earlier. Avery & Zeckhauser suggest three potential solutions:

1. Subscription services – readers pay a fee that goes to evaluators. This is not dissimilar to the principle that applies to professional critics, and would be of little use to us if we wish to build a system that self-organises.

2. Transaction-based compensation – evaluators are paid for evaluations, with a variable scale based on the usefulness of their evaluations when correlated with others and a special premium being paid for early evaluations. This model works well for BizRate, which compiles consumer ratings for ecommerce sites and encourages consumers to rate sites with the incentive of potentially substantial discounts culled from commissions paid by participant ecommerce sites. A similar system is used by Epinions.com, which offers a nominal fee to reviewers based on the number of times their reviews have been read (Piller 1999).

3. Exclusion – non-evaluators are excluded from benefiting from evaluations, again weighted to provide stronger incentives for early evaluations. However, Avery & Zeckhauser (1997) warn that such a system might provide low-quality evaluations, which in turn means that the value of evaluations is lower which in its turn means that there will be fewer participants- a vicious circle if ever there was one. From the point of view of this thesis, as a means of enabling learning exclusion seems counter-productive.

Context dependency

Lueg writes that "there is no such thing as context-independent information" (Lueg 1999). Information has different value in different contexts of usage and according to its origin and timing. This is captured by the notion of QOI (Quality of Information) (Valovic 1994). Collaborative filters are an effective means of capturing and using values about resources within a limited context, such as recommending books or films that people will like or small communities with shared interests in a fixed temporal context. In many learning contexts the power of collaborative filtering will be dissipated because (as already noted) the essence of learning is about change. Resources that were of value when we were learning about our ABC will not help us much when we are learning about Einstein's Theory of Relativity. In a smaller way, this problem will affect most sorts of collaborative filtering approach. Even with a focussed cohort of learners, one of the major issues that has been already identified is that individual learners will always bring their own unique context of prior knowledge and frameworks for understanding. If a collaborative filtering approach is going to be successful, it must somehow incorporate this context-sensitivity.

Dimensionality

To adapt to different contexts, a collaborative filter should be aware of how resources are clustered, or categorised. In essence, the only metadata of significance to most collaborative filters are single-dimensional scalar features such as good to bad, useful to useless, used to not-used. A partial solution is provided by Delgado in the RAAP (Research Assistant Agent Project) and MyLinx collaborative bookmarking systems, where the algorithm used to discover related resources incorporates a content-based system for relating ratings and the classification of resources. In this manner, ABC can be kept separate from Einstein, and the ratings of resources applied in context (Delgado, Ishii & Ura 1998; Delgado 2000). Powerful though this approach might prove to be, it is still largely concerned with simple binary classifications and a single dimension of value. Although classifications allow moderately sophisticated metadata to be mined, the simple good-bad metadata are not sufficient to fully address the needs of learners. Learners represent the embodiment of a huge diversity of learning styles and learning needs. Although we might identify the required content accurately and even match similar past needs, there is still a relatively low probability of a good match between learner and resource. An example may help to clarify this point: if learner X has knowledge of subjects A,B,C and D and learner Y knows about B,C,D and E, any decent collaborative filtering algorithm would identify a strong correlation between them. However, X's prior knowledge of A will mean that classifications within that context will perhaps not be helpful when Y comes to approach the same problem. Worse still, Y's early assessment of valuable resources may not be helpful even to Y once the topic has been learnt. There is a strong temporal dependence in learning resources because learning changes us.

Karamuftuoglu recognises the problem of dimensions of quality when applied to the process of IR (Information Retrieval). In IR we seek resources based on their relevant features, usually related keywords or concepts. However, he points out that many features of resources (he refers to these as ‘documents’ but we can extend the term to a broader set of resources) cannot be easily summarised this way:

> mere description of the topic is often not adequate. Many other factors usually affect learning, such as availability/accessibility of the material, its language and so on. These and other factors as well, such as style of the author, readability, narrative structure and many more. All of these affect the desirability of a document.
>
> (Karamuftuoglu 1999)

This insight will have great significance when we come to look at the CoFIND system.

Descriptionsofrelationships

The relationships between different objects of study have already been identified as an important contribution made by teachers to the educational process. Such relationships may relate to sequence, as in what should come next. This is always going to be a complex problem and one that requires expertise in both subject matter and pedagogy. It is not always clear what that entails. There are usually many ways to organise a particular piece of learning material. Should it be based on the conceptual mappings of the subject expert, a simple to complex pattern to assist the learner or any one of a vast range of other alternatives? In many ways the answers to these questions are what distinguishes good teaching from bad, and it is hard to conceive of such order emerging out of mindless interactions. The key point goes back to a simple maxim stated by Ramsden:

> An effective course will have its material arranged in such a way that the issues generate confidence and interest in students.
>
> (Ramsden 1992)

There is no simple prescription for this, and the needs, skills, learning preferences or learning styles of the learner will play a large part in determining the optimum course through a given body of material. I have already observed that the Web provides a mass of learning resources from which to choose. Many of these resources are already shaped according to their authors’ beliefs in their utility. Learners are not faced with a blank palette to paint trails. Instead, there is a rich diversity of possibilities from which to choose. The problem is not in creating the trails, but in choosing the right one at the right time. Like so many of these problems, there is an issue of scale. Within a given course there may be a range of topics and within each topic a set of subtopics and for each subtopic an optimal way of addressing the subject matter. If, as Vygotsky tells us, developmental processes lag behind learning processes (the gap between them being the zone of proximal development) then it would be foolish to learn, say, differential calculus before basic arithmetic. Within the topic of basic arithmetic, there may be a set of sub-processes leading from addition and subtraction through to multiplication and division. Within each of those processes there may be steps from simple digital manipulations through to complex fractional calculations. Identifying topics and subtopics is more complex, therefore, than simply selecting the best path. Equally, the effects of different learning styles (perhaps I should use a more neutral term such as 'learning preferences') might make the best path for one student very different from that which is best for another. Paths branch and intertwine in myriad ways. It is important to consider how such paths might be constructed emergently.

Pathfinding and trails

> Look at every path closely and deliberately. Try it as many times as you think necessary. Then ask yourself, and yourself alone, one question...Does this path have a heart? If it does, the path is good; if it doesn't it is of no use.
>
> (Castenada 1974)

Bush and the Memex

Vannevar Bush is widely hailed as a visionary, the creator of the concept of hypermedia in the form of his imagined machine, the Memex (Bush 1950). The Memex was beyond the possibilities afforded by the technologies of the time, but conceptually incorporated many of the features that we now recognise in hypermedia's most prevalent form, the World Wide Web. One important aspect of the Memex which tends to be missing, however, is the simple ability to record and annotate paths ("associative trails") through linked media. This is not to say that such a thing is impossible, merely that the process of authoring for the Web is not an intuitive nor a particularly widespread skill and even amongst practitioners is usually done alone, if not in private.

A simple implementation of trails may be found in such systems as Walden's paths (Furuta 2000), where a user may create linked and annotated sets of Web pages described as a 'path'. Although not a self-organising technology (it is very much a design tool) it suggests a technique for dealing with one of the most important teacher roles, that of sequencing resources to provide a coherent learning experience.

The creators of CoMentor make explicit reference to Bush's trails in their technical report (Roschein, Mogensen & Winograd 1999) and CoMentor is a little better than other annotation systems at providing a structured path through multiple resources. Users are able to create 'tours', nothing more than a list of links that appear on one side of a two-frame set, the other side containing the resource itself. At least that is the theory, but of course there are many Web pages which automatically extricate themselves from other sites' framesets. When it works, the tour mechanism in CoMentor allows multiple trails to be set up to provide a variety of paths through the same resources. CoMentor makes use of its own metadata description language, PRDM (Partial Redundant Descriptive Meta-Language), thereby providing yet another incompatible format for sharing metadata. This is a problem that may be solved by RDF (Resource Description Framework), the W3 Consortium's answer to the exchange and use of metadata (Berners-Lee, Connolly & Swick 1999).

Another approach to trail sharing is taken by VISVIP, a system to visualise paths taken by users through a Web site by recording information from Web server log files, then using 3D mapping techniques to display individual users' paths through the site (Cugini & choltz 1999). Although designed as a usability-testing tool, the ability to distinguish paths through a complex site is a form of visual metadata that might allow similar paths to be followed by other users. Unfortunately, it is inherently limited to a single Web site and is not designed to collaboratively generate paths.

The Nestor system (http://www.irpeacs.fr/~zeiliger/nestor.htm) is a client-side tool that extends the bookmarking functionality of Microsoft's Internet Explorer browser. It does so by graphically representing the paths that a user takes from one page to the next, drawing links as and when they arise and making connections where appropriate. Users may heavily customise and annotate these maps using symbols and text, leading to what looks rather like a mind map (Figure 5-8).

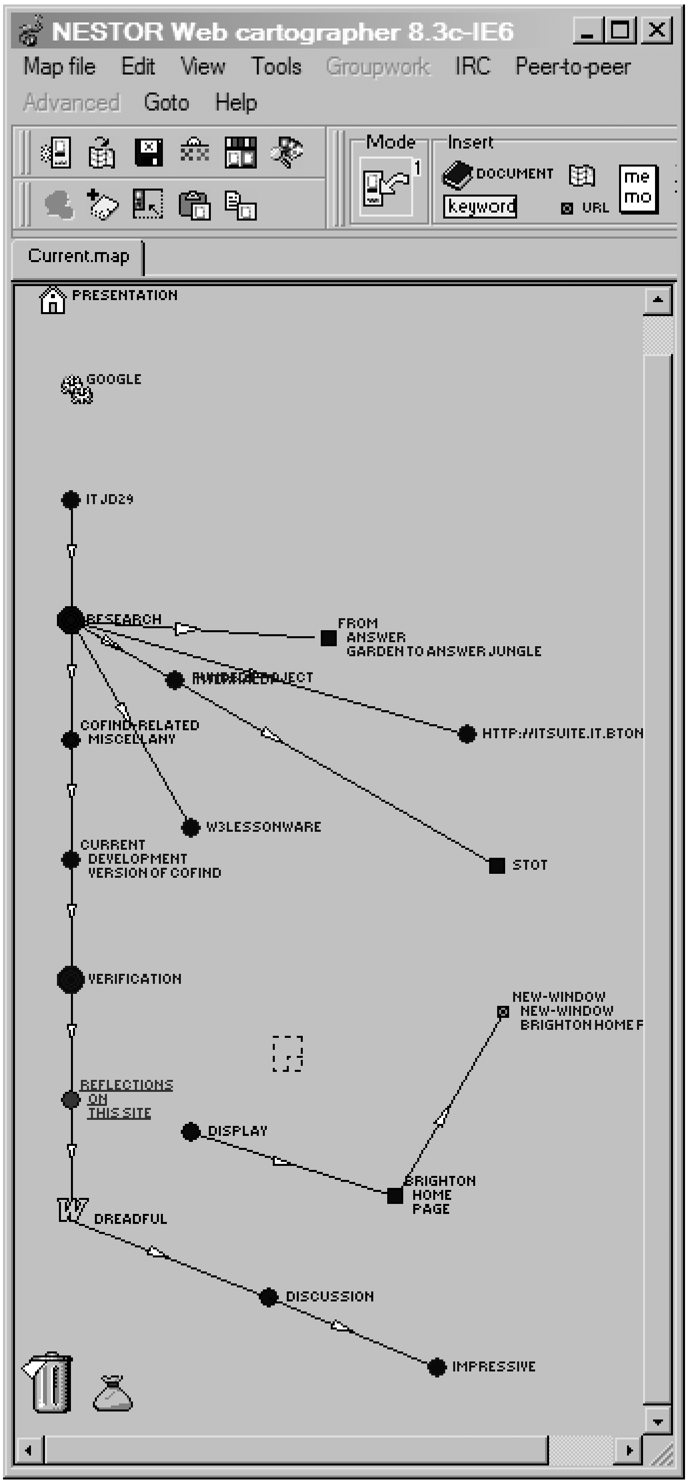


Figure 5-8 – Nestor's map interface

A particular beauty of the system is that these maps may be shared with others and combined, although visual annotations are lost in the process. Users can navigate sites together and make use of a built-in IRC real-time chat client to discuss what they find there. Not only that, but there is also a collaborative annotation tool for sites visited, which uses FTP and/or file server protocols to store its annotations, which are group oriented so that only those with whom a user wishes to share annotations will see them. Although Nestor's only significantly emergent feature is the ability to combine maps, it represents an attitude to collaboration and virtual presence which extends the concept of community-building far beyond the simple chat, forum and email systems which currently dominate the available communications tools available on the Internet.

Chalmers et al have designed a system which makes use of the Web browser's history file to identify user paths (Chalmers, Rodden & Brodbeck 1998). The system makes use of the paths collected of multiple users to attempt to generate recommendations, using a form of collaborative filtering technology. Their Path Model is based on capturing actual activity, following the example of the architectural theories of Hillier and his space syntax, which looks at people's paths through a city as the defining characteristics of spaces as opposed to the prior classifications of architects and town planners. A related approach is taken by Wexelblat & Maes (1999) to store group interaction histories. Their system (known as *Footprints*) is elegantly stigmergic, incorporating some active collaborative filtering techniques with passive collection of data about paths travelled within a Web site. The system has been shown to improve the efforts of a group searching for information (Wexelblat & Maes 1999), but there is a major weakness in this tacit recommendation technique, inasmuch as actual browsed paths are not at all likely to be congruent with ideal paths. As we already know, the Web leads us down a mass of dead-ends, useless paths and meanders. Worse still, from the point of view of learners it gives little or no indication of appropriateness of the link, no clue as to why it happened to follow the previous link nor what or even whether there was a specific goal in mind.

Another alternative is to make use of 'digest' documents (Maltz 1995), perhaps with annotations around and within the digested document. Like Walden's Paths this is not a collaborative act in itself, although like Walden's Paths, a digested document may be part of a self-organising system.

Alexa (*Alexa Technology Overview* 2000) is a browser add-in that has a variety of functions, but is primarily a recommendation tool, which actively recommends sites which resemble the one that you are currently viewing. It makes use of a number of recommender technologies including:

- the usage paths of the collective Alexa community
- clustering - the hundreds of millions of links on the Web can be used to find clusters of sites that are similar and relevant to one another.
- text analysis
- users' suggestions (collected using the Alexa browser).

Unfortunately Alexa's makers do not publish its algorithms, but its ability to structure the Web and recommend paths is formidable. Regrettably, this structure is generated without regard to pedagogic needs and so is as likely to recommend a good place to buy related books as it is to provide a sensible path through a topic.

A notable problem which besets most annotation systems is the changing nature of the web. Not only can documents move or be removed altogether, they can be modified independently of any comments added to them. Thus, any in-place annotations can become irrelevant or lost. Most implementations simply allow this to happen, but such an eventuality would be awkward or harmful if it were to happen mid-stream in a learning conversation. An alternative used by Alexa and by Google is to cache copies of the annotated pages, but not only might this raise a hornets' nest of copyright and intellectual property issues, in time-sensitive pages such as weather reports it might be positively harmful.

Collective Mental Maps

Francis Heylighen (1999) has been researching in areas which closely overlap with the concerns of this thesis, seeking emergent properties of the actions of groups of individuals to create what he describes as Collective Mental Maps (CMMs). His aim is to solve the typical problems which occur when a group of intelligent individuals attempt to combine their knowledge as, for example, we find in a committee. The typical committee exhibits no more (and often a lot less) intelligence than its individual members. Problems with such systems are manifold, ranging from pecking orders, to differences in mental maps, vocabularies and conceptualisation, to difficulties with volumes of data. A typical solution to this problem is an organisational hierarchy, of which Heylighen writes:

> Although no president, chief executive or general can oversee or control all tasks performed by different individuals in a complex organization, one might still suspect that the intelligence of the organization is somehow merely a reflection or extension of the intelligence of its hierarchical head.
>
> (Heylighen 1999)

Heylighen's solution to hierarchies' weaknesses is to look for the computerised equivalent of the archetypal stigmergy of ant trails. In essence, a weighting is applied to sites which have been visited so that those sequences which are used more often are given greater weight, following the application of collaborative filtering algorithms. The main problem with this approach is that it fails to capture the true nature of trails as they apply to learning situations. The first difficulty with Heylighen's system is pragmatic. It is difficult outside an experimental setting to capture the true sequence of a user's explorations. His first experimental solution is based on observing user behaviour given a small subset of 150 words. When transferred to the Web, Heylighen's solution relies on associated documents, not those which follow a particular order of access. Secondly, a learning path is not a continuous sequence. Learning occurs at different rates, with varying amounts of time required for assimilation of ideas, concepts and knowledge in general. A given path may be separated by minutes, hours, days, weeks, months or years. A collaborative path based on movements from one document to the next will not capture this, and so may be of little pedagogical benefit.

Adaptive and Intelligent Educational Systems (AIES) and Adaptive hypermedia

Adaptive and Intelligent Educational Systems (AIES) come in many forms and represent a well-developed field. They are explicitly aimed at providing paths through materials which are not fixed and which adapt to their users. In this section I shall discuss a couple of implementations that are worthy of note because they explicitly aim to be complex evolving systems.

An AIES is an offshoot of one of the earliest forms of computer aided learning technology, the intelligent tutoring system (ITS). An ITS uses domain knowledge and information gleaned about students to provide a tailored experience for the learner, based on their perceived needs. Brusilovsky (1999) has identified four basic forms of AIES technology: *curriculum sequencing*, *intelligent analysis of students' solutions*, *interactive problem solving support* and *example-based problem solving support*. Of these, *analysis of student solutions* and *interactive problem-solving support* fall squarely into the arena of AI and are not very interesting from a self-organising perspective, although of course such approaches might form the basis of resources which could be used within a self-organising environment. *Example-based problem solving support* currently falls into a similar category, as it relies on identifying relevant examples in the students' previous experience that might assist with the current problem. *Curriculum sequencing*, on the other hand, offers many opportunities for collaboratively generating paths through topics. Brusilovsky identifies two levels of sequencing, high level and low level. High level sequencing determines, for instance, the next learning subgoal, set of concepts, lesson or topic to be taught. Low level sequencing sequences tasks within the higher level subgoals, for instance selecting problems to be solved and tests to be performed. A particularly powerful subset of these sorts of technologies are those which can be described as 'adaptive hypermedia'. Brusilovsky divides these into those providing adaptive presentation and those providing adaptive navigation support, the latter of which fits naturally with the paradigm of the web. The kinds of adaptation that Brusilovsky identifies are direct guidance, adaptive link notation and adaptive link hiding. Typically, such systems apply some form of user modelling to identify what would be most suitable for a given student at a given stage of development. In early systems this modelling was designed by programmers and resource designers, but recently several systems have been developed which make use of a form of collaborative filtering to match similar users. It is this group of technologies that offer the most interesting possibilities in terms of self-organisation, with a range of results which would not have been predictable by the designers in advance.

Edmons proposes a system which will explicitly use principles of self-organisation to co-evolve knowledge as a result of the participants' participation. Users will post messages that may be hyperlinked to each other and to resources on the web. This will make use of an evolutionary algorithm to create and destroy nodes and links according to their success, measured by frequency of linking. Edmons correctly notes that:

> Death of forgetting is an important mechanism in evolution. It allows for greater adaptability because resources are re-distributed to newer trial solutions. It thus reduces the chance that the population may get 'locked-in' to unproductive avenues.
>
> (Edmons 2000c)

Edmons's system is still in the early stages of development, but it is interesting inasmuch as it incorporates a range of technologies used by the collaborative filtering community as well as concepts borrowed from neural networks. (Edmons 2000a)

Bollen observes that the Web provides a potential for the evolutionary development of knowledge, but does not yet actively support it. The theoretical basis draws heavily on the ideas surrounding memetics:

> Ideas, chunks of knowledge, can be considered specific entities that rely on human or other carriers to multiply, mutate, adapt and survive. The human population and the technology devoted to communication can likewise be regarded as a huge ecology populated by ideas, theories or knowledge in general
>
> (Bollen 2000)

To prove the potential, he created a HyperCard application that demonstrated the potential for self-organisation in a hyperlinked network. Measurements of node/link fitness were taken locally, based on the principle that there should be no central control. Nodes were simply words which users linked to other words. At the start of the experiment, all words were weakly linked with all others, but as users followed links the weighting of the strengths between the words increased. These links were transitive, so that if a link were followed from A to B and then from B to C, a small amount of extra weight was applied between A and C. Weightings took account of symmetry, so that a link from A to B would also slightly strengthen the link from B to A. Cluster analysis showed the network ordered itself into clusters of related concepts in a fairly consistent manner with little sensitivity to initial conditions. If such a system could be applied to the larger world of the web, there is some potential for creating self-organised collaborative generation of paths and relevant topic groupings.

Assessment

Collaborative filters could equally be applied to the process of assessment although, to the best of my knowledge, no one has yet done so. The collective expression of preference of basic collaborative filters might make an extremely good gauge of the value of a piece of work when considered as a resource. The book charts found at Amazon.com play exactly that role. They provide a useful degree of feedback to the author of the effectiveness of the work, thus closing a feedback loop for formative assessment. There is no reason in principle why such an assessment could not be used in a summative fashion, although issues of trust and authenticity might need to be addressed with care.

The role of assessment has already been identified as a central feature of any effective educational experience. In the context of a self-organising system the obvious place to start looking is in the area of collaborative assessment. McConnell (1999) discusses a system that uses electronic submission but is not automated. It is a rigorous process of peer review, with plenty of open feedback loops, allowing the submission of several drafts for peer review before final submission. By making the process of assessment iterative and governed by peer feedback, McConnell provides a mechanism for self-organisation. He goes further than this, involving students in the process of generating criteria and in the ongoing evaluation of the assessment process. Electronic support is provided by a traditional discussion forum, but it is the way in which it is used that provides a means of self-organisation. McConnell points out that a unique feature of asynchronous networked discussions such as this is the ability to view and review reified discussions:

> By being able to access previous entries posted by members of the learning set, the participant is able to develop, through reflection on the discussion, new understanding which can lead to new knowledge.
>
> (McConnell 1999)

A similar point is made in (Dron, Mitchell & Siviter 1998). Learning is seen as an emergent property of the process of conversation and reflection enabled by the technology.

McConnell draws attention to several pre-requisites for collaborative assessment to work effectively, central to which is the need for trust. “It is highly unlikely for us to be able to introduce these processes into a networked learning course that does not function as a co-operative learning community.” He summarises what is needed to support a networked learning community as:

- ? openness in the educational process;
- ? self-determination in learning;
- ? a real purpose in the co-operative learning process;
- ? a supportive learning environment;
- ? collaborative assessment of learning;
- ? assessment and evaluation of the ongoing learning process.

(McConnell 1999)

Many of these features are related to the idea of community and support. Developing such a community is often the role of a moderator or teacher. If we are to create an effective self-organising learning environment then we must seek techniques for helping a sense of community to develop effectively. We may have some difficulty convincing award-granting bodies of the objectivity of such a system, but it must be remembered that we are seeking ways of enabling the self-organisation of online *learning*. This may mean a departure from the formal traditions which are embodied or entombed in the university system.

Conclusions to this chapter

This chapter has examined a wide range of technologies that have some form of self-organised character or which help to moderate communication within groups. A common feature of all these systems is that they make use of user-defined metadata to structure their content and affect their behaviour. Sometimes these metadata are implicit (likes and dislikes expressed through usage) and sometimes explicit, but always they dictate the form of self-organisation that occurs.

Within a context of direct communication between participants it is useful to have some form of structure. The most interesting tools in this context make use of indirect and artefactual communication. In particular, collaborative filters and collaborative path generators apply principles of self-organisation, which allow the evolution of something akin to a group mind, ways of structuring information into something not unlike what might be achieved by an individual exerting conscious control. Many of these technologies may have some pedagogic benefits but as often as not the kinds of forms which emerge are not of much use in an educational setting. The particular nature of education hinges around the kinds of roles that I have identified for teachers and the nature of learning as a process of change. Metadata that express how things are now do not necessarily help to predict how things should be. Perhaps they should themselves change and adapt to learners' changing needs. The next chapters shall report on systems which I have been developing which develop this concept and are more focussed on providing a foundation for learning ecologies.

Chapter 6 : The development of CoFIND: building self-organising networked learning environments

About this chapter

This lengthy chapter describes the development and use of the CoFIND (Collaborative Filter in N Dimensions) system, a piece of software I have developed as a result of this research which has also helped to define the ideas that the research embodies. The motivation for the CoFIND system and some of the theoretical reasoning behind it is explained, including methods of self-organisation and its relationship to the previously identified teacher roles.

The chapter starts with a brief definition of the system followed by an explanation of the motivation for it and a description of the principle objects (resources, qualities and topics) which drive it.

The bulk of the chapter consists of six related studies. The first of these discusses the theoretical foundations, development and use of CoFIND's first version and the lessons learnt from it.

Based on the lessons of CoFIND 1 and further theoretical inputs I go on to describe the foundations and development of various iterations of CoFIND 2 which followed and which form the basis of the remaining studies.

The remaining five studies (one on the subject of topics, four on the subject of qualities) are concerned with iterations of the next version of CoFIND which were used to investigate different aspects of the system's behaviour and how it has been used by learners.

Although I provide conclusions to each study and a brief overall conclusion to this chapter, most of the conclusions to these studies are considered at length in Chapter seven.

Methodology

Appropriately enough, CoFIND has developed in an evolutionary manner, a set of trials and errors, some planned, and some exaptions based on fortuitous spandrels. It started at an early stage in my research from a slim theoretical base which was initially only aimed at looking at evolutionary processes, and has incorporated further theoretical inputs (especially methods of positive feedback based on stigmergy and theories of instruction) as I have learnt about them. Many lessons were not to do with issues of self-organisation at all but had to do with HCI (human-computer interaction) problems. However, these are not the primary focus of this research and are not pursued at any great length.

What is CoFIND?

CoFIND is a Web-based database-driven system which allows learners to collaboratively generate and use a list of learning resources. These resources are organised not by an individual or team of individuals, but as a result of the individual interactions of the learners with each other and the system (Figure 6-1). Making use of the principles identified in Chapters one and two, it is intended to be self-organising.

From its second iteration onwards CoFIND directly aims to address the functions of a teacher identified in Chapter three, including those of a *subject expert* and *a facilitator of communication*. In all iterations it attempts to structure a body of instruction for easy assimilation by the learner, in an attempt to fulfil the roles expressed by Bruner (Bruner 1966), *to specify ways a body of instruction should be structured for easy assimilation by the learner* and *to specify the most effective sequences to present materials to be learned*. I shall also observe that it may provide a method *to control the nature and pacing of rewards and punishments in the service of learning and teaching* as well as helping *to provide some of the experiences which implant a predisposition toward learning*. Although Bruner's meta-theory of instruction does not prescribe how a theory of instruction will look, the fact that CoFIND fulfils these basic criteria defines it as an instructional system, if not necessarily a very good one. Being Web-based, it lends itself well to a distance education environment. We have seen how Moore & Kearsley (1996) describe a distance education system as a "network of knowledge sources, processors, managers, communication media, and learners." With a significant emphasis on the management function, CoFIND combines all of these into a single package. This will be discussed later in this chapter and in Chapter seven.

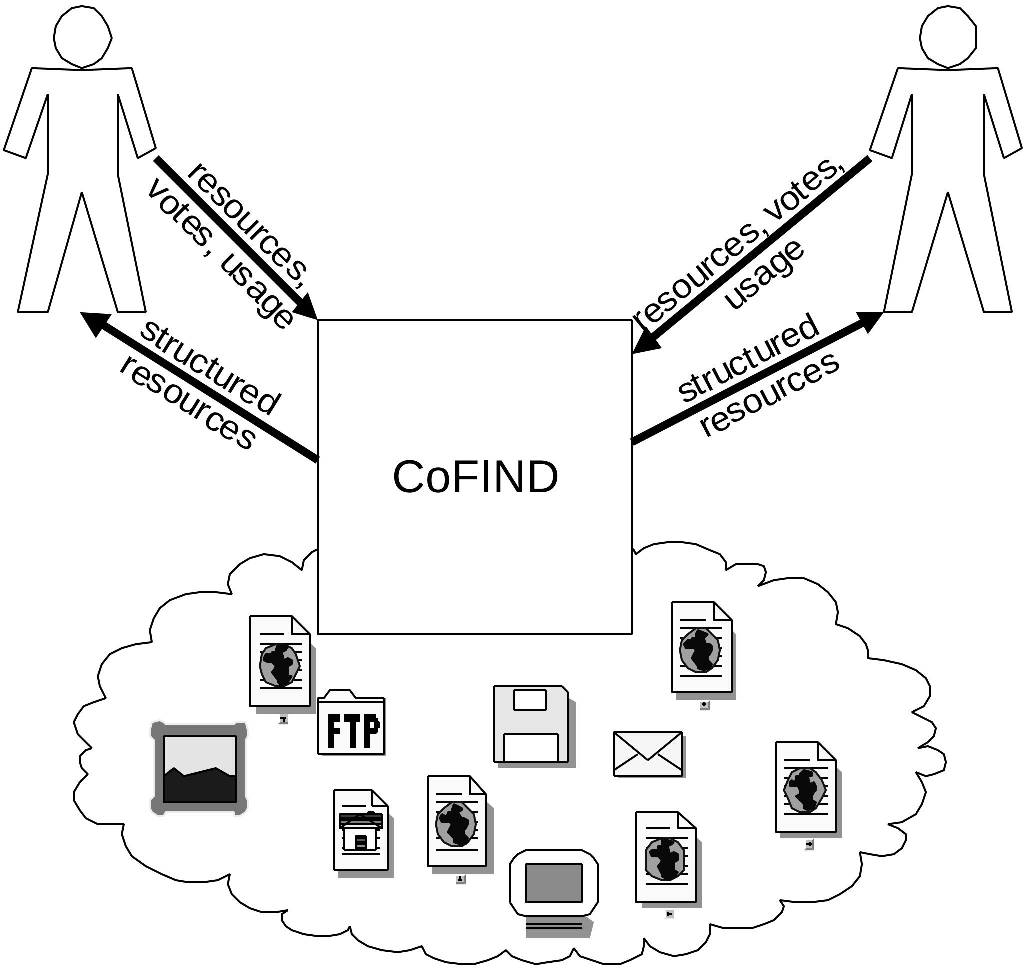


Figure 6-1 – CoFIND overview

Motivations for CoFIND

> Dynamic systems of instruction and learning, in information-rich environments, cannot and should not be concerned with the production and dissemination of instructional materials, since there is already an abundance of content around us.
>
> (Saba 1999a)
>
> To attain knowledge, add things every day. To attain wisdom, remove things every day.
>
> (Lao-Tsu)

Early thinking about the design of CoFIND focussed on placing learning resources into an ecology that forced them to compete with each other. The intention was that the learning resources themselves should adapt to this evolutionary landscape through a process which encourages authors to make changes to those resources in response to feedback generated by the system.

At this stage I was only slightly familiar with the range of existing collaborative filters and I was not concentrating on the roles of teachers. I had observed, like Saba (1999a), that there are many potentially useful resources for learners on the Internet. In Chapter four I discussed how there are too many of them and that the problem is thus one of quality of information (QOI), finding those which will be most useful. As a teacher of networking technologies my subject area is better catered for than many, but the exponential growth of the Internet means that the problems of QOI which I face when searching for something useful will need to be addressed even by those dealing with the most obscure fields of study.

CoFIND 1 was designed to help learners choose between resources from which to learn, by:

? putting resources into competition with each other through a discriminatory process of voting

? providing a means of discriminating useful from less useful within a given context of learning needs.

Through this mechanism I hoped that a feedback loop might also affect the providers of such resources, indicating where they could be improved and driving the creation of better resources through an evolutionary process. I had already identified that what I would come to recognise as a simple collaborative filter, even an automated collaborative filter which matches similar users, was not going to be an effective tool, due to the high degree of temporal and context sensitivity in learning. What was useful today and yesterday does not necessarily predict what will be useful tomorrow as learning changes people and no two learners are the same. They will be changed in different ways. Despite this, many of the places that they visit along the way may be the same and CoFIND was designed to capitalise on this.

Terminology

In discussing the uses of CoFIND I will be using a number of words in a specific sense. In particular I shall talk about *resources*, *qualities* and *topics*.

Resources

CoFIND is concerned with helping learners to discover, store and retrieve resources from which to learn. All iterations of CoFIND have allowed any resource which can be referred to with a Uniform Resource Locator to be entered into the system. Later versions also explicitly allow the learner to enter information about other kinds of resource, such as books, plays, films, people, places and things, as well as to create and upload computer-based resources to the system. The use of the word *resource* in this context is equivalent to that of the proponents of Resource-based Learning (RBL).

Qualities

All iterations of CoFIND have made use of the concept of *qualities*, metadata which describe the value of resources. These metadata are used to provide ratings which help to provide the rank order for resources. Qualities are metadata about a resource which describe its value, which might include but not be limited to the kinds of things identified by Valovic (1994) as applying to QOI or the selection criteria of Hofman & Worsfield (1996) discussed in Chapter five. Typically adjectival in nature, they indicate what it is that a learner likes or dislikes about a resource. Examples might include *good for beginners*, *amusing*, *helpful* or *comprehensive*. In the CoFIND systems, learners themselves are the creators of these qualities. In keeping with the philosophy of self-organisation, there are no initial constraints on what may be entered as a quality. If a learner decides that what is valuable about a particular resource is the amount of yellow on a Web page then there is no restriction that prevents that quality being added. This can in principle lead to the generation of many qualities of little or no utility to the bulk of users of the system. To introduce constraints, these qualities are allowed to starve to death, out-competed by other, more successful qualities, in a process akin to that of evolution. The mechanism for this has developed over the course of this research and will be discussed later.

Qualities are the *n* dimensions which gave CoFIND its name and are a response to the pedagogical weaknesses of the self-organising environments described in Chapter five. The need for them is based on the recognition that, in the absence of a trusted teacher, it is not enough for learners to be told that a resource is useful or not useful, good or bad. A learner needs to know *how* it is useful, in what ways. Learning is about change, with dynamically changing needs arising as a result of learning. Saba says

> instructional and learning systems must be able to assess prior knowledge of each learner at the onset of an instructional session and be able to provide differential learning experiences for each student based on his or her prior knowledge of the field (Saba 1999a).

Saba is correct, but could go further. It is not just prior knowledge but learning styles, requirements, future intentions, personal taste and an indeterminate number of qualities of resources that will influence whether or not a learner will find them useful. The layer of metadata created by qualities allows for a flexible set of behaviours that enable the system to finely adapt to its learners and the resources that are fed into it. Traditional automated collaborative filters are based on matching similar preferences in users. CoFIND makes those preferences explicit, effectively reifying user models so that a user is not pigeonholed into a particular niche, but may select a model which fits his or her current needs, changing that model as learning occurs and those needs develop. This makes the system primarily suited to mature learners who are able to express those needs. In another sense, qualities act as a means of making concrete the different realities referred to in Chapter one (Hunter & Benson 1997) which are created by social interactions.

Topics

Later versions of CoFIND make use of the concept of *topics*, which are typically binary classifications. This usage follows conventional terminology and the use of the word found in the MDC (Model for Distributed Curriculum) framework proposed by Murray (1998):

> Topics can refer to any type of knowledge or learned behaviour, including concepts, facts and procedure, and there are no restrictions on the size or level of granularity of the knowledge they refer to.

Topics arrived in the CoFIND systems later than Qualities, but also contribute to its n-dimensionality.

Generations of CoFIND

Much of the rest of this chapter will be concerned with discussing various implementations of CoFIND. Table 6.1 provides an overview of the most significant of these.

Table 6.1 – the main iterations of CoFIND

Version	*Main distinguishing features*
CoFIND 1	A simple shared bookmark system making use of qualities, several selectable at once, with voting for resources using a simple “I agree” button
CoFIND 2	Introduced topics. Only one quality is selectable at a time, with a voting system based on a Likert scale. It also contains a discussion mechanism and a means to add non-Web resources. This system went through various minor iterations to correct problems with the interface and to balance the degree of stigmergy it employed
CoFIND 2.5	Topic labels dynamically sized based on a stigmergic/evolutionary mechanism
CoFIND 2.6	Quality labels dynamically sized in a similar manner to the topic mechanism

CoFIND 1

This instance of CoFIND was originally reported on in Dron et al (1999) and in an extended form in Dron et al (Dron et al. 2000e), which forms the basis of the study which will follow.

The problem

The problem that CoFIND 1 sought to address was simply to provide a means to collect and organise resources through the combined actions of its users, centring around evolving qualities as the means of speciating different learning needs. Qualities were to be used by learners to identify resources matching their needs.

A description of the CoFIND 1 system

Users are required to log in to the system by providing an email address. This is not for security, but to keep a track of individual users on the system. In this early iteration I did not attempt to limit the number of times anyone could vote for a resource though the fact that this information was recorded was intended to act as a deterrent.

On entering the system the user is presented with a form containing a list of qualities which have been entered by other users of the system, ordered according to popularity of usage (Figure 6-2). This screen also allows users to enter a search term or terms, with a choice between boolean OR and AND searches. Users may select one or more qualities.

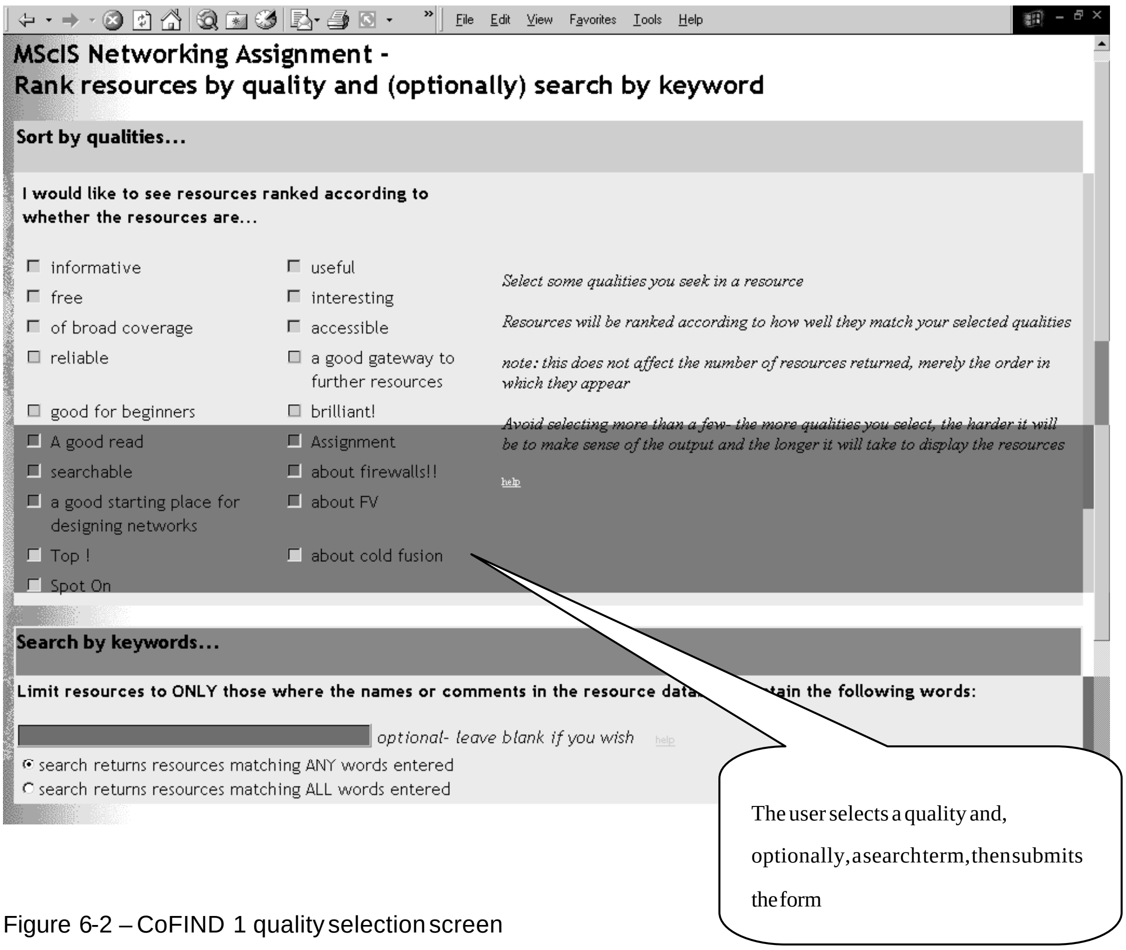


Figure 6-2 – CoFIND 1 quality selection screen

On submitting the form, the user is taken to the second page (Figure 6-3) which shows the results of the search, along with the first few hundred characters of any comments that have been made on each resource. A simple barchart graphic indicates the number of votes given for each selected quality for each resource. If there are many qualities selected then the system runs slower, the quality barcharts are confusing and the resulting order of resources can be quite strange. In this way, the process is self-limiting as users will learn not to select too many conflicting qualities. Resources are ordered according to number of ratings for the selected quality or qualities. Users may choose to rate any given resource for the selected qualities (and only the selected qualities) by clicking an "I agree" link. A link is provided should the user wish to see how the resource has been rated using other qualities (and to rate it using those qualities) as well as to see the full range of comments. By making it harder to rate using unselected qualities, the user is thus encouraged only to make use of selected qualities, creating a positive feedback loop where success may be rewarded with further success. Later I would come to recognise this process as stigmergic.

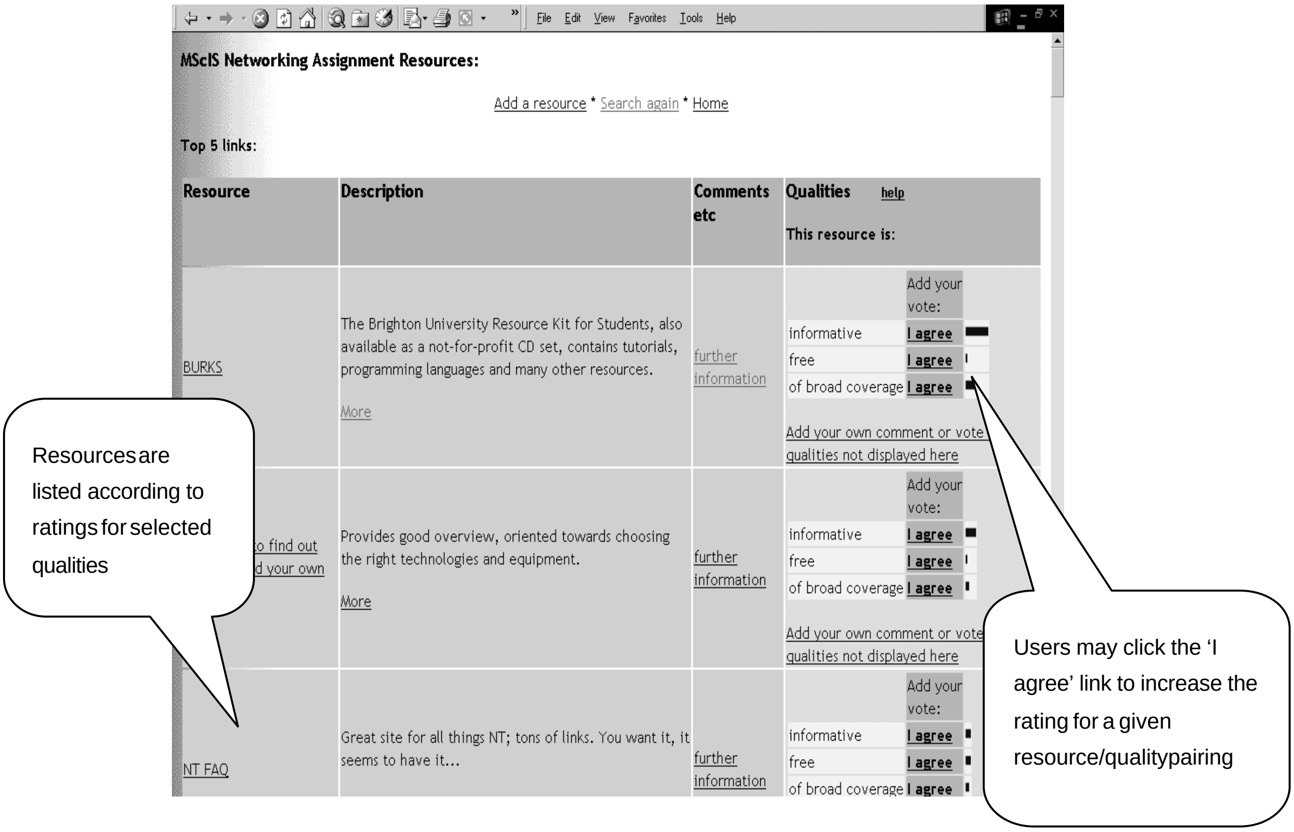


Figure 6-3 – CoFIND 1 resource-display screen

CoFIND ratings

The first iteration of CoFIND was a simple system, although I shall observe that this simplicity was in some ways a blessing. It attempted to be no more than a collaborative bookmarking system, albeit with a tendency to evolve. It had the following functionality:

? learners could enter new qualities and resources

? resources could be rated according to the entered qualities

? little-used qualities died whilst popular qualities flourished by moving towards the top of the selectable list.

CoFIND 1 used a binary rating system for resources (implemented by simply clicking an ‘I agree’ link), based on the principle that the cost to the user should be kept to a minimum. The algorithm for evolution in the first iteration of CoFIND was very simple, using a count of votes, the algorithm known in the literature as POP (Cohen & Fan 2000). Using POP, the score for a given resource is based on the algorithm:

SCORE(A)=rating(U(1))+…+rating(U(N))

When seeking resources based on qualities, more than one quality could be selected at once, with resources being ranked according to the aggregate of quality ratings for the resource

Qualities were dropped from the selectable list if they had not been used (selected or used to provide ratings) for more than a fixed number of days that I initially set to one week. This period was based on an educated guess about the quality birth-rate and could be manually adjusted if I so wished. Death of qualities thus resulted from disuse. If the system was not used for a week, this meant that it no longer presented any qualities for the user to select. This was clearly a piece of sky-hooking which would later be fixed in CoFIND 2.

Theoretical underpinnings – self-organisation

CoFIND 1 makes explicit use of evolutionary theory. In particular, it provides a mechanism to place resources and the metadata which describe them into competition with each other, leading to survival of the fittest. Based on the principle discussed in Chapter two that the slower moving parts of the system dictate the development of the faster moving parts (Brand 1997), I was trying to build an environment (the slow moving part) where evolution would be likely to lead to usefully organised learning resources.

As explained in Chapter two, evolution requires reproduction with variation and competition. Competition occurs amongst both resources and qualities:

? **Competition amongst qualities:** Unpopular qualities lose the evolutionary struggle, achieved by emphasising those which are most used and de-emphasising those which are least used. Qualities are produced by learners, who also provide their only source of food (votes and usage). Once produced, a given quality may be more or less successful. Reproduction may be seen in terms of the number of resources rated. Reproduction with variation may be seen as a process of refinement, following the Lamarckian principles underlying memetics (Dawkins 1991) . If a particular quality does not quite capture a user's needs it may suggest one that is more appropriate, in which case the user may enter another quality that is more appropriate

? **Competition amongst resources**: the success of resources is measured mainly in terms of how well they are described by the qualities entered into the system, which in turn defines their rank order.

In developing CoFIND I was looking for spandrels and exaptions, by-products of other processes which led to advantages for the system and its users (Gould & Lewontin 1979).

Following Dennett's (1995) analysis of evolutionary processes, as much as possible I was attempting to allow the system to pull itself up by its own bootstraps, trying wherever possible to avoid skyhooks and reduce the influence of the designer in dictating the precise form of dynamic growth and change of the system.

From the complexity theorists CoFIND borrows the idea that to achieve growth the dynamics of the system should be able to reach a point balanced at the edge of chaos (Kauffman 1995). The significant input from this is that Stalinist and Red-Queen regimes should be watched for and avoided.

Collaborative filtering technologies were identified as potentially powerful mechanisms for self-organised collaboration but not supporting the unique needs of learners. CoFIND 1 seeks to extend the concept to provide educationally useful recommendations. CoFIND 1 is based on identifying patterns of abstracted similarity between resources, not only *what* resources contain to make them useful, but through the use of qualities *how* those resources are useful, in what context, to whom. It seeks user-perceived metadata about resources that describe not only positive/negative feelings towards those resources but which characterise what it is about those resources that induces these feelings.

Based on the principle extracted from the earlier discussion of problems of categorisation, CoFIND 1 was aimed at a small and focussed group of learners with shared needs and presumably similar use of categories. By a happy exaption, this small size also caters for the need for parcellation identified by evolutionary theorists from Darwin onwards.

Theoretical underpinnings – learning theory

Although it could help to support a resource-based learning environment, CoFIND 1 used very little explicit instructional or learning theory. At this stage I was not attempting to mimic the role of a teacher, merely to make it easier for learners to find things to help them to learn, to enable a form of emergent collaboration of the sort discussed in Chapter one (Nachmias et al. 2000) but without the aid of specific moderators. Having read a fair number of books and papers describing the creation and use of Web-based resources for learning, I was assuming that not all of the teachers and instructional designers who had created many of them were mistaken in their beliefs that these were learning resources. It was as a direct result of discovering the possibilities inherent in this system that I began to investigate the ways that teaching can occur, leading to various elements of functionality found in CoFIND 2. However, certain presuppositions do underlie its construction. Notably, it attempts to replace the skill and expertise of a teacher in discovering resources, an important feature of a teacher as discussed in Chapter three. It also presumes that it is possible to improve learning through the use of Web-based resources, drawing on large amounts of work on RBL.

CoFIND 1 case study

I have already discussed the use of a web-based discussion forum for an exercise performed with a group of forty-two MSc information systems students studying networking (see the final case study of Chapter four). This forum was part of a larger system designed to support the learning needs of the group faced with a problem-based assignment, with CoFIND providing its central knowledge base to assist with learning new facts. To recap, the students all had first degrees in non-computing subjects and were typically dedicated and motivated, a prerequisite for this very intensive conversion degree. This motivation is clear from the fact that by far the majority had not come directly from finishing a first degree but had given up full-time work to start the course.

The students' task

Around half way through their conversion masters degree, the students were required to design a network, a task that would take significant research to complete, with much of the knowledge required being new.

CoFIND was provided as a collaborative database of resources relating to the assignment. Students were expected to search the Web for resources such as information on network installation, tutorials on network design and manufacturer's sites. This would have been a normal part of the process of completing such an assignment, but in a more traditional exercise there would have been little explicit sharing of resources. Students were offered up to five percent of their marks for their contributions to CoFIND, whether adding resources or commenting on or voting for existing resources. They were also asked to use the system to submit the URLs of their finished reports, which would then be formatively rated by their peers.

The students had participated in a pilot trial of CoFIND for one week prior to the start of the assignment, which was intended to iron out any bugs in the system and difficulties the students might have with using it. It also provided a useful list of qualities with which to start the final version.

I had primed CoFIND with three relevant resources and seven qualities (‘interesting’, ‘useful’, ‘reliable’, ‘informative’, ‘a good gateway to further resources’, ‘of broad coverage’, ‘accessible’) that had arisen in the earlier pilot trial. Throughout the study, conscious of the need to avoid behaving as a sky-hook I did not make any further contributions. The starting state of the database is simply part of the shape of the evolutionary landscape. I was looking for the dynamics of the system, what happens next rather than how it came to be.

Some Results

The system was very popular and received many positive comments. A typical comment was ‘we should have had something like this for the entire course’. Another student wrote:

> “Some of the links in the Resource database have been very useful for gathering material for my dissertation "Wireless data transmission". “

That the system was turned to a slightly different use is an interesting and unintentional spandrel, but there is little indication beyond this isolated instance that it was exploited to provide assistance with other information needs.

The main appeal to students was that it was a searchable collaborative resource database- a shared bookmark space for storing useful URLs and associated comments. Thirty-six out of the forty-two students discovered over seventy relevant resources over the two week assignment with a range and quality surpassing my (presumably expert) attempts spanning several years to build a similar list of links. All the students who did not contribute resources made comments on existing resources, indicating that they had spent some time looking at them. Given the allocation of marks to this process, this was not too surprising.

Although CoFIND 1 was designed only to handle resources that can be specified with a URL, it proved flexible enough for one of the students to use it to recommend a book- the ensuing votes and comments showed that this was a very successful choice. As a result of this, later iterations of CoFIND attempted to make use of this exaption by providing explicit support for non-Web-based resources.

Growth of qualities was generally restrained. Only a few new qualities were added to the original seeding values until the final hand-in day, at which point a Cambric explosion of qualities occurred, mainly along the lines of '"Brilliant!", "Top !" and "Spot on", all applied to the students' own work. Until that point I had suspected that the students had not grasped the mechanics of adding qualities and that I had made the process too obscure, but this showed otherwise. With sufficient motivation, qualities were rapidly added. As Wilson and Ryder say, "There must be a legitimate self-interest to sustain individual participation" (Wilson & Ryder 1998). Finding the key to that self-interest remains a problem for use of the system. The extrinsic motivation applied here works to a point, indicating that CoFIND may be usable within a traditionally taught environment. It is interesting to note the similarity of the terms used in this last flurry of CoFIND activity, suggesting that the mechanism of reproduction with variation may be valid.

Early questioning suggested that students might not have added new qualities because the existing ones mostly suited their needs and they were avoiding unnecessary effort. One student commented

> "I liked the voting but didn't see the point of qualities."

Voting was not as common as I had hoped for. The process was apparently too tedious and went virtually unrewarded. Further questioning has since revealed that this was partly the case, but there was also widespread misunderstanding of how the system was designed to work. Many students appeared to be using the system as though it were a standard search engine, a problem that affected Stenmark's trials of a similarly tangential system (Stenmark 1999). Indeed, some students added qualities that forced it to behave as a search engine; for instance 'about firewalls'. Mainly, those who added qualities appear to have been those who understood the principles having read the accompanying help and listened to the introduction to the tool. Although I adjusted the interface following feedback from the pilot trial, difficulties understanding the mechanics of voting may still have influenced the results. A similar issue was that the students were at first unsure of the difference between quality selection and inputting search terms. One student made the comment that a resource was 'good for beginners' without voting for the quality 'good for beginners'. Again, there were clearly some user interface issues to be resolved.

Some qualities were a lot more successful than others, with the most popular qualities gaining nearly three times as many votes as the least popular, when measured over an equal period. Qualities that started successfully remained successful, which was an encouraging indication of a positive feedback loop, although there was a significant amount of fluctuation from one day to the next.

UsefulQualities

Qualities rose up the list relative to other qualities. For example, the quality ‘brilliant!’ was initially created as a quality of one group of students’ report, one day from the end of the assignment. It was immediately taken up by all the other groups as they handed their work in on the final day (clearly a successful quality when applied to students’ work), and within a day of entry was being applied to other resources and appearing half way up the list.

CompetingQualities

There was no clear evidence of the effect of votes for one quality affecting votes for any other, although the fact that students could only vote using a limited number of qualities in a given space of time suggests *a priori* that competition must have played a role in selection pressure. However, the relatively short duration of this study and relatively small number of qualities only allows us to represent the coarsest of trends.

One of the students commented:

> “Just to be controversial, how about an option to vote against something ?”

Although this would have made the system less easily usable, it would have introduced more selection pressure and was an option taken up in CoFIND 2.

Combinations of qualities

To provide flexibility users were allowed to select multiple qualities, with the results displayed being ordered by a simple aggregate of ratings. This could lead to some curious results. For example, if a user selected “good for beginners” and “comprehensive” then highly rated resources for either *or* both would be returned. This could easily lead to contradictory results. We could imagine that a resource base containing a beginner’s guide to networking and the complete set of technical RFCs for TCP/IP might both be returned near the top of the list. This is an undesirable state of affairs. A more sensible algorithm would have displayed resources which matched *both* qualities prior to those which matched *either*, but even then the problem would recur further down the list. Multiple quality selection might be seen as desirable in terms of serendipitous diversity, but it presents huge problems if we wish to return sensible results.

Other Problems

Users did not have the ability to change details after a resource had been posted, mainly because I considered that it would be too easy to cheat- for instance, users could amass votes for a known popular site and then redirect it to their own home pages. The flip side of this is that it made it very difficult to deal with resources whose URLs changed. The world of the Web is often ephemeral and fleeting. Resources which were useful today may have changed or vanished by tomorrow. This is especially true in the context of computer networks. Looking back on the resource which were generated by the students over two years ago, up to half of them are no longer valid links and it is impossible to say how much the remainder have changed. Given the subject matter, some technologies are of far lesser significance than they were two years ago. Given time, most will fade into insignificance.

The system for ordering resources in CoFIND 1 is based on a simple count of votes for selected qualities, accompanied by a bar-graph display of those votes. This becomes unwieldy as more votes are generated, leading to bar graphs which take up most of the available display space, even when using a large, high-resolution monitor. In essence, the system was not scalable, although it did not reach a point of awkwardness during this exercise.

Conclusions for the CoFIND 1 study

CoFIND 1 provided a wealth of useful information which could be used to contribute to the development of its next iteration. In particular, the following observations proved important:

? the use of qualities helps to differentiate different kinds of resources. CoFIND 1's way of using qualities had a number of weaknesses which needed to be corrected, notably a lack of scalability and confused results from the ability to select multiple qualities

? the fact that a student used it to recommend a book suggests that there should be support for non-Web-based resources such as books and films

? the means of ordering resources resulted in excessive positive feedback and a certain fuzziness due to the ability to select multiple qualities, which diluted the effects of competition

? existing resources could not be modified, whereas the URLs to which they referred might well alter, thus limiting the value of the system to a relatively short period. A system such as CoFIND 1 relies upon a single cohort of learners following a single topic at more or less the same time. There is a great deal of time-dependence in a system which is by its nature dynamic

? although the small, tightly focussed group was to an extent an exaption more than a planned feature, this meant that the group was more likely to share a set of values and meanings than were the system to be implemented with a larger, less focussed or more dispersed group. The principle identified earlier that evolution tends to occur more rapidly in parcellated populations (Calvin 1997; Gould 1978) leads to a useful mechanism for reducing the bloated excesses of results returned by large search engines and directories. A small group of users may make use of such large search mechanisms to find resources, which may then be added to a small database. If a small group with a common learning interest collaboratively compiles such resources then there is a much higher chance of relevance than for each individual to wade through the mass of results from a large search engine. Using an evolutionary model, a context-dependent taxonomy is developed which captures the usage of the group's tacitly negotiated and agreed set of evaluations. Ambiguities and disagreements between different agents are ironed out by a process of pointing to examples of instances which satisfy the criteria of the metadata. We may not all agree with the classification of a particular Web page as 'brilliant!' but a majority verdict within the group allows others to understand the schema being employed by a process of example. This parcellation was also a limitation, confining CoFIND to a specific context, group of users and moment in time

? death of qualities was simply based on whether or not they had been used for a pre-specified amount of time, common across the whole system. Death was thus not a product of competition, relative to the system, but instead represented a sky-hook, which meant that when I came to demonstrate the system at conferences after the study had finished many of the qualities had died

- the software provided little help with discovering an appropriate sequence in which to view resources. Although the tightly focussed nature of the exercise meant that some indication of currently popular resources could be gleaned from which qualities and resources came top at any given time (for example, 'good for beginners' being more popular at the start of the exercise) and thus collaboratively suggest a path, this would not scale well over a longer time-period or when looking for a more diverse range of resources for different topics.

- motivation has proved to play an important role, although it is not clear from this trial how it can lead to an appropriate result, where the ends are of value to learners. The explosion of qualities which occurred at the end of the study did not lead to those which would be particularly helpful in finding learning resources

- positive feedback acts as a positive stimulus in driving the organisation of the system, but the simple algorithms of CoFIND 1 are not well tuned to avoid Stalinist and Red Queen regimes, leading to Stalinist effects in the ordering of resources and Red Queen effects in the ordering of qualities.

CoFIND 2

Many of the lessons learnt in CoFIND 1 were fed into the design of CoFIND 2, with varying degrees of success. This section begins with a description of the main iterations of CoFIND 2 before going on to discuss a series of studies using the system. The studies performed using iterations of CoFIND 2 are here somewhat artificially divided into two sections, dealing separately with topics and qualities, these being the two areas of greatest interest while I developed the system. In real life, the two were usually inseparable and interlinked, which is reflected in references within the text between the two.

About the CoFIND 2 system

Overview

CoFIND 2 incorporated a number of enhancements to CoFIND 1 in its mechanisms for self-organisation. Most notably it added:

? the means for users to create topics, thus allowing a single system to be used for many purposes in a variety of ecological niches

? an option for users to enter free text to describe resources inaccessible via the Web

? the means to upload files

? a threaded discussion system

? a real-time chat room, to allow users to interact more freely.

Most of CoFIND 2's features were customisable, so that the creator of a system could choose whether or not to use the chat room, the discussion forum, multiple topics and even whether or not to use multiple qualities. This was primarily to allow me to study the effects of different parts of the system in isolation.

About topics

Although it provided a useful method for appraisal of resources, CoFIND 1 was doomed only to be capable of supporting a single subject area and topic, strongly focussed. This was a little like providing an island (to improve the rate of evolution) but failing to provide any means for the island population to meet any others. It led to a range of problems which relate to the pedagogical need to structure the learning experience and to provide relevant resources to a learner's current needs:

? qualities are topic-dependent. For example, the kinds of qualities which relate to learning to program a computer may not be the same as those needed to design a database, although both may be attempted by a single cohort with a unified set of learning objectives

- ? qualities are sequence-dependent. For example, as a group works through a set of topics, ‘good for beginners’ may take on a different meaning depending on what has come previously. For instance, the W3C Web site may be quite unsuitable for beginners in HTML, but (for those with a background in HTML) may be very suitable for beginners in XML
- ? a given area may naturally subdivide into different subtopics, with varying sequences and different learning needs for each subtopic.

Two alternative solutions presented themselves. The first (and the more ambitious) was to allow different iterations of CoFIND to talk to each other, exchanging qualities and resources. This raised a range of wonderful possibilities such as the invasion of one ecosystem with another or for cross breeding to occur. However, maintaining separate databases seemed inefficient and hard to control, and suffered from the disadvantage that resources that might be appropriate in more than one topic (for instance, a portal that might be good for everything from weather to shopping) would not be available immediately to users of both systems. A simpler solution would be to keep virtual ecologies within a single system. CoFIND 2 was therefore designed to incorporate the concept of topics.

Theoretical underpinnings

CoFIND 1 was the subject of a very successful conference, producing a top paper award (Dron et al. 1999) and some very useful feedback from members of the Web-based education community. In particular, issues were raised with the scalability of the system beyond a specific community at a specific time with specific goals. Several suggestions were made as to ways the system could be used as a virtual learning environment and as an assessment and evaluation mechanism for courses. The combination of these ideas and background reading about network-based learning led me to a more ambitious goal than that of the original CoFIND, to use CoFIND to seek ways of enabling self-organised groups of learners to replace the controlling influence of teachers in the learning process altogether, thus letting teachers’ roles become more polarised as guides on the side and creators/distillers of resources. CoFIND 2 was my first attempt to achieve that goal.

Theoretical underpinnings- self-organisation

CoFIND 2 built upon the same basis as CoFIND 1, but went further. In particular:

? it refined the evolutionary model, introducing many more distinct but occasionally interconnected islands in the form of topics, in keeping with the principle of parcellation discussed in Chapter two. Following this principle, islands thus created were connected weakly by isthmuses of potentially shared qualities and resources

? parcellation through the use of topics made it possible for islands to form which had different purposes, thus facilitating the use of the system not only as a knowledge repository but also as a means of formative assessment and evaluation

? The algorithms used to order resources and qualities were designed to achieve a better balance on the edge of chaos and to provide a richer set of inputs to the dynamics of the system.

Theoretical underpinnings- learning theory

CoFIND 2 incorporated a number of features which I had identified as necessary to the role of a teacher. This is discussed in more detail towards the end of this chapter, but in overview the contributions of learning theory were as follows:

? Having identified that communication is a vital part of the educative process (repeatedly in Chapters one to three) I sought to provide as many links between users as I could. Given that CoFIND is a Web-based system I was particularly keen to make use of Moore's theory of transactional distance (Moore & Kearsley 1996) where structure and dialogue provide a continuum which underlies any distance education system. CoFIND already provided some kind of structure, but it seemed important to balance this with its corollary of communication. Communication was not just limited to comments and votes but was extended to include systems which enable dialogue, and through the reification of discussions to enable learning to arise as an emergent property as discussed in Chapter five (McConnell 1999). CoFIND 2 thus seeks to provide support for the development of a learning community, with all the benefits that brings

- Like CoFIND 1, CoFIND 2 provides a mechanism for RBL, a means of sharing knowledge and resources to provide something akin to subject expertise. In all CoFINDs, the intelligence involved in selecting suitable resources springs not from one individual but from the collective operation of the group mind

- Through their topic mechanisms, later versions of CoFIND 2 made use of stigmergy to provide a guided path through resources, beginning to provide the sequencing of materials to be learnt required by Gagné's instructional theory.

- Like CoFIND 1, CoFIND 2 enables the provision rewards and punishments in the service of learning and teaching in the form of ratings and comments. The use of topics allows specific areas to be created for the uploading or linking of student work, thus enabling a feedback loop.

CoFIND 2's match with learning theory is discussed in greater detail in the next chapter.

A description of CoFIND 2.0

When users first reach the CoFIND 2 system they are required to enter their email addresses and passwords. This helps to ensure that individual users are accountable for their actions. Unlike CoFIND 1, users are only allowed to vote once for a given resource/topic/quality combination. If they vote twice, their previous votes are overridden by the subsequent votes. Although this means losing the self-organising benefits of the earlier system it ensures that the results are a fair reflection of the group dynamic, preventing the possibility in CoFIND 1 whereby one user could disproportionately influence the results by misusing the system. Sadly my implementation of this makes the system less easy to use, and has occasionally introduced some bugs which have prevented use of the system. As one disgruntled user put it in a personal email,

> john the system keeps loosing my login status and password so i have to
> keep registering again!
> i don't mind but it getting a bit of a pain in the ass!!

This is a rather negative example of the environment affecting the dynamics of a self-organising system, but it does illustrate the importance of providing a fertile environment where dynamic change can occur.

The first screen that the user of CoFIND 2.0 sees provides access to topics, qualities and resources within a single window (Figure 6-4). This was intended to make the system easier and faster to use than the two stage process of CoFIND 1, although the overloaded interface actually made it harder for many users to understand.

At the base of the screen is a control panel containing a listbox of topics (in order of posting), a listbox of qualities (ordered using the algorithm described below) and a search like that used in CoFIND 1. If the administrator has allowed it, the control panel also contains a link to the discussion system for the currently selected topic, the chatroom, the means to add resources (including free text entries), qualities and topics, the file upload facility as well as a link to the system help file and configurable preferences.

Only one topic and one quality can be selected at a time, thereby enhancing stigmergy and avoiding the fuzziness that plagued the earlier CoFIND when multiple qualities were selected. This first iteration drifted into a Stalinist regime by making the most popular quality the default selected. It was thus far too easy for users to bypass the need for quality selection. This was later corrected.

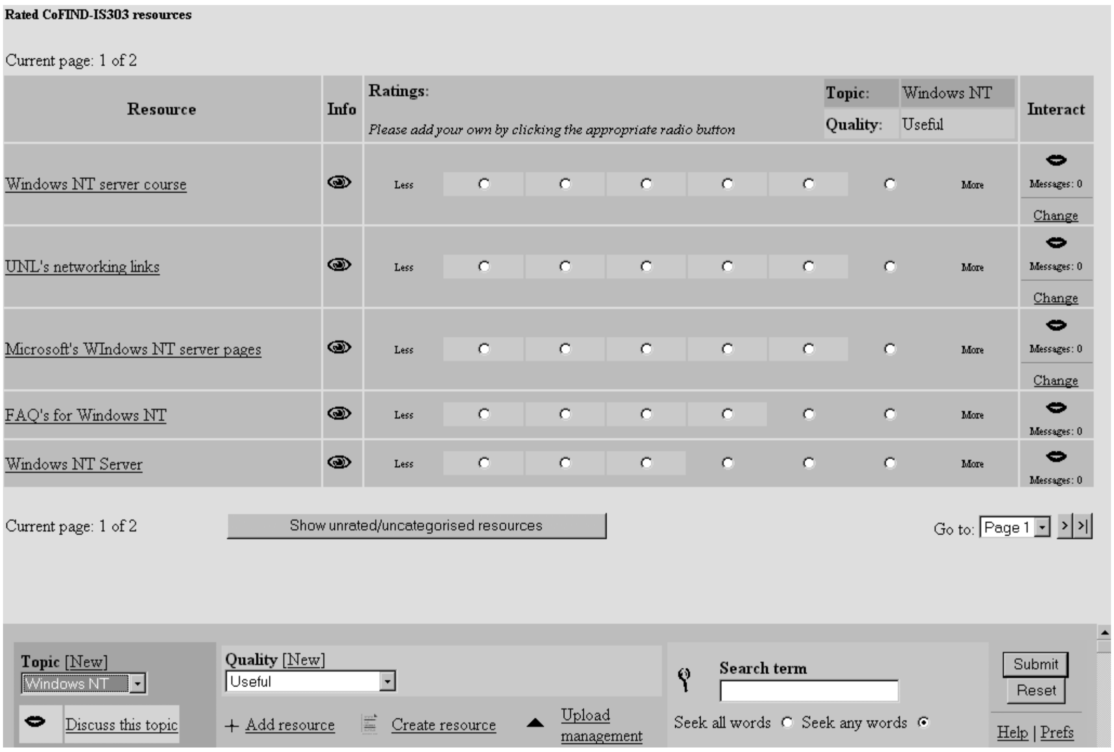


Figure 6-4 – CoFIND 2.0 main screen

Resource display and ratings

Above the control panel is the main window, which displays resources and current ratings. Resources are displayed in order of rating for the current combination of topic and quality (the algorithm for this is discussed below). If there are any resources which have been rated for the current combination of topic and quality, these are the only ones displayed, along with a button which allows users to see unrated resources. The system used to display ratings is also used to add them. It was expected that through this mechanism users would be influenced by existing ratings in their choice of rating, but this was a two-edged sword and for many users the double function of the rating display made the process less intuitive and I have frequently been asked how ratings should be applied from users whose mouse-pointers were resting on a rating button.

Clicking at an appropriate point on the rating bar allows the users to add their own ratings, on a scale of 0 to 5. This scale is intended to make it hard for users to remain neutral, thus driving the ratings in a distinct positive or negative direction, thereby enhancing the stigmergic effects of existing ratings.

By clicking on an eye () icon, users can see more information about a resource. Unlike CoFIND 1, the only way that ratings can be applied is within the context of the selected topic/quality combination. This is intended to magnify the stigmergic effects of ratings.

By clicking on a lips () icon, users can discuss individual resources using a threaded discussion subsystem, in a manner inspired by the D3E system discussed in Chapter five. This subsystem is fairly conventional, apart from providing the option to add a particular message as a resource which may then be rated like any other.

The chatroom is a primitive HTTP-based system and has no special functionality. It is there purely to facilitate communication. The reason it was added is the principle identified in Chapter three that a teacher should be a facilitator of communication.

Algorithms for qualities in CoFIND 2

The POP algorithm used for CoFIND 1 had weaknesses. Popular resources that had been rated early on tended to stay on top, maintaining their advantage even in the face of strong competition. Although this is evidence that there was an effective stigmergic feedback loop (highly rated resources would appear at the top of the list of returned resources, thus making it more likely that they would be selected and thereby increasing the probability of their being rated) the system had a tendency towards a Stalinist regime where new resources were given little chance to successfully compete.

While CoFIND 1's rating system showed a Stalinist tendency leading to permanently successful resources, by contrast the qualities tended to enter a chaotic regime. Because multiple qualities could easily be selected, there was a high level of dynamism in the movement of qualities on the selectable list.

To compensate for CoFIND 1's Stalinist tendencies of resource order and to provide scalability, CoFIND 2 uses a six-point Likert scale to rate resources according to qualities, which allows a more sophisticated algorithm to be used to display resources, based on a combination of time-based weighting, averaged ratings and number of votes cast.

A further benefit of using the Likert scale is that it allows negative feelings to be registered. Even in this form, the feedback loop is highly stigmergic, and plays a strong role in preventing lower-placed qualities from rising up the list. Little-used qualities provide small lists of relevant resources, so remaining little used. To prevent stigmergy drifting into Stalinism, when new qualities are added they are given a weighting that is designed to ensure that all qualities have a chance to survive by placing new qualities near the top of the list. This weighting is usage-based: normal use of the system will rapidly lower the quality's position in the list if it is not successful. This mechanism is a skyhook, but it is a pragmatic solution to the problems of novelty. In a large system (exactly as in large populations in biological ecosystems) there is little chance for novel adaptations to spread. In an educational environment it is important that any system developed is of benefit to learners from the start. Whilst evolutionary mechanisms can be applied to the structuring of metadata, it is unethical and impractical to apply those same mechanisms to the learners themselves.

The weighting mechanism in CoFIND 2

New qualities start with a weighting equivalent to a count of the largest number of ratings given to any quality in the system. The purpose of this is to ensure that new qualities have a fighting chance. It leads to the new quality being near the top of the list, but seldom right at the top, as existing high-flying qualities will usually have some weighting of their own.

Each time a quality is selected by any user, the weighting for that quality increases by one. Each time a user logs into the system (any user), the weighting is reduced by one for *all* qualities at once. This process is applied to all qualities equally until they reach a weighting of zero, at which point their success is determined solely by usage. If the system is little used, with few logins, weightings in general will be fairly high whereas a heavily used system will reduce weightings rapidly. This is in contrast to the simple time-based system of CoFIND 1, which led to no qualities surviving if the system was little used. The effect of CoFIND 2's weighting algorithm is to adjust the dynamics of quality starvation according to the level of usage of the system. Weightings are multiplied by the count of votes to provide rank order. The system is thus organised dynamically according to level of usage.

Resource display algorithm in CoFIND 2

Resources are displayed in order of the average of their ratings. On its own, this would mean that a resource that has been rated once could be considered as more successful than one that has been rated many times, even though that single rating might be strongly atypical. This is counter-intuitive as it would seem that a large number of ratings are more likely to give a reliable indication of the value of a resource than a few. Therefore, to provide a positive skew where more ratings have been given, more frequently rated resources appear before less-rated resources where the average rating is the same. The algorithm to achieve this takes the average rating and added a decimal fraction based on the cosine of the number of votes:

SCORE(A)= ((rating(U(1)+...+rating(U(N))/SUM(U(N)))+COS(SUM(U(N))

There are weaknesses in this system. In particular, there is an averaging of the averages: an average of 4.99 with few ratings could be treated the same as an average of 4.01 with many ratings. It also still means that if ninety nine out of one hundred users rated a resource highly and one rated it low, that resource would appear lower in the list than one that had been rated highly once by a single user. This is not usually as great a problem as it may appear, as a fast-acting negative feedback loop prevents a low-rated resource from staying at the top for long. If a resource were selected because of its early appearance in the list and it turned out to be disappointing, it would probably receive a low vote, thus rapidly reducing the average rating and sending it tumbling down. Similarly, votes for often-rated resources would be less statistically significant than those which were seldom rated. This is in keeping with the way that parcellated populations are able to change rapidly in biological ecosystems and indeed provides concrete evidence that the phenomenon occurs. The larger the population, the less the effects of changes to particular species (Gould 1978, p.61). In keeping with the work of Kauffman (Kauffman 1995) discussed in Chapter two, this maintains a balance just the ordered side of chaos, and so helps to maintain distinct species, giving sufficient time for a proper ecology to develop.

Stepped enhancements of CoFIND 2: CoFIND 2.1-2.6

CoFIND 2.1-2.4

CoFINDs 2.1-2.4 were mostly bug fixes and trials of different methods of organising topics.

Various methods of organising topics were attempted. CoFIND 2 provided a simple list in order of posting. However, a simple list, unless it were ordered by an expert, made it difficult to distinguish an appropriate order to follow the topics, nor did it give any means of identifying groupings and subgroupings of topics.

- CoFIND 2.1 allowed users to optionally specify a “parent” topic when adding a new one, but this was not at all in keeping with the general principles of self-organisation which I was aiming to achieve and I dropped it shortly thereafter.
- CoFIND 2.2 implemented a system that put most-used topics at the top of the selectable list, which meant that the most popular topic was likely to be selected. This was limiting in that it failed to capture any relationships between topics (as would be required for the implementation of collaborative trails, for instance) and

more than one topic might be appropriate at any given time. However, it did allow self-organisation to guide users to what the group felt was the most relevant topic at the time, as in the absence of other constraints users would be more likely to select from the top of the list.

? CoFIND 2.3 added options to allow the user to customise various aspects of the system, including system colours, number of results and qualities displayed. It was intended (in the spirit of self-organisation) that the average/most popular of these would feed back into the default interface displayed to new users, but this seemed fairly trivial and was never provided to the users.
If there were no rated resources for a given topic, earlier versions of CoFIND 2 would simply display a message to that effect and provide an option to see unrated resources. This was unfriendly and counter-intuitive. CoFIND 2.3 always displayed resources in order of the most highly rated for the selected topic/quality combination, followed by the most highly rated for other qualities in the selected topic, followed by the most highly rated overall for all topics. Rated resources were distinguished from unrated resources by a title indicating their status and a differently coloured background. As a result, even in the absence of relevant ratings users were likely to see resources in the right topic. This led to some problems for users. As one student commented:

> A minor point that confused me at first was that no matter what topic or quality I chose I always saw the same resources. I would have found the navigational process a lot more intuitive if say, when I selected the topic "Networks & Modems" I only got resources for Networks & Modems, or whatever. However, that is a minor point and overall I found CoFind very useful.

Similarly, another student mailed me:

> The fact that resources appear throughout different categories is good in a way: you don't miss out on valuable info by looking in another category. But when I do multiple queries and get the same resources I might feel that I'm not getting the best info. (Even tho I probably am...)

Despite this, the modification was kept for all later generations of CoFIND as the point of the system is to influence, not dictate behaviour. In keeping with the evolutionary underpinnings of the system, I wished to allow for serendipity and chance to play a role, allowing exaptions to occur.

? CoFIND 2.4 arose as a result of discovering the Stalinist effects of showing just a single quality in a dropdown listbox. The interface was thus adjusted to prevent this happening (Figure 6-5).

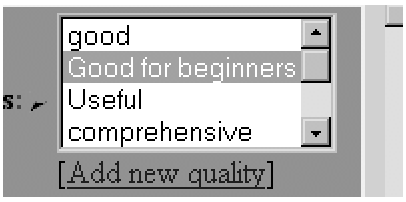


Figure 6-5 – CoFIND 2.4 quality selection box

Carelessly however, the system was left so that the top-rated quality was still the default selected. This problem was resolved after early trials.

CoFIND 2.5

The first major change to the interface from that of CoFIND 2.0 was found in CoFIND 2.5. After my previous attempts at organising topics it became clear that a simple list was not capable of providing a rich enough view of the system nor sufficient self-organisation. If anything, dynamic ordering of topics of the sort found in CoFIND 2.2 and above made the system hard to use for (to the end user) no clear benefit. CoFIND's interface was confusing and I was becoming increasingly keen on using stigmergy as a method of allowing users to influence each other's behaviour. These two drivers led to a more radical method of self-organisation.

On entering the CoFIND 2.5 system users are presented with a topic selection screen. The CoFIND 2.5 topic selection screen (Figure 6-6) is a physical workspace providing a blank palette of four distinct sectors. Learners can fill these sectors with topics of their choosing, selecting which of the sectors contains their topics. It is intended that these sectors will exhibit some clustering of related topics, inasmuch as users are likely to add new topics to sectors containing those which they consider similar. In fact, there is little evidence of this actually occurring, a fact which may be due to the interface design but which might also be affected by dissimilarity of use of categories as discussed in Chapter four, notably in relation to (Lakoff 1987) and (Macskassy et al. 1998).

The choice of four sectors is certainly a piece of sky-hooking but is not altogether arbitrary. If each of the four sectors is filled with seven items of short text of the largest possible font size using a standard browser at a resolution of 1024 x 768 pixels, then the items all just about fit on the screen. The significance of the number seven is based on the work of Miller, who demonstrates that this is approximately the number of items that can easily be assimilated at a glance (Miller 1956). There are however no constraints on the number of topics which may be entered in any sector, leaving the choice of whether to add more to the users of the system. In the longest study so far, over eight months of continual use by thirty-six students, the maximum number entered in any sector is eight, which perhaps suggests some degree of self-limitation in accordance with Miller's observations. As each sector fills up, competition sets in. More frequently used topics take up more room by showing their names in a larger font (as shown in Figure 6-6, actually taken from CoFIND 2.6 which has an identical topic interface).

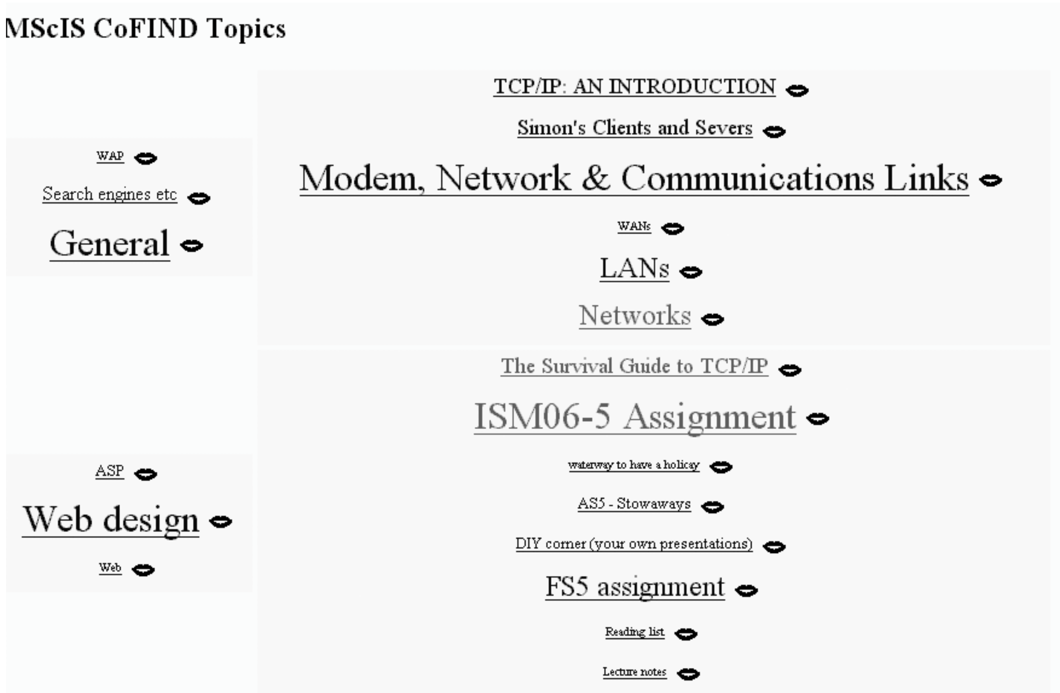


Figure 6-6 – CoFIND 2.6 topic selection screen

After topic selection, the user is taken to substantially the same screen as that of CoFIND 2.4 (Figure 6-7).

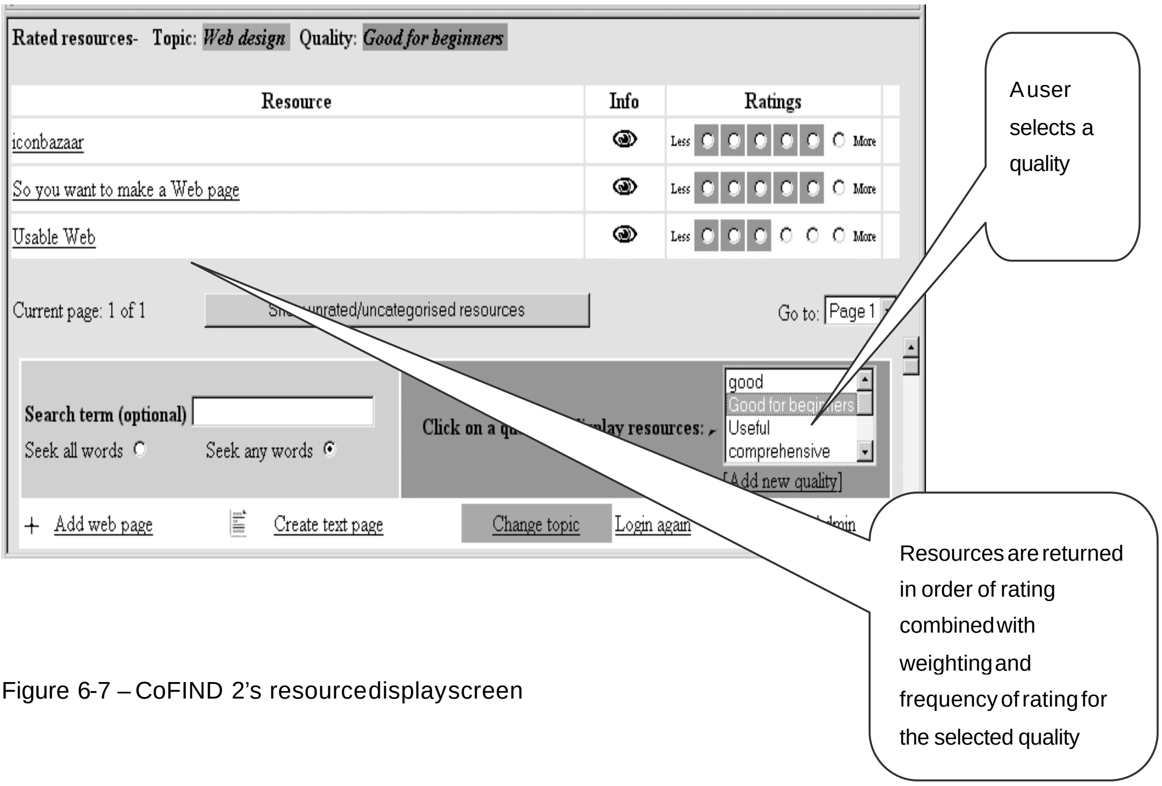


Figure 6-7 – CoFIND 2's resource display screen

By trying a variety of different algorithms I discovered that if the upward and downward pressures are equivalent, then topics of roughly equal popularity jostle to be the biggest and oscillate around a similar size and, in their jostling, can actually avoid reaching a successful plateau. The first test iteration of CoFIND 2.5, based on a simple algorithm where selection resulted in an increase of two magnitudes of font size for the selected topic and a decrease by one magnitude for the others in that sector, resulted in low local optima being reached when there were many topics in a sector. In evolutionary terms, there were no key species to dominate the environment.

The final iteration of this algorithm was responsive to the size of the environment, following the evolutionary principle defined in Chapter two of small, parcellated populations evolving more rapidly but still allowing the appearance of dominant species in environments with more diverse populations. Each time a topic is selected the font size rises by a factor related to the number of topics within that sector (current-rating + number-of-topics-in-the-sector, for legibility's sake capped at a maximum of 6) and the font sizes of the other topics in that sector all get smaller by a factor based on the inverse of the number of topics (1/number-of-topics-in-the-sector, for legibility's sake capped at a minimum of -3). Unpopular topic labels eventually get to be very small, though in this version there is no actual death, whilst popular topics tend to remain that way for some time.

The mechanism results in a lot of oscillation when there are few topics in the sector (especially in web browsers which are only capable of displaying three different font sizes using the *font* tag) but is much more stable when there are many topics. By relating growth and shrinkage to the number of competing topics, successful topics will continue to stand out when there are large populations as effectively as when there are small populations. The net result of this process causes a form of stigmergy, where it is expected that learners are led down popular paths, thus increasing the success of those paths, thereby amplifying the behaviour patterns of the group to provide structure.

CoFIND 2.6

Following the success of the adjustment to the topic selection interface, I applied a similar technique to selecting qualities. After selecting a topic, the user is taken to a quality selection screen, where qualities are displayed in a list the same order as earlier CoFIND 2s. However, the qualities vary in relative size according to the number of resources that they have been used to rate. This is intended to give a richer means for users to identify qualities of value and uses stigmergy to drive the success of more valuable qualities.

CoFIND 2.6's weighting mechanism for qualities

The size of a label is related to the number of times a given quality has been used to rate resources. In addition, qualities are displayed in the same order as in earlier versions of CoFIND 2. It is thus by design quite common in the early stages of quality evolution to find smaller labels closer to the top of the list than larger ones, as shown in Figure 6-8.

The objective of using stigmergy in CoFIND is to enhance and emphasise patterns of behaviour. By providing different cues to the user (order and size), a more complex set of interactions can be elicited. The size of the quality is a good indicator of the relative number of explicitly rated resources which are likely to be found, whereas position is an indicator of the relative perceived usefulness of the quality, gleaned largely from implicit usage statistics (users will click the qualities which they believe will be more useful).

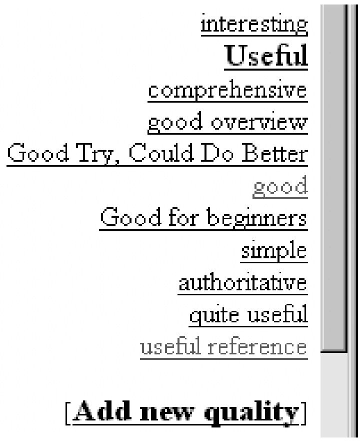


Figure 6-8 –stigmergy andqualities

The assumption (explored in Quality study 3 later in this Chapter) is that users are encouraged to select a quality by its position and/or by its size. If a user selects a quality from the top of the list, it will not necessarily return a particularly useful list of resources. Despite this, this process should usually result in those qualities at the top of the list also having the largest labels as, once selected, a given quality will then be more likely to be used to rate resources. The fact that this synchronisation does not occur straight away introduces a latency that should magnify the overall stigmergic effect, following a pattern similar to that of Senge's Beer Game (Senge 1993). Within CoFIND, the analogous positive feedback loop which causes ill effects in the Beer Game should be actually beneficial, leading to increased polarisation of the use of qualities, hence to a richer structure.

Inheritance

CoFIND 2.6 also allows new qualities to inherit ratings for resources from older qualities. For example, a user may create a new quality such as "humorous" which can inherit all the ratings applied for the quality "funny." As there are no limitations on choice of qualities from which to inherit, the user may equally select "dull" as the parent quality. Such inappropriate choices will usually lead to useless results (a user seeking funny resources would instead find those which were dull) and thus the processes of natural selection will remove the newly added quality quickly. This mechanism is intended to help counter some of the effects of the cold start phenomenon by building on existing foundations in a manner which is in keeping with the evolutionary foundations of CoFIND. Earlier versions which allowed users to add qualities were to some extent evolutionary, inasmuch as one quality might suggest another which was more appropriate, but this was rather like allowing mutation of the genotype without passing on the phenotype. By allowing inheritance of votes not only the structure but the form is passed on to the next generation. Unfortunately no students used this option in any of these studies, which suggests the interface was not clear and/or the students did not see the point of using it.

Feedback loops in CoFIND 2.6

Figure 6-9 shows a number of the competing positive and negative feedback loops that drive CoFIND. By way of summary:

? a resource's position in the list of returned results is affected by choice of topic, choice of quality, the rating of a resource for that quality and the competitive effects of ratings for other resources.

? a learner's choice of quality is affected by its position in the list of selectable qualities, by the learner's perception of its intrinsic value (ascertained by its label), by its size and by the previous utility of that quality in selecting resources of value to the learner. Quality study 3 in the next section offers confirmation of this, showing that the effects of list position and size affect the likelihood of users selecting and using a given quality

? a quality's position in the list of selectable qualities is affected by how often it has been used to rate and how often it has been selected to find resources

? it is assumed that a learner's rating for a resource is affected by the perceived match of that quality to the resource as well as the utility value of so rating that resource

? a learner's selection of a resource is affected by:

  ? his or her perception of the intrinsic value of the resource (usually by its label and/or description or by messages which relate to it, perhaps by recognising the value of the opinion of those who have discussed it or commented on it. The influence of the label is discussed in Quality study 1 in the next section, where I observe that inappropriate labels appear to act as a strong disincentive to users selecting resources

? the resource’s position in the list of returned results. This is confirmed by Quality study 2 in the next section, where I observe that the vast majority of clicks on resources are registered on the first page whether the resources have been rated or not

? Selection of a topic increases its size whilst reducing the size of other topics. A learner’s selection of a topic is affected by its perceived intrinsic value and by its relative size on screen. This is confirmed by the study of topics in the next section where the CoFIND system was subverted by a determined user increasing the size of a topic of minimal intrinsic relevance to achieve more visitors to his own page.

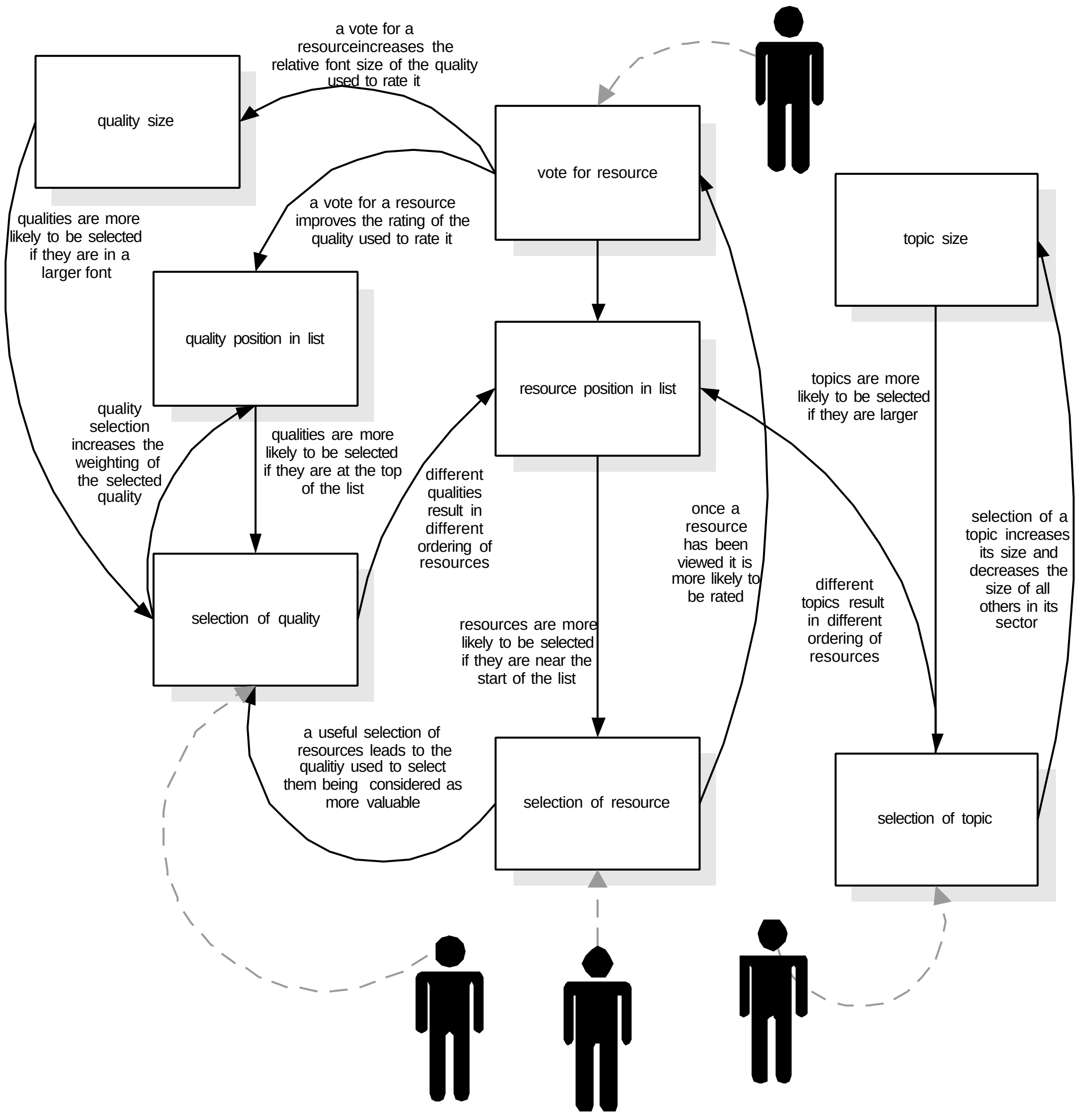


Figure 6-9 – feedback loops within CoFIND

Thus, CoFIND 2.6 is a highly dynamic system that is constantly in a state of flux. Stability does occur, partly because of the evolutionary mechanisms that result in the fittest topics, qualities and resources surviving, and partly as a result of the intrinsic utility of the survivors.

Casestudies

Having described the various main iterations of CoFIND, most of the remainder of this Chapter is taken up with a description of five case studies. In the first of these I look at the use of topics in CoFIND 2.6 and how the use of stigmergy appears to influence behaviour, as well as how easily such a system might be subverted by an individual to achieve specific ends. The remaining four studies (quality studies 1 to 4) look at the ways that qualities were used, taking examples from CoFIND 2, CoFIND 2.5 and CoFIND 2.6 to illustrate some of the issues that arose and conclusions which could be drawn.

CoFIND 2.6 case study: The topic system

The problem

Having designed a stigmergic topic mechanism I wished to investigate how it was used, especially the ways in which it might influence behaviour and bring structure to a group's exploration of resources.

Background

This study relates to the use of CoFIND 2.6 by a group of 36 MSc Information Systems students. The students were inexperienced computer users with existing degrees in mainly arts and humanities subjects, learning about information systems for the first time. CoFIND was originally presented as a means of sharing discoveries of resources to help provide background information for the taught course, but was later used as a repository for the students' own work so that they could benefit from the feedback implicit in CoFIND. CoFIND was only used to support the networking component of the students' studies.

The study

Figure 6-10 shows the topic screen after the students had received their first introduction to CoFIND 2.6 in a tutorial session. The system had been shown to them in overview and they were encouraged to think of it as an aid to learning to help fill in the gaps left by the lectures. For the tutorial the students had been asked to find resources relating to LANs and add them to CoFIND. However, from the size of its label, *Web design* appears to be a more interesting topic to the students. Even within a controlled environment, CoFIND was exhibiting self-organising characteristics. It seems that the combination of what was clearly an interesting topic together with the large size of the label *Web design* attracted more visitors than the allotted topic.

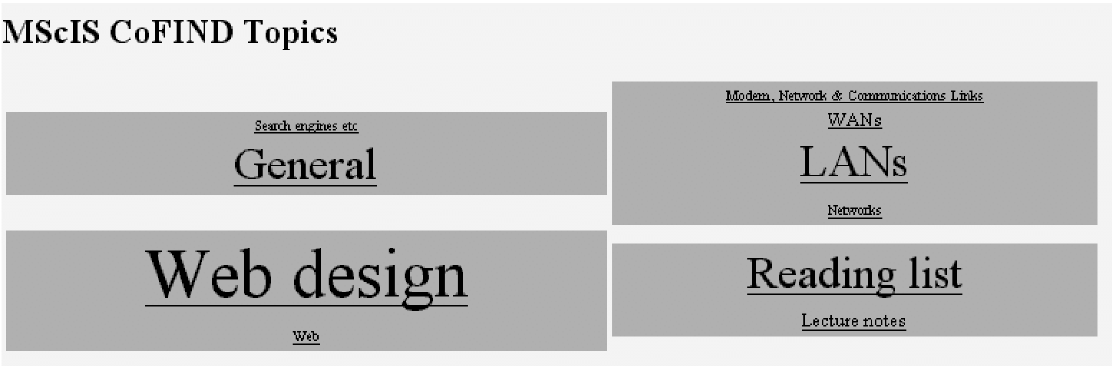


Figure 6-10 – CoFIND 2.6 topicselectionscreenshowingself-organisation (perhaps)

It is possible that it was the interest factor of the topic itself that was solely responsible for the number of clicks on the link rather than the effects of stigmergy. Bearing this in mind it is instructive to look at Figure 6-11, which represents the same database some six months later. It may not be clear from the illustration, but it is worth noting that the system acquired a new livery of colours after complaints from the students, suggesting that the interface is another area ripe for the application of some form of self-organisation. This was partially implemented in CoFIND 2.3 by allowing users to customise the colour scheme through the use of style sheets, with a mechanism built in to discover the most popular scheme. However, this was little used, perhaps because it was hidden away.

The prominent topics are mostly closely related to the development of the course at the time of this snapshot: a project on ASP and a strong interest in XML in personal projects, for example, relegate the previously ascendant *Web design* to a minor role, whilst *Reading list* has almost disappeared, because (presumably) the students already knew all that they needed to know in that topic. *Simon's Clients and Severs [sic]*, however, is an anomaly. It was claimed to be a mistake by the student who added the topic, caused by a misunderstanding of how to add some of his own work to the system. In fact, there is good evidence that this was not so, because the student repeatedly clicked the topic label over a period of a few minutes immediately after adding it, thus increasing its relative size and prominence.

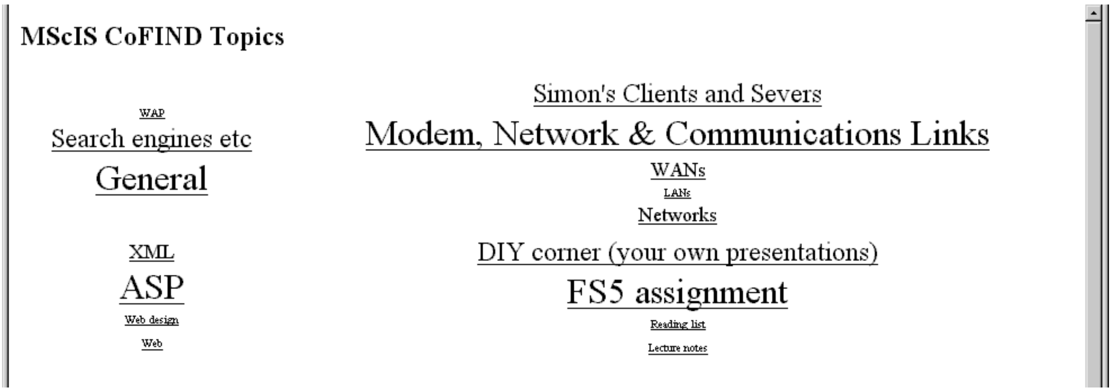


Figure 6-11 – CoFIND 2.6 topic selection screen, showing *Simon's clients and severs [sic]*

It is (even when spelt correctly) a topic of only marginal interest in the context of the course. What is fascinating is that the topic, though it later waned, got to be quite popular, visited by twelve different students over two months. This compares with only ten different visitors over a similar period to *ASP*, a topic which was being covered in class and therefore of greater intrinsic interest. It is tempting to conclude that usage was being driven by stigmergy, kick-started by the student who added the topic in the first place. It was specifically mentioned by a student evaluating the system as being "off-putting that a topic entered in error (Simon's Clients and Servers) was so prominent."

Limitations of the topic mechanism

The topic mechanism is faced with the problem that, once a population of topics reaches a certain size, novelty will not get a look in if the ecosystem is already well established. A solution may be the introduction of death to topics. Anomalies such as *Simon's Clients and Severs* should be capable of dying, but it might be a bad idea to kill off most topics. Assuming the maximum number of topics supported in a given sector were seven (but the principle applies to almost any arbitrary figure we choose) it is entirely conceivable that more than seven topics might be appropriate to a group's needs. This is a different problem to that of dying qualities. The death of less useful qualities is far less devastating than the death of topics, as whichever quality is chosen the user will still see resources displayed first which most closely match the topic chosen. If a user is seeking resources related to Ethernet there is no point in displaying those relating to mail servers. An alternative might be to relegate rarely used topics to a second page, or to provide users with the ability to hit a *kill* button that would eventually result in a topic's death.

Two main dynamics are available to affect change in the topic ecosystem, the selection of topics and the creation of topics. The rate at which these occur can feed back into the dynamics of the system. If the rate of addition of topics is high, then the 'death' rate should be higher, whilst if the rate of use of topics in a sector is high it should limit the mortality. Different sectors might exhibit different characteristic behaviours, which would in turn affect how they are used, which would affect behaviour etc. In keeping with the self-organising principles of the system, these behaviours should be affected by the way that users use the system, leading once again to the control mechanism whose mode of control is affected by what it controls.

A further development of this system should be to allow each sector to compete with other sectors, affecting the space that the other sectors take up on the screen and the consequent size that topic labels may reach. This is in keeping with the findings of Chapter two, including Kelly's notions of chunking, Gould's assertions about island populations and Kauffman's experiments with NK networks (Kelly 1994; Kauffman 1995; Gould 1978).

Although the topic mechanism allows a path through topics to be dynamically generated, it does not make use of any semantic information to establish relationships between different topics. Topics are traversed 'blindly' (although the decisions of individuals to traverse those paths are anything but blind) and so links between them, the structuring espoused by Whelan (1988) discussed in Chapter three, does not emerge. It would perhaps be useful to capture the history of the paths between topics in some way. These could be represented graphically by trails of greater or lesser prominence based upon the paths actually taken by learners, but this remains an unimplemented feature because it is far from a perfect solution. As in the case of Collective Mental Maps discussed in Chapter five (Heylighen 1999), actual movements through a body of material are temporally contextualised and do not necessarily show a particular user's preference given reflective experience, only what they did at a given time (which may well have been mistaken or accidental).

Conclusions following this study

The stigmergic topic mechanism has resulted in the self-organised structuring of resources, with an environment created by its users and influencing their behaviour. This environment does not necessarily lead to a structure which helps its users to learn, which is inevitable when the motivations of the users are not all learning-related. The following points are particularly significant:

? changing font sizes may bring about stigmergic effects, influencing user behaviour

? evolutionary competition is an effective means of restraint within the system

? the limitation of four sectors is artificial and a clear example of acting as a skyhook. A better mechanism would allow sectors to grow unrestrainedly, allowing self-organisation to decide the appropriate number of sectors

? the system is too easy to subvert and requires a stronger mechanism than simple competition to kill off useless topics

? the system as it is does not scale well. With a relatively small number of topics this is partly a problem of interface design, but a large system with unrestrained growth in topics would require the introduction of death or, at the very least, relegation

- there should perhaps be a means of capturing historical information about trails so that future users could benefit from the collaborative trail blazing of earlier cohorts.

Qualities: four studies

This group of studies looks at ways in which qualities are used, what benefits and disadvantages they bring and how they affect users of systems. There are four main studies in this section:

Quality study 1: Website Evaluation System	This study attempts to look at qualities in isolation in an exercise where students entered and used qualities to evaluate Web sites. It uses a cut-down version of CoFIND 2.0
Quality study 2: N- vs. 1-dimensional evaluations	This study compares the behaviour of groups who are able to use qualities and groups who are only able to use a single quality.
Quality study 3: Stigmergy and qualities	This study looks at the effects of applying CoFIND 2.6's overlapping stigmergic mechanisms to the display of qualities.
Quality study 4: The effects of topics on qualities	This study compares the use of qualities by the same group of users but applied to two different topics.

It is the nature of these studies that there will often be occasions where the learning outcomes are not necessarily perfectly correlated with the intended object of study.

Quality study 1: WebSite Evaluation System

The problem

Even in the early topic-less CoFIND 1 studies it was hard to separate out the effects of qualities, given the effects of constantly adding new resources. Once topics were introduced, it became even harder to divorce qualities from the changing environment they inhabit. With the help of my supervisor (Chris Boyne) a study was designed to look at qualities in isolation, without giving users the ability to add resources or topics.

The process

This study was first discussed in Dron et al (2000d). It involved a group of fifty level two undergraduate students at the start of their Human-Computer Interface (HCI) module. The students were all very familiar with using the Web but had not yet studied HCI in any detail.

A two week exercise was prepared which was intended to encourage students to reflect upon the qualities of Web sites which matter when choosing to rate them as good or bad. A version of CoFIND 2.0 was prepared which did not allow the students to do anything apart from add qualities and use them to rate resources. The objective was to identify how qualities would be used when divorced from dynamically changing lists of resources and topics.

Twenty Web sites were carefully chosen by the tutors of the course to cover a wide range of subjects and HCI issues. All the sites had good points, but the tutors considered that each suffered one or more weakness in their design for usability. These sites were entered into CoFIND by the lead tutor. The students were strongly encouraged to rate the resources using the existing qualities or (should they prove insufficient) to add new qualities. Students were also free to use the discussion mechanism to comment on the resources if they wished, but there was no requirement for them to do so (and none of them did so).

The system was seeded with four qualities (*frustrating*, *hard-to-use, attractive, interesting content*), mainly by way of example. These qualities were used by the lead tutor to rate the resources as he saw fit, so that from the start selecting any quality would produce a list of relevant resources, thereby reducing the problems of a cold start. It is worth noting that two of these seeding qualities encouraged the use of negative qualities.

All students were asked to contribute to the system by using qualities to evaluate at least ten sites and to add new qualities if they wished.

Evaluation

Three sites received a large number of ratings: the University of Brighton's own site, SNARG (http://snarg.net a remarkable Web art installation) and to a lesser extent the site for the Beano comic. The ratings for each of these sites were very mixed and demonstrate that a typical good-bad range of votes of the sort used by a conventional collaborative filter fails to capture the subtlety of feelings that mark out a user's attitude to a site. For example, SNARG achieved high ratings for positive quality of *innovative* as well as the negative quality of *confusing* whilst getting low ratings for *hard-to-use* and *frustrating* (i.e. users felt that it was not hard-to-use and not frustrating). Despite being a dedicatedly visual site that presents itself as a work of art, SNARG received low-average ratings for *attractive* and *artistic*. It would have been hard to glean this information using traditional two-dimensional numeric ratings and much more difficult to glean a consensus opinion using conventional seals of approval such as abstracts and critiques. Had I provided the students with pre-entered qualities I would not have come up with *Author info* or *Association member,* although when presenting these results to a group of Web design teachers they revealed that these were exactly the kinds of things they encouraged students to look for as a guide to the quality of a site. This indication that, even at a relatively low level in the educational hierarchy, the students themselves were able to share sophisticated concepts without tutor intervention can only be regarded as a very positive indicator of the potential for a CoFIND-like system.

Only seventeen of the twenty resources were rated by the students. The three unrated resources were not hidden away at the bottom of the list of the returned resources for any of the originally entered qualities, so it is tempting to conclude that students were put off the sites by their titular descriptions. This most basic, influential and accessible form of metadata is clearly of great importance and raises a wealth of thorny issues already alluded to, especially with regard to the problems of shared classifications. If learners do not share a vocabulary then useful resources might well be overlooked, although the use of ratings at least ensures multiple perspectives on the value of a resource. In this way resources in CoFIND perhaps stand a better chance than those in systems which lack a rating mechanism.

Only four of the fifteen qualities added by students were negative, and these were the first four added at the start of the assignment. As the assignment progressed, all of the remaining qualities were positive. Although the negative qualities continued to attract a reasonable number of votes (relatively speaking, proportionally the same as those given to positive qualities), there is a suggestion that positive qualities were considered more appropriate when viewing sites. It seems likely that the early arrivals were influenced by the seeding qualities entered by the tutor, suggesting that some reproduction was involved, if only at a high level of abstraction. The positive feedback mechanism driving this might also be seen as a close relative of stigmergy, with communication occurring through the addition of qualities of a similar sort to those already there. As negative qualities have seldom arisen in other instances of CoFIND the large number appearing here suggest that this might have been the case, although the nature of the evaluations may also have had some influence. Other uses of CoFIND have been marketed as a means to discover explicit learning resources, which has been the primary role even when the system has been used for assessment and evaluation.

As can be seen from Table 6.2, there appears to be a certain amount of stigmergy going on- qualities that were created at the start remained popular throughout, an unlikely event were there not a positive feedback loop driving it. Many qualities made a brief appearance then died, despite the fact that they were given a weighting algorithm to start them off near the top of the list, so stigmergy did not lead to a Stalinist regime.

Only 17 of the 52 students actually contributed to the system, and even then not all of them rated the requisite ten sites. The most likely explanation for this is that the exercise was not assessed. This study was situated in a system which is at odds with the ways of learning that CoFIND is expected to support. A system driven by extrinsic motivation fails when that motivation is not applied (Holt 1977). The issue of motivation will arise again in later studies.

Table 6.2 – use of qualities over time for the HCI module

Quality and date added	Total votes	15/02	16/02	17/02	18/02	19/02	21/02	22/02
Frustrating (added 10/02/00 16:06:00)	9	2	1	2	2		2	
Hard to use (added 10/02/00 16:13:18)	11	4	2	3	1			1
Attractive (added 10/02/00 16:14:29)	40	9	9	13	7			2
Interesting content (added 10/02/00 16:17:34)	13	6	2	2	2		1	
Messy (added 16/02/00 14:33:27)	3		2		1			
Slow (added 16/02/00 14:36:31)	5		2	1	1		1	
Boring (added 16/02/00 14:41:44)	5		1	3			1	
Confusing (added 17/02/00 09:06:18)	10			6	4			
Navigation (added 17/02/00 13:40:09)	3			2	1			
Orientation (added 17/02/00 13:40:30)	6			5	1			
Appropriate Links (added 17/02/00 13:40:56)	6			4	1	1		
Innovative (added 17/02/00 14:00:11)	4			3	1			
Association Member (added 17/02/00 14:00:56)	5			4	1			
Author Info (added 17/02/00 14:09:19)	5			4	1			
fun (added 17/02/00 15:10:02)	3			1	1			1
Artistic (added 17/02/00 15:26:52)	4			1	1	1	1	
Informative (added 17/02/00 15:35:16)	4			2	1		1	
Indispensable (added 19/02/00 15:51:18)	2					1	1	
rich (added 21/02/00 13:14:11)	3						3	
TOTAL VOTES	141	21	19	56	27	3	11	4

Conclusions

? qualities provide useful differentiation in determining the ways that a site can be valuable. Negative qualities are less likely to be entered than positive qualities

? qualities are not the only metadata. The fact that some resources were unrated strongly indicates the importance of names and descriptions in adding resources. This is a problem that is unlikely to go away in any iteration of CoFIND, unless resources are represented by relatively value-free icons or numbers. Given CoFIND's usual need for a rich learning environment with as many cues as possible to help learners find good resources, this might not be very practical

? stigmergy again proves an important factor in guiding users to relevant resources and the algorithm used does not appear to lead to a Stalinist regime

- the qualities that were entered are related to the use to which they were put. Due to the requirement of the assignment to rate web sites, few of the qualities which were entered related to specific learning needs, but instead captured something about the quality of web sites from a variety of perspectives. This is a point which will be returned to later

- when the students are motivated by assessment, work which is not assessed is of a low priority. CoFIND is not inherently motivating.

Quality study 2: N- vs. 1- dimensional evaluations

The problem

This study is an attempt to investigate ways in which the behaviour of users is affected by the ability to use qualities, the effects of using an n-dimensional as opposed to a single-dimensional collaborative filter.

Design

A version of CoFIND 2.5 was built with the option to provide an interface for any selected user which did *not* make explicit use of multiple qualities, but instead forced them to use the single quality of “good” (which was also available to those who *were* using a full range qualities). Resources were displayed in order of the average of all ratings, the tentative (but as it happens correct) assumption being that most if not all qualities entered would be positive. In all other respects, including the manner of rating, the system remained identical whichever interface was used.

With two broadly comparable groups at my disposal (final year network management students and MSc students studying network technologies) for whom CoFIND would make an appropriate learning aid, I used the same system for both groups, hoping that this would provide some cross-referencing, leading to more valid results.

Network Management group

Approximately half of eighty-two students on a final year network management module were randomly assigned by the system to use the simplified, quality-less interface, whilst the remainder could use qualities. This assignation occurred by setting a random flag at the time the students first registered to use the system. Neither group was explicitly informed of the other, although the fact that CoFIND was initially used in a crowded computer laboratory meant that there was a likelihood that neighbours might spot the slightly different interface.

The students were told that they were using an experimental system which I hoped would be helpful as a means to find background reading for the module, thus helping to clarify areas which were not adequately covered in lectures and tutorials. I tried to encourage them to use it by suggesting that it could prove very valuable when revising for exams.

The students were given an hour’s tutorial to introduce them to CoFIND during which they were asked to use search engines and/or sites which they already knew about to seek relevant learning resources. Beyond this, they were left to their own devices to use the system as they saw fit. Because of the partially online nature of the module and because of a culture of optional attendance at tutorials, only around half of the students turned up for the tutorial sessions. However, all 82 students logged in at some point over the four weeks of this study and added a further 76 resources to the fifteen I had primed the system with.

Although in weekly lecture sessions I reminded the students of the existence of CoFIND, this was by way of encouragement and I did not require them to contribute to it as a condition of attendance of the module. In this way I was hoping to see what happened when relatively self-motivated users used the system, without particularly strong extrinsic motivation being applied. However, the fact that I had told them it would help them with their revision for exams combined with the desire of some students to please the tutor almost certainly meant that my hopes to encourage relatively pure self-organisation were doomed to failure.

Use of the system

Users able to use qualities rated resources slightly higher overall than those who were not, although this did not appear to be a big enough difference to be worth investigating. In its first day of use, the system started with four qualities that had been added by me and one that was added by a student (“Topical”). Only one further quality was added over the entire four weeks (“to some extent complex”). Overall, the figures shown in Table 6.3 were achieved after four weeks using the system, by which time there were ninety-one resources available (fifteen added by me, the remainder added by the students).

Table 6.3 – the effect of the use of qualities on ratings for the network management group- overall

Use of qualities	Average rating	Number of ratings
Using qualities	2.9	66
Not using qualities	2.6	73

Breaking the ratings down by quality reveals the pattern of behaviour indicated in Table 6.4.

Table 6.4 – the effect of use of qualities on ratings for the network management group- by quality

Average rating	Number of ratings	Quality
2.9	41	Good
2.67	3	Informative
3	9	Reliable
2.67	6	Simple
3	2	To some extent Complex
3.4	5	Topical
Not able to use qualities		
2.6	73	Good

The large number of ratings amongst quality users for “good” is partly explained by a continuing poor bit of interface design, which left the most-used quality as the default selected, although this was modified after the first week so that no default quality was selected. This over-enthusiastic application of stigmergy, combined with the stigmergic effects of large numbers of ratings being more attractive for those seeking rated resources, resulted in what looks suspiciously like a Stalinist regime.

MSc group

An almost identical system to that of the network management group was given to the group of 36 MSc Information Systems conversion students who were the subjects of the previous discussion of “Simon’s Clients and Severs”, with a similar random split between those able to use qualities and those who were not. Like the network management students they were given an introductory tutorial and were told that the system would be helpful as a means of sharing resources which they would discover during the course of their double-length year-long module. Unlike the network management students I did not emphasise the value of CoFIND in helping them to achieve good exam results. This was not a particularly conscious decision, although it reflected my assumptions about the stronger intrinsic motivation of the MSc students and their greater thirst for knowledge. However, it will be seen that this assumption may have played a role in leading to a different pattern of use.

I gave the students a little background information about the system, explaining how the earlier (CoFIND 1) system had been useful to the previous year’s intake. Unlike the network management students I intended that CoFIND would go on to play a minor role in the students’ assessment (described later in Quality study 4) and this was made clear to them. I exerted little extrinsic pressure on the students to use the system at this stage beyond the first tutorial, but it is certain that my enthusiasm for the system and the students’ desire to succeed in achieving an MSc played a strong role in encouraging them to use it.

Although the MSc students were looking at many of the same issues and technologies as the network management students, they were mostly inexperienced computer users in the process of conversion from arts graduates to information systems professionals, near the start of their studies. They started using the system a few days after the network management students. This provided a chance to change the default selection problem for qualities and remove a couple of bugs, but otherwise the system was the same as that used by the network management students.

Use of the system

The results given in Table 6.5 are those which occurred over a four-week period (the same as the network management study), by the end of which the students had sixty-one resources to rate, twenty added by me.

Table 6.5 – the effect of the use of qualities on ratings for the MSc group- overall

	Average rating	Number of ratings
Able to use qualities	3.1	49
Not able to use qualities	3.2	119

Once again, it seems to make little difference to average ratings whether qualities are used or not. There are however a couple of interesting characteristics which are worthy of note:

1. a proportionally similar number of resources has been added by the MSc and Network Management groups, but there are proportionally far more ratings provided by the MSc students. This helps to confirm the MSc group's greater intrinsic motivation as well as perhaps reflecting their better understanding of the purpose of the system

2. there is a huge discrepancy between the number of ratings given when qualities are used as opposed to when they are not.

Why the discrepancy?

As the interface to resources was effectively identical for both groups of users, it would seem that those who were able to use qualities did not like to use the system and/or found it too difficult to use. I correlated the results with the number of logins. Over the period in question, users able to use qualities only logged in fifty one times whereas those who were not logged in one hundred and two times. Feedback from students as to why this was so confirmed that they did not particularly like using qualities. Partly this was because they saw qualities as getting in the way. One student commented astutely:

> "Topic categorisation was useful. Quality categorisation was less useful. Perhaps too many similar categories or joke categories. Quality ratings however were quite useful- almost always a good bet to start with the highest rated."

Although a little disappointing as a criticism of the idea of using qualities, this is good confirmation of the positive benefits of stigmergy in driving students towards useful resources. Another reason qualities were unpopular was that they made the system hard to use. A student commented:

> "Didn't have a clue what I was supposed to do with it. I remember the first time I was introduced to it and everyone started to carry out the exercises you set immediately. Whereas, I thought what am I supposed to be doing here?
>
> I'll be honest Jon - it was far too complicated - not enough instructions"

Another said:

> "Interesting System. Confusing. I find it hard to get an overview of it.... In this session I spent more time working out how COFIND worked and contributing to it, rather than to utilising the resources within it."

Why then was this discrepancy not obvious in the network management group? This seems to relate to the way in which the exercise was presented to each group combined with experience in navigating unfriendly interfaces. The network management group were all seasoned computer users at the end of a four-year course (during which time it is certain that they would have had to negotiate a large number of unpleasant interfaces), but the MSc group were mostly relative beginners. The exercise had been presented to the network management students as a means to achieving a useful resource base which would be an aid to getting better exam results, whereas the MSc group was only told that it would be a useful resource base. I have already observed the importance of motivation in making such a system work, and the goal-directedness of the network management students helps to confirm this.

Confirming the effect of qualities on ratings

To confirm the findings of the network management group the effect of qualities on ratings was studied for the MSc group, which exhibited similar features. There was a strong but less pronounced stigmergic effect for the quality "Good" (Table 6.6), so the change in the interface seems to have countered the Stalinist regime. It is interesting that "Good for beginners" achieved the next highest number of ratings, which is in accordance with the level of the students, who at that time were relative beginners in computing in general.

Table 6.6 – the effect of use of qualities on ratings for the MSc group- by quality

Average ratings	Number of ratings	Quality
3	1	Comprehensive
3.29	21	Good
2.67	12	Good for beginners
4	1	good overview
3.5	2	quite useful
2.89	9	Useful
3.67	3	useful reference
Not able to use qualities		
3.19	119	Good

The effect of ratings on the selection of resources

Click-throughs (users clicking on links to resources returned by the system) are only a rough guide to usage as they do not reveal repeat visits due to local bookmarking, direct input of URLs or use of the browser's own history file, not do they give any clue as to how a non-electronic resource is used. However, I captured information about them in order to find comparative patterns of behaviour. Statistics were gathered for both the Network Management group and the MSc group based upon the number of click-throughs on links to resources. These were analysed to try to discover how they were affected by existing ratings both when using qualities and when using the simple bipolar rating system.

Network management group results

Two hundred and twenty four click-throughs were registered for the network management users who were able to use qualities. Sadly a bug in the system prevented the click-throughs of those not using qualities from being registered until the final week of the exercise. The following results therefore represent the state of the system after the first three weeks, without considering what happened after the system was made to work again.

The vast majority of click-throughs were for resources which appeared on the first page of results whether students were looking at rated or unrated resources (Table 6.7). Of those which occurred on later pages, *all* were for unrated resources, implying that the users had browsed through to find those which looked interesting. The interface played a significant role in this and quite frequently (mainly in the early stages) there would only be a single page of results for a given quality. However, it seems to lend weight to the assumption that resources that appear at the top of the list are more likely to be clicked upon. Stigmergy clearly worked in this case.

Table 6.7 – the effect of pages on click-throughs

Number of click-throughs	Page on which resource appeared
Student looking at rated resources	
111	1
Student looking at unrated resources	
106	1
5	2
1	5
1	6

A less obvious result is achieved when we look at the number of click-throughs on pages where a quality is selected, broken down by whether the student was looking at rated or unrated resources (Table 7.8).

Table 6.8 – the lack of effect of ratings on click-throughs

Quality	Number of click-throughs according to whether the students were looking at rated or unrated resources	
	Rated	Unrated
Good	103	21
Informative	2	17
Reliable	4	37
Simple	1	33
Topical	1	5

The hands-down winner in the quality stakes, ‘good,’ exhibits the expected behaviour, that students clicked on resources which had been rated as good far more frequently than those which were unrated. The other qualities unexpectedly display exactly the opposite pattern. The main reason for this seems to be that there are fewer resources available that have been rated for those qualities. We appear to be victims of the cold-start phenomenon. This is confirmed by a breakdown of the pages on which the resources appeared (Table 6.9):

Table 6.9 – influence of pages on click-throughs

Number of click-throughs	Student looking at rated or unrated resources	Quality	Page on which resource appeared
103	Rated	Good	1
15	Unrated	Good	1
5	Unrated	Good	2
1	Unrated	Good	6
2	Rated	Informative	1
17	Unrated	Informative	1
4	Rated	Reliable	1
36	Unrated	Reliable	1
1	Unrated	Reliable	5
1	Rated	Simple	1
33	Unrated	Simple	1
1	Rated	Topical	1
5	Unrated	Topical	1

Table 6.9 indicates that the vast majority of the click-throughs on unrated resources occurred on the first page of returned results. For resources which have not yet been rated in the current topic for the selected quality, CoFIND 2.5 displays resources which have been rated using *other* qualities in the current topic *before* resources which have not received any ratings in the current topic. It seems likely that users had found resources that matched their needs (in the right topic) without the use of qualities. The cue for this was probably the title of the resource, a factor that I have reported on elsewhere (Dron et al. 2000d). No matter how sophisticated we may seek to make our use of metadata, titles are metadata which are far richer semantically than what we provide with qualities and ratings.

From this the value that was placed on the resources once they were actually clicked on is unclear. We can get a clue however from looking at ratings given after pages had been visited. Only sixteen ratings were given by users who had been identified as visiting a given page by clicking on the link provided prior to rating it, suggesting most of the other ratings occurred when the resource was added. Of those fifteen, only eight of the ratings were for the quality 'good,' a disproportionately small number when compared with overall ratings. This is a somewhat encouraging result, as it indicates a feedback loop between the discovery of a resource and how it is rated, with better differentiation through the use of qualities.

One student provided four of those ratings, another provided three, resulting in an exaggerated effect from a small number of raters (Table 7.10). In itself this is not a bad thing- ecologies are often swayed disproportionately by a small range of factors, and the pattern is very similar to that found in usage against participation ratios in discussion groups.

Table 6.10 – ratings following a visit to a given page for the network management group

Quality	USERID	URL
Reliable	10	http://www.ieng.com/univercd/cc/td/doc/cisintwk/ito_doc/nmbasics.htm
Reliable	10	http://www.hssworld.com/hss_mindsystem/netmgt/netmgt_beginners.htm
Reliable	10	http://www.cisco.com/warp/public/cc/cisco/mkt/enm/
Reliable	10	http://netman.cit.buffalo.edu/
Good	14	http://www.dhcp.org/
Informative	39	http://www.it.kth.se/edu/gru/Telesys/96P3_Telesystem/HTML/Module11/NetworkManagement Security-1.html
Good	41	http://www.northernlight.com/
Simple	52	http://netguru.net
Reliable	52	http://www.ieng.com/univercd/cc/td/doc/cisintwk/ito_doc/nmbasics.htm
Simple	52	http://www.cisco.com/warp/public/cc/cisco/mkt/enm/
Good	63	http://thebusiness.vnunet.com/
Good	93	http://www.protocols.com/pbook/
Good	93	http://www.dhcp.org/
Good	99	http://www.helmig.com/
Good	99	http://www.ieng.com/univercd/cc/td/doc/cisintwk/ito_doc/nmbasics.htm
Good	152	http://www.antionline.com/2000/10/02/23762/62141678-0252-KEYWORD.Missing.html

MSc group results

The bug in the system which prevented the capture of click-throughs for users of a single quality did not affect the MSc users, having been cured as a side-effect of other minor bug fixes applied before the start. I was interested to see whether the use of qualities had any effect on click-throughs (table 7.11). When looking at these results, it must be borne in mind that the pages were visited exactly half as many times by the group using qualities as the group who were not.

Table 6.11 – the effect of page number on click-throughs for the MSc group

Number of click-throughs	Quality	Page on which resource appeared
For **rated** pages		
		For those able to use qualities
2	Comprehensive	1
51	Good	1
1	Good	2
13	Useful	1
7	Useful reference	1
30	Good for beginners	1
		For those unable to use qualities
265	Good	1
19	Good	2
For **unrated** pages		
		For those able to use qualities
7	Authoritative	1
8	Comprehensive	1
22	Good	1
2	Good	2
19	Good for beginners	1
1	Good for beginners	2
12	Good overview	1
3	Good overview	2
1	Good overview	3
1	Quite useful	1
4	Quite useful	4
10	Useful	1
4	Useful	3
10	Useful reference	1
5	Useful reference	2
2	Useful reference	3
1	Useful reference	5
		For those unable to use qualities
42	Good	1
1	Good	2
17	Good	4
3	Good	5

Those unable to use qualities were more likely to click on a resource on the second page of rated resources, almost certainly because (due to the larger number of ratings) there was more likely to *be* a second page of rated resources. Even so, there is a pattern indicating a preference for clicking on an item that appears on the first page, showing a strong stigmergic reaction.

The pattern for clicks on resources appearing as unrated for selected qualities was also fairly predictable, although there is a surprising surge on the fourth page for those who were not able to use qualities, not seen at all for those for whom “good” was just another quality. Close examination of the records reveals that 15 of these click-throughs came from a single user over the course of half an hour. It is not clear why she chose to click on every resource on the fourth page rather than any other, but it is the kind of anomalous behaviour which might help to drive change and prevent positive feedback loops in other parts of the system, especially the stigmergic topic mechanism. [2]

Those resources rated as “good” were correlated with those given ratings for other qualities to discover the degree of overlap. For all but one resource, there were more ratings given using the simple scale than for ratings given using qualities. Only one resource out of sixty-one was *only* rated by those able to use qualities. I could not discern a strong pattern distinguishing the ratings using qualities from those that did not. The largest number of votes for any single resource was nineteen, for the WebMonkey site. Thirteen of those were given by users who were unable to use qualities, ranging from zero to five (minimum to maximum) six giving top marks of five, three giving four marks, two giving three and two giving zero. Of the six votes given using qualities, marks ranged from one to five, with a similar distribution. Three used the quality “good,” two “useful” and one “good for beginners.” The suggestion is, at least for WebMonkey, qualities are not especially useful as indicators of the value of the resource, at least when there are few ratings on which to base a decision to use a resource. Once again we are victims of the cold start problem. With insufficient ratings for qualities, there is simply insufficient information on which to base judgements. The pattern for the network management group was depressingly similar, although there were several resources that were only rated once, with a fair number being rated by those who could use qualities. Again, the cold start problem raised its ugly head.

[2] This is confirmed by results of studies conducted since the first submission of this thesis, where a group of students required to simply explore the system rather than to use it as intended drove the topic labels to a state of equilibrium by methodically clicking each one in turn.

Conclusions

? using a listbox for the selection of qualities was a bad idea. At first I made the mistake of leaving the most popular quality as the default, but even after changing this so that no default was selected there was still an element of Stalinism creeping in where there was a strong tendency to select the first item in the list

? the small number of ratings given for each quality, exacerbated by the relatively infrequent use of the system by those using qualities, led to a far greater cold start problem for users of qualities when compared with those who were given the simple good-bad scale. It is unsurprising that the quality “good” was used a lot by those able to use qualities, as it would always return more results than any other quality, hence leading to a stronger stigmergic reaction than would occur in a purely quality-driven system

? the vastly greater number of clicks on resources appearing on the first page of results, whether rated or otherwise, suggests that the number of resources returned on the first page should be as large as possible, within the practical limits imposed by the speed of servers, Internet connections and browsers

? qualities actually seem to get in the way of achieving useful results. This is a result of an overly complex interface, the cold start phenomenon and the extra cognitive load that the use of qualities brings.

Quality study 3: Stigmergy and qualities in CoFIND 2.6

The problem

The previous study suggests that providing a list box for the presentation of qualities was a poor piece of interface design. The use of font sizes for topics provided extremely useful stigmergic effects, which could equally be applied to the presentation of qualities, at the same time improving the interface. The challenge was therefore to discover whether providing a more stigmergic interface to qualities would have any influence on the students' behaviour. This led to the development of CoFIND 2.6, described earlier.

Design

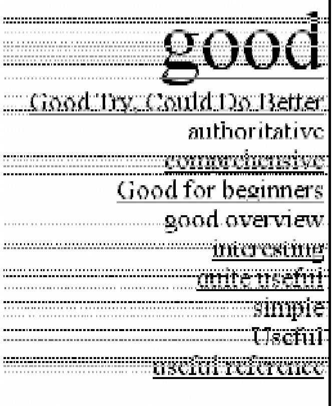
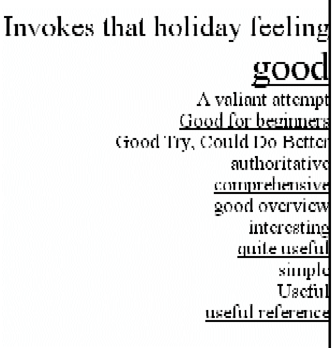
Despite the reluctance of the students to use the system when using qualities I was convinced that their use had some value. After the previous study all MSc users were converted to be users of qualities for the remainder of the academic year, a period of around six months. At the same time, the students were given CoFIND 2.6 with its stigmergic quality-selection mechanism.

This study looks at CoFIND during a period of relatively intensive use, when the students were adding work they had created themselves as the result of an assessed assignment. Part of the assignment required them to look at and assess each others' work. via CoFIND. It is a pity that I felt I had to use this extrinsic motivation, but as I have observed already, CoFIND is only part of a larger system and in the context of the University environment in which it was used this was a necessary evil. The assignment required the students to create a Web application to support a fictitious company selling waterways holidays, hence the preponderance of joke qualities such as "floats like a brick" and "waterway to have a holiday." No marks were given for their assessments of each other, but I had threatened that a small number of marks would be deducted for failure to consider other students' work as this was felt to be an important part of the learning process. There was no need to implement this threat as all students looked at and rated at least two of their colleagues' applications.

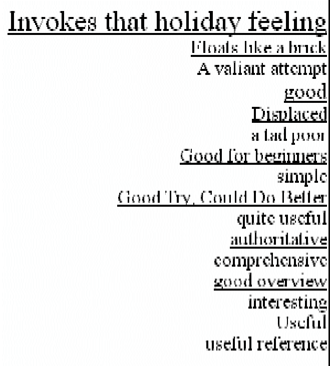
Qualities red in tooth and claw

The results of tracking the movement of qualities for the assignment topic over a five day period when voting was at its peak are shown in Table 6.12:

Table 6.12 – The effects of stigmergy on quality selection

Day	Appearance of quality-selection screen	Commentary	Votes cast
1		At the beginning of the cycle, the quality “good” is by far the most popular. The next three qualities have been added by students to rate their assignments, but despite their appearance near the top of the list, they have not been attracting many votes	Good try, could do better: 1 vote Good : 7 votes
2		“Invokes that holiday feeling” has been added on day 2, and is already clearly attracting a large number of votes. “Good” is fighting for its life. Of the ten votes it received this day, six were prior to “Invokes that holiday feeling” being added. “A valiant attempt” has been added but, strangely, no one has used it to vote for any resources	Invokes that holiday feeling: 12 votes Good for beginners: 1 vote Good: 10 votes

Day	Appearance of quality-selection screen	Commentary	Votes cast
3	Invokes that holiday feeling good a tad poor Displaced A valiant attempt Good for beginners simple Good Try, Could Do Better authoritative comprehensive good overview interesting quite useful Useful useful reference	By day 3, "Invokes that holiday feeling" has become a clear winner and "Good" is fading fast. "A tad poor" has been added, but is not popular. "A valiant attempt," bereft of any votes, slides gently down the list	Simple: 2 votes Invokes that holiday feeling: 12 votes Good for beginners: 1 vote Good: 2 votes Displaced: 1 vote A tad poor: 1 vote
4	Invokes that holiday feeling Floats like a brick A valiant attempt good a tad poor Displaced Good for beginners simple Good Try, Could Do Better quite useful authoritative comprehensive good overview interesting Useful useful reference	By day 4, "Good" is no longer an interesting quality. Although its size indicates that it is being little used for voting, the new quality of "Floats like a brick" has made its appearance. "A valiant attempt" makes a sudden break and is pushing its way up the field with a surprising 13 votes. A single user gave nine of these in the morning, with the remaining four being added by three users in the afternoon. Given	Simple: 1 vote Quite useful: 1 vote Invokes that holiday feeling: 8 votes Good for beginners: 1 vote Good: 1 vote Floats like a brick: 4 votes A valiant attempt:

Day	Appearance of quality-selection screen	Commentary	Votes cast
		that two days have gone by with no votes for "A valiant attempt" this is a strong indication that the boost it was given by a single user pushing it back into the fray	13 votes
5		By day 5 (the end of the assignment) the top places have achieved a certain amount of stability. "Floats like a brick" has received two more votes, so lingers near the top due to the boost it initially received for novelty.	Invokes that holiday feeling: 10 votes Displaced: 1 vote Good: 2 votes Floats like a brick: 2 votes

Evaluation

There is clear evidence here that CoFIND was both shaping and being shaped by its users, with emergent behaviour of qualities arising in several instances, most notably in the behaviour surrounding "Floats like a brick" and "A valiant attempt," where stigmergy appears to have had a significant effect on users' behaviour.

The system exhibits a suitable degree of "stickiness" so that popular qualities do not die instantly (for instance, the persistence of "good" despite its fall in popularity). Valuable qualities remain selectable and prominent, yet current user interests guide behaviour significantly.

Despite stigmergy dictating an overall shape to resources and qualities, CoFIND allows for novelty, user preferences and an interplay between usage and voting.

An interesting side effect

At the beginning of the year the system started with ratings added when half the group had no choice but to rate according to the quality “good” (see Quality study 2), so that quality was by far the most prominent when I allowed everyone to use qualities at the end of the year 2000. Despite having an obvious lead at the start, the quality “good” only accounted for a further 56 votes out of 586 given in total after the ability to use qualities was granted to all users. This is less than ten percent (9.6%) of all votes, as opposed to 21 out of 49 (42.8%) given by those able to use qualities when the other half of the group was using "good" as the only possible quality. Although there were more qualities for “good” to compete with as time went by, this is a strong indication of the influence of stigmergy on voting. After everyone was forced to use qualities in their voting, both “interesting” (173 votes) and “Useful” (105 votes) were significantly more successful than “good”, whilst “simple” trailed only slightly with 49 votes.

Conclusions

? the combination of ordering of qualities and varying font size provides stigmergic effects which affect the likelihood of users clicking on a given quality

? combining two different mechanisms for ordering qualities gives a richer range of stigmergic effects than one alone, as seen in the case of “A valiant attempt.”

? when given the choice, users seem to prefer qualities in more dimensions than the simple “good-bad” scale, despite the fact that these are harder to use in practice.

Quality study 4: The effect of topics on qualities in CoFIND 2.6

The problem

From the earlier study comparing n- and 1-dimensional ratings, it was apparent that qualities seemed to act as a disincentive to use CoFIND. Because of this I was keen to discover whether there was any value in using them at all. I therefore investigated in what ways different topics would result in different ecosystems of qualities.

Design

This study involves the same group of MSc students first introduced in the discussion of "Simon's Clients and Severs" and also observed in Quality studies 2 and 3. It looks at the use of CoFIND as an adjunct to a pair of assessed exercises which took place later in the same academic year as Quality study 2, the latter of which formed the subject of Quality study 3. As a result of Quality study 2 the students were familiar with CoFIND and had already used it as a means of sharing their discovery of resources. The system was also used to post notes of presentations the students performed in small groups each week in class, meaning that they were used to regularly accessing it. However, as can be seen from Figure 6-11 the system was not hugely popular and little use was made of it outside the assessment periods. My presupposition that the students would be motivated to use it as an aid to learning was clearly over-optimistic, although when questioned they were generally positive about it, clearly recognising its benefits. One student commented that he:

> "Found CoFIND useful as a "knowledge sharing" tool. "

Another observed:

> "Overall I think the system is excellent and I have used it several times. The idea is superb and it's great to be able to share resources and obviously reap the benefits of getting access to sites that have been rated by peers etc"

It is interesting that this student, despite obvious enthusiasm, only used it "several" times. Because CoFIND was not the main learning environment it was usually just an adjunct to the students' learning experience. Once again this illustrates the importance of context and the effect of the overall system on the behaviour of its parts.

One student mailed me to say:

> "It's a good source of knowledge when u know specifically what u r looking for, i.e., stuff I know has been covered in course. I tried the search facility when I was after stuff for dissertation but I didn't get much"

This gives a clue that the narrowly focussed range of issues discussed which arises from creating a highly parcellated environment might prove to be a limitation when learners are not all grappling with the same problems. Even within the tightly constrained and coherent subject matter of the MSc Information Systems there are distinct individual learning experiences which are not shared in any way with others on the course. It suggests that students were acutely aware of the needs of the community of which they were a part and only posted resources which appeared to meet those needs.

Selecting appropriate topics to compare- usage patterns

Knowing that there were notable peaks in use during the year, the first task was to identify appropriate points at which to sample the use of the system so as to identify useful topics to compare. Having identified these topics, it was then a simple matter to compare and contrast the use of qualities within them.

Over the course of the whole academic year there were a total of 754 ratings given and 176 different resources added.

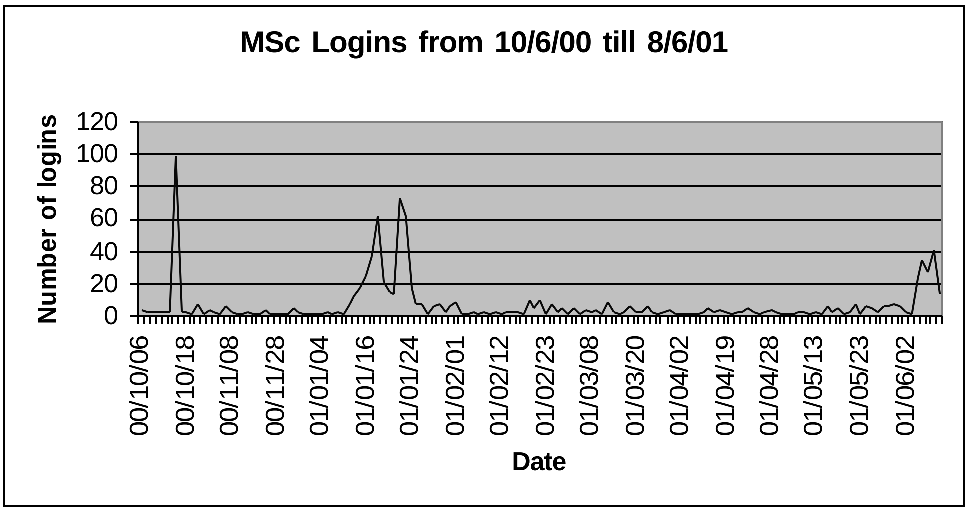


Figure 6-12 – CoFIND usage throughout the year (MSc group)

The pattern of logins is shown in Figure 6-12, with peaks corresponding with the need to use CoFIND in assessed work. This is a clear and graphic indication of the importance of the role of motivation in using the system, although it is a pity that the context of this system required that motivation to be extrinsic.

Comparison of the use of qualities for different topics

The peak in usage near the start of 2001 shown in Figure 6-12 relates to an exercise where the students selected a topic of some relevance to the module and wrote brief tutorials on the subject, with marks deducted for those who failed to rate at least one other student's work. The peak near the end of the academic year relates to a second assignment with the same requirement to rate at least one other piece of work, where students were required to produce a Web site based on an ongoing case study. Table 6.13 indicates how the votes for these topics were distributed.

Table 6.13 – different uses of qualities for different topics

Quality	*Topic*			
	FS5 assignment	% of total	AS5 – Stowaways	% of total
Comprehensive	34	**11.8**	0	**0.0**
Good	19	**6.6**	22	**25.0**
Good for beginners	31	**10.8**	3	**3.4**
Good overview	31	**10.8**	0	**0.0**
Good Try, Could Do Better	20	**6.9**	1	**1.1**
Interesting	18	**6.3**	0	**0.0**
Quite useful	8	**2.8**	1	**1.1**
Simple	31	**10.8**	3	**3.4**
Useful	94	**32.6**	0	**0.0**
Useful reference	2	**0.7**	0	**0.0**
A valiant attempt *			15	**17.0**
Displaced *			1	**1.1**
Invokes that holiday feeling *			35	**39.8**
Floats like a brick *			6	**6.8**
a tad poor *			1	**1.1**
Total votes	*288*		*88*	

? qualities added during the later (AS5) assignment which were not available in the earlier (FS5) assignment.

Figure 6-13 shows the relative ratings (as percentages) more graphically.

Evaluation

There are four things worthy of note here:

1. As the graph shows, there is virtually no similarity between the patterns of ratings for the two assignments. This strongly emphasises the importance of topics as a means of isolating specific learning experiences, and that different groups of qualities will develop in different ecosystems. From the point of view of my thesis this very positive result suggests that there may be some value in the use of qualities.

2. The spread of ratings is not even as more qualities are added. In fact, in the latter (AS5) assignment there was greater polarisation of quality usage than in the earlier assignment, despite the presence of more qualities. This indicates that an evolutionary mechanism might be very helpful in removing the less useful qualities, though in this study there were insufficient qualities to allow death to remove them.

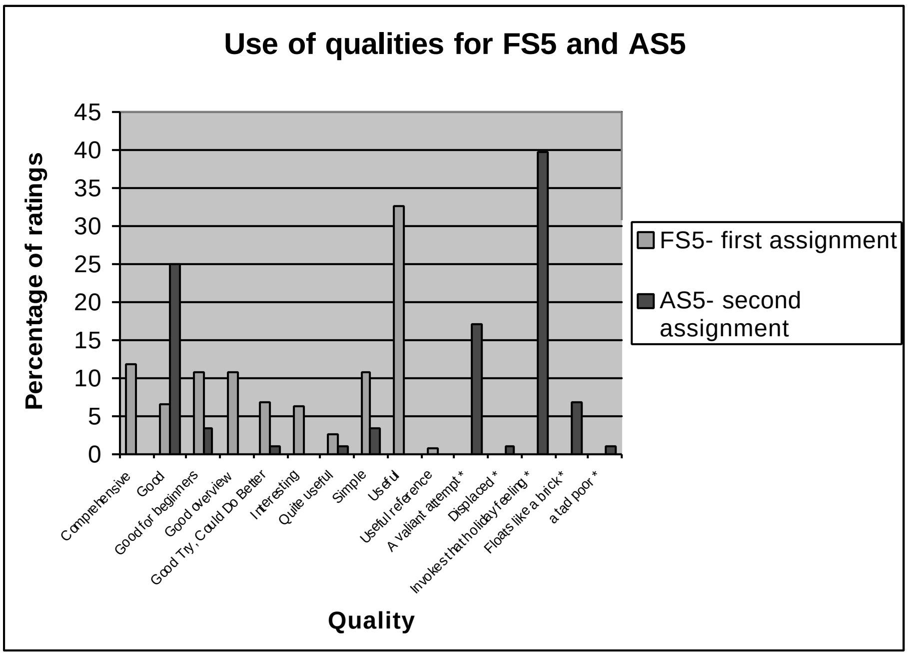


Figure 6-13 – comparison of the use of qualities for different topics

3. Whereas the first assignment (FS5) produced resources which were clearly of benefit to the students inasmuch as the resources helped in their revision and in understanding the course in general, the second (AS5) offered no such obvious benefits (despite the fact that, as their teacher, I felt that looking at and evaluating each others' work would be beneficial to their learning). This is reflected in the huge difference in the number of ratings given, especially significant in the highly

context-sensitive quality of “Useful,” which received 94 ratings for the first assignment and none at all for the second. As already observed, motivation to use the system is of vital importance. Here this is brought into sharp relief, indicating that users are more likely to look at and rate resources where there is a clear and obvious benefit in doing so.

4. The difference in use of qualities is extremely revealing and demonstrates how CoFIND may self-organise to educational or non-educational ends depending on the needs of the users. To reiterate, the first assignment resulted in resources that the students were aware of being of some direct use in revision for their examinations. It is thus significant that the four most popular qualities for the first assignment are those which I, as a teacher, would recognise as being pedagogically valuable:

? *Useful*: no ratings in the second assignment

? *Comprehensive*: no ratings in the second assignment

? *Good for beginners*: about three percent of the ratings in the second assignment, and there is reason to believe that the students were using it in the sense “Good try for a beginner” rather than as a gauge of its pedagogic value. This flexible usage provides interesting evidence for seepage across borders of the sort seen as important by Collins & Berge (1996), discussed in Chapter three.

? *Good overview*: no ratings in the second assignment.

Other qualities of value to learners which received no ratings at all in the second assignment were “interesting” and “useful reference.” This is in stark contrast to the qualities used in the second assignment when the students were not considering the potential pedagogic value of the resources, leading to the most popular qualities being “Invokes that holiday feeling,” “Good,” and “A valiant attempt,” none of which would be very helpful in seeking something from which to learn. This is also true of the other qualities that were entered for the second assignment, “displaced,” “floats like a brick” and “a tad poor.” This strong demarcation is a very positive result which suggests that, given the right motivation and a framework in which to use the system, qualities can provide some structuring of resources which would be helpful in learning.

Conclusions

The use of qualities is highly dependent upon context. Different circumstances and needs will cause the same group to select different sets of qualities.

To tend towards the use of qualities which will achieve the kind of structure that might be suggested by a teacher, there is a strong need for users to be using qualities with the clear goal of establishing those which are pedagogically useful. CoFIND will develop to the needs of a community, no matter what those needs are. This will only result in a system of education if the desire of the learners is to use the system as such. It is unfortunate that there was a need for an external stimulus (exams) to drive the students, but this does not invalidate the principle. Where there is a desire to learn and an intention to provide ratings that help that process along, the kinds of qualities that develop seem to be suited to that purpose.

Note: the posting and creation of online documents

It would have been desirable to allow users to create their own resources online, closing the feedback loop so that ratings given to those resources would have some effect on their further development. With this goal in mind, mechanisms were created for entering free text and for uploading files. However, problems with security and slightly shaky implementations meant that, although they were sometimes available, they were not widely used and I never fully tested these mechanisms. The free-text entry system was occasionally used, but not in a focussed enough way to draw any conclusions and I disabled the file upload system on all iterations because of security concerns.

Also provided was a means of discussing resources using a threaded discussion forum, but it was seldom used. This was partly due to poor interface design, but largely it seems to have failed because the students on which the systems were tested saw no special need for it. Each group already had their own newsgroups as well as seeing each other in class. If they felt the need to comment on a particular resource, I had provided a comment mechanism already. It would have been easy to provide suitable exercises which would have required the students to make use of the subsystem, but my interests generally lay elsewhere and this aspect of CoFIND has so far been neglected.

Conclusions to this chapter

In this chapter we have looked at the CoFIND system's development and a number of studies of its use. Although these studies have shown the weaknesses of trying to shoehorn one system into another, that qualities reduce the usability of the system and that a lot of work needs to be done before the system can begin to replace a human teacher, there are encouraging signs that the application of stigmergy and evolutionary processes, especially when applied to user-generated metadata, can lead to organisation of resources which fit some learning needs.

The following chapter discusses these conclusions in greater depth and explores some of the ramifications leading from the studies described in this chapter. In it I will be discussing how closely the system has come to achieving its goal of becoming a self-organising network-based learning environment and how it might be extended to better achieve that goal.

Chapter 7 : CoFIND: current limitations and future horizons

About this chapter

This chapter represents the main conclusions that I have drawn from the studies of the previous chapter. In particular, I discuss the extent to which CoFIND has achieved its aim of being a self-organising learning environment. Following a brief discussion of the limitations of the methodology employed, the chapter is a little artificially divided into two main parts, looking in the first at the self-organising nature of the system and in the second at its success as a learning environment. It is inevitable that there will be some crossover between these two parts as the system's self-organisation can only be considered in its context as a learning environment, and as a learning environment CoFIND's self-organising nature plays a major role in determining its effectiveness.

Methodological limitations

CoFIND has only been tested within a conventional University teaching environment and thus is vulnerable to criticisms such as those of Illich discussed in Chapter one, that it is inevitable that learners in such an environment will not often be puzzled by and interested in the same problems at the same time (Illich 1971). I have not been examining truly self-organising learning environments but instead have been looking at them as components of a larger whole. This has meant that the qualitative approach I have taken to the research involves a great deal of interpretation and extrapolation. The action research methodology I have employed has proved useful as a means of application development and theory refinement, but the situated nature of the studies means that the theories so developed are only tested to the extent that they provide input to the development of new systems and any generalisations are at best tentative.

As I am not stepping outside of the system of formal higher education, the steps I make must necessarily be small and the effects of the larger system will always impinge upon the small systems that I have created. For example, students always have significant alternative sources of knowledge to CoFIND, they are motivated by the need to pass examinations rather than to learn about a given topic, and there is a limit to the time they can allocate to what is perceived as a fairly peripheral activity. It is significant that the most enthusiastic use of the system so far has been when it is used to provide formative peer assessment of the students' own web pages. Like any computer system, it does not exist in isolation and, as an adjunct to existing working systems, offers insufficient extra value to encourage widespread successful use. It is a recurring theme of the studies which I have performed that they repeatedly confirm the findings of the discussion in Chapter one, that educational systems dictate the behaviour of their parts.

A real test of the CoFIND system would be to unleash it on a group as the primary means of tuition. This would require significant commitment on the part of the learners, not only to their own learning but also to the needs of others. This is not easy to attempt with an experimental and unreliable piece of software, which at best illustrates some of the approaches that might be taken when building a truly complete, self-organised system.

There is still a great deal of work needed, not only technically, but also in creating an environment in which CoFIND can thrive. Working methods need to be addressed: for example, how should a group decide the best forms of assessment? CoFIND provides the technology to support the group in identifying the best of a range of assessment tasks and to help assess the learning of its participants. There is still a need to generate or discover appropriate assessments in the first place, to make a decision that an assessment would be helpful at a given stage, to collaborate effectively on the tasks required and so on.

Systems dictate behaviours. CoFIND can only function effectively as a part of a larger system, all parts of which need to be geared towards self-organised learning.

CoFIND as a self-organising system

The cold start

In common with many other forms of recommender systems discussed in Chapter five, CoFIND suffers badly from the cold start phenomenon at several levels:

? without resources, the system is useless, so there is little incentive to use it until resources are available. However, it must be used in order for resources to be added

? without ratings, it is not easy to identify the value of resources. However, the incentive to rate is low, hence the system will not be used extensively, hence there will be few ratings. The use of qualities makes the cold-start problem far more acute than for existing collaborative filters

? it is easy to add qualities, but by the nature of things those qualities will not have been used to rate resources and hence will not return useful lists when selected. If they do not return useful lists of resources then they will not be used, therefore a limited number of qualities will be far more successful than the rest. Although this is typical of an ecosystem, there need to be more ecological niches to be filled so that relevant qualities will get a look-in.

It would be good to provide positive feedback loops from the start and to grow by chunking (Kelly 1994). Existing implementations are either force-started by scheduling work around the addition of resources, providing a small, pre-built environment or (more extremely) allocating marks to students based on their degree of participation. Although this is not exactly in the spirit of self-organisation it still allows a high degree of self-organisation to occur. In the Web site Evaluation System, the students were prevented from adding new resources or topics altogether, yet qualities and resources were still able to interact and self-organise. As long as there can be new input into the system to maintain it, the system is able to continuously adapt to its users.

Skyhooks

Any ecosystem has a number of givens that are not themselves capable of evolving. In biological systems, laws of physics dictate the way that atoms are assembled and interact, the forces of electricity, magnetism, the effects of gravity, the chance (or at least contingent) arrangements of mountains, seas, rivers and so on. Similarly, memes replicate in societies, and technologies such as television and the Internet improve their speed of transmission and replication (Dawkins 1991). An ecosystem has a context and a makeup that depends on its medium. It is likely that replicants will affect their media- life has played a large part in shaping the planet for the benefit of life, some memes have improved the chances of memes replicating (for instance, memes that suggest that more communication is a good thing). However, the context of any ecosystem is not entirely generated within the system. Not only is the ecosystem affected by the environment it is adapted to, it requires input from outside of the system. Complex, non-linear systems such as educational systems are open, requiring an input of something equating to energy to maintain its order (Doolittle 2000). These are the principles on which CoFIND is based. It is fed with a stream of information from the Internet and knowledge, aims and intentions from its participants, and it is intended to form a landscape in which learning can be organised and structured. Some things are just a part of CoFIND's landscape and play a similar role to the laws of physics in a biological ecosystem. It must be a web-based system of some sort, it must work on a two-dimensional computer screen, it requires learners to give it inputs and so on. However, some aspects could contribute more to the self-organisation of the system. For example:

? the algorithms for fitness

? the number of qualities available

? the number of qualities which may be selected

? the layout and colours of the interface

? the number of resources displayed at a time

? the overall site structure and navigation

I have taken some steps towards this already in some iterations of CoFIND by allowing users to select from a range of stylesheets and to choose the number of resources and qualities shown at a time. These are intended to feed back so as to provide new users with the majority's favourites, but it is a simple and non-adaptive mechanism.

Evolving an algorithm for fitness presents a range of difficulties and magnifies existing problems. The cold start phenomenon would be a lot colder if we included the time taken to evolve an effective algorithm to display resources, and it is hard to see intermediary fitness levels which would encourage users to continue using (and thus refining) the system. It is also hard to see what kind of measure of fitness for an algorithm would be useful, unless it is that users use the system. If users select from the top of the returned list of resources more often for one algorithm than another then perhaps it could be seen as successful, but if useful resources are not at the top of the list then the users are not going to be keen to use the system at all. Perhaps small adaptations with minimal and random effects could be developed for a range of CoFINDs and their results amalgamated or placed into competition with each other, but this requires much more experimentation than I have as yet been able to perform.

From time to time I have considered attaching a thesaurus such as WordNet to CoFIND to supply the occasional random mutation in qualities, again allowing new qualities to inherit votes from their parents. This method would be more Darwinian than the Lamarckian evolution observed in the more 'natural' mechanism. However, I have already observed that Lamarckian evolution, where changes to the phenotype feed back into the genotype, can result in more efficient and focussed evolutionary change (Kelly 1994, pp 457-8), so such a mechanism would probably be superfluous.

The ageing of resources

In Chapter four we looked at Valovic's view that the value of a given resource is not always constant (Valovic 1994). In fact, for many Web resources the value becomes zero as the resources go away, leaving a *404 not found* error message. The assumption that CoFIND will be used for a given cohort means that a greater value may be ascribed to recently rated resources than those which have not been rated for a long time as the former will most likely be relevant to the emergent needs of the cohort. There is therefore a need for some kind of ageing mechanism. For qualities this is accomplished through the use of the weighting mechanism. As loss of weight is proportional to usage of the system, it would seem to be an appropriate mechanism for the resources themselves or, at least, the ratings for them. However, some resources are more time-dependent than others. For example, a news item would usually be more transient than a critique of a classical philosopher. An obvious solution would be to allow users to decide an appropriate measure of transience, but to explicitly do this would not be self-organising and would increase an already over-large burden on the user.

Scheduling

It is sometimes necessary to schedule things, from synchronous meetings to deadlines for evaluation and assessment. Many collaborative scheduling tools already exist and there is probably no need to re-invent the wheel in this case. However, conflict resolution can remain a problem, although many systems will automatically seek common free times and schedule to suit. What such systems do not solve is the need for an appropriate sequence of learning opportunities or lessons, a problem that is logically insoluble if we consider CoFIND as a closed system, for learners by definition do not know which paths to take to learn from. Luckily, CoFIND is not at all a closed system and is fed by the Web and other resources as well as the combination of individual lumps of knowledge that the learners themselves bring to the problems they face. Such sequences may be discovered and collaboratively deduced by combining all this knowledge within a structure that CoFIND might (but does not yet) provide.

Tasks and synchronisation

Although CoFIND makes it possible for users to collaboratively generate paths through a set of resources, it is important to stress that it does not provide much support for the collaborative generation of learning activities to perform, such as tasks, assessments, evaluations, meetings, explicit collaborations and so on.

Even were collaborative scheduling to be provided, it would still not give any indication of what to put into that schedule. Similarly, it would not give much help with identifying when a given activity should finish- discussions, for example, might just be allowed to peter out. Likewise, the fact that CoFIND makes assessment a simple, unintrusive and emergent feature of the system does not help in deciding what is to be assessed in the first place.

It is currently assumed that all that is required is a group of motivated learners with a means to communicate, but it would be preferable for the system to provide assistance with the processes of setting learning activities. This could be provided in several ways, harnessing the aims and intrinsic motivation of the learners to learn. For example, users could enter suggested learning activities, which would then be chosen by others, with the usual stigmergic influences on choices. This is the method I am employing in the latest iteration of CoFIND. Alternatively, if there were no need to interact with others to perform a particular activity, activities discovered as a result of using resources entered on the system could be performed by individuals and the results simply added as resources which would be treated like any other. This issue is discussed further in the next part of this section.

Shapes and forms

A web-based course designed by a human being has a distinct shape and design which is relevant to its function. There is perhaps a need for a further level of design that allows users to collaboratively generate a ‘course page’ with links to the various parts of CoFIND that are appropriate to their needs. I have built a system that generates customised versions of CoFIND, but each CoFIND is still a monolithic system with greater or lesser functionality. A more componentised structure might allow for greater flexibility in how it develops. The issue of the design of the learning experience is discussed further in the next part of this chapter.

Clustering

Although CoFIND uses a form of collaborative filtering it is not an automated collaborative filter of the sort discussed in Chapter five (such as Firefly or RAAP) that matches patterns of like and dislike. One potential development would be to match resources together based on the similarity of patterns of qualities used to rate them. For instance, two resources which were considered both ‘good for beginners’ and ‘amusing’ might be considered as matching. What would being one of these species mean? There is a strong likelihood that such resources would have things in common- they might be easy to understand and funny, for example.

The system could also be adapted to match resources to learners based on the learners’ ratings of resources, and equally to identify similarities between learners based on their choices of qualities. This range of possibilities reflects the multidimensionality of the system, affording means of pattern matching which are unavailable in traditional CF systems and which relate to expressed and changing needs.

Metadata are more than just words

Most of the explicit metadata in CoFIND are verbal, with the exception of the size cues given by the topic evolution mechanism, and to an extent, the implicit metadata involved in ordering qualities and resources. There is no scope for even graphical metadata to evolve, let alone more exotic forms like tactile and olfactory metadata. Although the latter exotica are limited by the constraints of the medium, the limitations of not being able to evolve into a graphical form are more the result of conventional design thinking at the early stages of development. It would be quite appropriate to represent the value of a resource using an icon, or perhaps even just a colour. The limitations of HTML are partly responsible for this, but there is scope for a more exciting range of possibilities for future developments.

Relationships in general

The current iteration of CoFIND is highly limited in the range of metadata which may be used and specified, largely for pragmatic and contingent reasons which relate to my programming and design abilities. Subsuming all the issues around hierarchies, sequencing and trails, as well as a wide range of other concerns, the establishment of relationships between objects within the CoFIND system remains the key area for further research and development. It is possible to envisage a generic mechanism for establishing relationships between objects of all sorts on the system- resources, topics, qualities, messages and indeed the relationships themselves could all be in some way related to any other object in the system. The nature of those relationships would, in accordance with the principles of self-organisation, have to be generated by users of the system themselves and the strengths and value of those relationships would need to be collaboratively decided in some way. This could potentially allow the generation of a truly self-organised learning environment, without sky-hooks and with immense flexibility. The principle and the supporting technologies already exist, in the form of the Resource Description Framework (RDF) produced by the W3 consortium (Berners-Lee, Connolly & Swick 1999), which underlie the notion of the

Semantic Web. Based upon the work surrounding PICS (Platform for Internet Content Selection), a system for exchanging claims about qualities of resources, endorsements and other metadata, RDF goes a great deal further. RDF forms the basis of the Semantic Web, a means of semantically relating any assertion to any assertion, including that assertion itself. All of the metadata held in CoFIND already could be stored in RDF format. Since we could also use RDF schema to represent, say, hierarchies, sequences and assertions about things, we could use it to provide a rich semantic framework to structure the entire educational experience. Examples of relationships we could express might include such things as:

- A is better than B
- B is beautiful
- B is more beautiful than A by X amount
- B disagrees with A
- B builds on A
- A contains B
- B follows A
- the relationship ‘follow’ in ‘B follows A’ refers to an interval of time
- the relationship ‘follow’ in ‘B follows A’ is a kind of spatial relationship
- the spatial relationship referred to in ‘B follows A’ refers to a distance of five metres

This small selection out of indefinitely large range of possible relationships could in principle provide the framework to create a fully connected self-organising system, with all the hierarchies and subtle metadata about objects we could hope to express. Ambiguities reflected by different users’ usage of relationships could be resolved by a mapping process, which could itself be based on automated collaborative filtering principles. A further advantage is that it would allow interoperability with other systems, allowing for potential developments akin to the incorporation of mitochondria into eukaryotic cells discussed in Chapter two. It is difficult to imagine an effective and intuitive interface for such a system and as yet this remains a pipe dream, but it is the inevitable direction towards which CoFIND's development is heading.

Topics

In retrospect, I find myself leaning more heavily towards the original concept of separate CoFIND systems for each topic, occasionally communicating or invading each others' space. This is far more in keeping with the paradigm of distributed intelligence which characterises complex adaptive systems and, with suitable protocols for exchange of information in place, could actually allow differently constructed ecologies to compete with each other. Similar species (identified by close correlation of qualities and/or resources) could 'breed', spawning new super-CoFINDs or CoFIND colonies, with qualities and resources from both parents. In keeping with the genetic analogy, some qualities could be considered as dominant (due to success) and others as 'recessive'. The dominant qualities would have a more profound effect on the resulting resource lists than the recessive. Alternatively, CoFINDs might find themselves in competition with each other. This is a slightly bizarre notion as it is hard to see what the effects of losing the evolutionary struggle might be, although the loss of qualities meeting a threshold might be one result, together with the cannibalisation of successful parts of the loser by the winner.

CoFIND as a learning environment

Does CoFIND help people to learn?

I have not particularly looked for and therefore have little significant evidence that CoFIND actually helps people to learn. I do not perceive the evaluation of effectiveness in encouraging learning as being a requirement of this particular piece of research, although it is an obvious area for further investigation. Having said that, there are many ways in which CoFIND is demonstrably a learning environment, discussed later in this section.

Although there are some broad parallels with the organisation of resources akin to those of teachers, and although students seem to benefit from the use of the system, this may bear little relationship to CoFIND's intended functionality. Students like to be able to share bookmarks and apparently they perceive some benefit in voting for the usefulness of resources, but it is far from clear that the fine detail given by qualities is a necessary feature of the system for them to achieve this. For the purposes of this thesis, these issues do not matter a great deal. I have merely demonstrated that computer-mediated self-organisation is possible and could have a place in a learning situation, but I have not rigorously attempted to discover whether it achieves any further goals. I clearly believe that the system has pedagogic benefits (otherwise I would not have inflicted it on my students) but what I have been interested in here is the role of metadata in achieving self-organisation of a teacher-like quality. My intention is to replace a role or two of the teacher with a collaborative group mind, a function that, by my own criteria, CoFIND is performing moderately effectively. There is considerable doubt whether this group mind can match that of even the dullest of professors. In every one of the ten or so instances of CoFIND so far implemented students at all levels have found and rated a set of resources far better than those already discovered by the teacher alone, but there are problems with the ways in which structure has developed. The previously cited example of *Simon's Clients and Severs* is a good illustration of how a determined anarchist or self-publicist may easily subvert the system. It would be easy enough to programmatically prevent such an occurrence in future, but the fact that the ploy was successful shows that stigmergy can as easily lead to useless or even harmful categorisations as to those that have pedagogic benefits. Quality Study 4 also showed that the system may as easily turn to useful as to less-than-useful ends. The unpredictable nature of complex adaptive systems means that, no matter how carefully the environment is constructed, unexpected species may be successful or disruptive. In the natural context this may be seen in, for example, the spread of devastating virus infections, plagues of locusts or volcanic eruptions. Although the ecosystem will eventually adapt (perhaps growing stronger in the process), the devastation within a system that is designed to assist learning would be difficult to justify to the learners affected by it.

CoFIND as a replacement for the teacher

All versions of CoFIND were designed (explicitly or implicitly) to replace one or more roles of a teacher, with CoFIND 2 explicitly attempting to take on as many roles as possible. However, it should be borne in mind that it does this in the context of a firmly learner-centric and RBL approach, which amongst other things means that it does not attempt to address the creation of learning resources, merely the management and structure of them and elements of the learning experience.

It is worth reminding ourselves at this point of Bruner's specifications for a theory of learning, to provide a framework for the ways in which CoFIND can replace a teacher:

? it should specify the experiences which implant a predisposition toward learning

? it should specify ways a body of instruction should be structured for easy assimilation by the learner

? it should specify the most effective sequences to present materials to be learned

? it should specify the nature and pacing of rewards and punishments in the service of learning and teaching.

Chapter three identified some further prerequisites for teaching to occur including *subject expertise*, *communication* and an evaluative feedback loop (*reflective practice*). In the remainder of this chapter I will use this framework tied into some of the specific learning theories identified in Chapter three (notable those of Gagné but also referring back to other theorists discussed in Chapters one and three) to discuss how close CoFIND comes to managing to mirror the instructional process.

A theory of instruction should specify the experiences which implant a predisposition toward learning

In the main, this requirement will relate to the process of encouraging motivation, although of course the precept has a richer meaning than this. For example, the establishment of an academic community (something which is potentially enabled by CoFIND) will have a large role in enabling a predisposition to learning, not all of it motivational. Some specific ways in which CoFIND can address this requirement are discussed later when matching it to Gagné's nine instructional events, which attempt to make explicit the steps needed to allow this to occur.

A theory of instruction should specify ways a body of instruction should be structured for easy assimilation by the learner

CoFIND identifies the contents of a body of instruction, resources that are of use, in a manner appropriate to the learners who wish to use them. Implicitly, it specifies the limits of a subject through the use of topics, which it uses to guide a learner through a subject area. Through the mechanism of ratings and qualities it acts as a filter and a recommender of appropriate resources with an efficacy not far removed from, and potentially better than, that of a teacher.

Except in the coarsest of ways, CoFIND does not help to identify ways to structure a specific body of instruction, nor does it strictly speaking need to. The Web is awash with suitable resources that are structured to assist learners to learn. CoFIND's strength is that it allows learners to discover those structures that are most suited to their needs at any stage, rather than relying on the skills of a single teacher. However, semantic links between topics and the ability to generate different hierarchical levels would be of some benefit in allowing the self-organisation of a higher level of structure to occur.

Future developments of CoFIND need to improve the chat and forum mechanisms, so that emergent behaviour can arise of the sort seen in ChatCircles and D3E, discussed in a previous chapter.

A theory of instruction should specify the most effective sequences to present materials to be learned

Curriculum design

As discussed in Chapter three, sequencing in a traditional taught environment occurs on several scales, from the broader topics to the small movements within them. As CoFIND is designed to incorporate resources which will usually have some micro-levels of sequencing (if only in the form of a beginning, a middle and an end) its inability to sequence at a micro-level is not a fatal flaw. To provide ultimate flexibility and to incorporate learning objects, I would wish to see sequences occurring at different levels of a structural hierarchy. The question arises as to whether the mechanisms should be the same or whether there is a difference in kind between micro and macro levels. The current iteration of CoFIND uses a method of real-time sequencing based on dynamic usage, a kind of collaborative trail-blazing, but there is no means of breaking topics down, of identifying sub-topics and semantic links between them. This notably fails to address Whelan's distinction of structure and order discussed in Chapter three (Whelan 1988), providing the latter but not the former. As already observed, we might make use of a trail mechanism to show who chose what next, but have already identified that this is an imperfect mechanism for learners whose paths may be weak and confused as they are only learning. At least CoFIND *does* offer a means for comparing paths created using other tools such as Walden's Paths (Furuta 2000) discussed in Chapter five.

A theory of instruction should specify the nature and pacing of rewards and punishments in the service of learning and teaching.

Rewards and punishments can take many forms, although formative assessment is probably the most prevalent way of providing this. In CoFIND, the same mechanisms that work for evaluation can also be applied to assessment. The rating mechanisms can be closely coupled to assessment criteria in the form of qualities. This allows for collaborative decisions to be made about goals and achievements. The comment system, the discussion mechanism and even chat are all effective ways for feedback to flow through the system in a more conventional manner. Coupled with the ease with which online resources may be developed and posted to the CoFIND system, it has the potential to make an excellent formative (if perhaps not summative) assessment system. Despite the potential, it still requires participants to make active choices about forms of assessment, times of assessment and so on. Although these activities can be discovered in pre-existing resources and the value of those resources can be evaluated using CoFIND, the decision to assess at a particular juncture cannot be supported emergently. Someone, or something, has to make the decisions.

CoFIND was not originally created with assessment in mind, although several of the studies discussed earlier have made use of it for this purpose. The use of qualities in more than one context, both as an evaluation mechanism and as a means of assessment can be seen (following Gould) as a kind of exaption, with new and possibly unexpected uses developing from a single beginning. There are analogies for this in biological evolution, such as the development of fins in aquatic mammals from limbs, the peacock's tail for attracting a mate, the eye from simple light sensors and so on. Provision of an adaptable mechanism is a prerequisite for evolution of any sort to occur. The fact that a single mechanism has more than one use within the system is a strength from the point of view of self-organisation, allowing unexpected forms to occur. Unfortunately, although users can base new qualities on old, CoFIND's qualities do not have the capability to grow in complexity. A quality is a fixed entity. CoFIND 1 allowed users to select multiple qualities, but this led to too many connections and too little competition between qualities However, in principle, repeatedly used combinations of qualities could be seen as new structures akin to multi-cellular organisms. In CoFIND 1, there were difficulties in deciding how to treat resources which were rated low for one selected quality yet highly for another, as (for instance) the average of *amusing* and *reliable* is not a quantifiable nor a meaningful variable. One solution might be to allow selection of more than one quality with user-defined weightings for their utility (for instance, making *amusing* a more important quality than *reliable* when returning results). This might make CoFIND a subtler tool, especially for assessment, allowing users to collaboratively generate not only the criteria for assessment but also a measure of the importance of those criteria. It has not however been implemented, as it would increase the cognitive load for the user, as well as the time taken to find resources.

Beyond Bruner

In Chapter three I suggested that Bruner's theory of instruction did not go quite far enough in capturing the essence of teaching and that there are other important requirements for instruction to be effective, notably subject expertise, the formation of learning communities and the use of reflective practice.

Subject expertise

CoFIND excels in the area of subject expertise, by bringing the filtering and generative power of a group of learners to bear on the vast pool of expertise that is afforded by the World Wide Web. Even the small scale implementations I have discussed have resulted in a range of high quality resources structured to help learners discover those of greatest relevance. In this way it can far outstrip any single teacher in finding suitable resources from which to learn, and can exceed the efficacy of subject gateways due to the selection of resources which are most suited to the group's specific needs. This has been observable in all the studies so far and at every level. Saba would approve. He writes:

> In the current information-rich environment, the main task in instructional systems design is not choosing, chunking, sequencing, producing and presenting content for a hypothetical mass audience, but helping the learner to find content that is relevant to his or her level of knowledge and understanding of a particular topic within a discipline.

(Saba 1999a)

Community

CoFIND has built-in means of communication. Not only does it have a discussion forum and chat, but the ability to create and share documents, the ability to add comments, even the voting process and the act of participation itself all result in the flow of information in a communicative process. It is impossible to even use the system without in some sense communicating with other users in the community, if only by contributing to the stigmergic trail. However, the ability to chat and to discuss topics and resources does not automatically create a community. It is not a case of 'if you build it they will come.' Communities take rather more to build. We must rely upon the users themselves to build this community, so it is essential to create an infrastructure that makes it easy for them to do so. Like Brand (1997), Preece (2000, p 110) notes:

> The architecture of a house is intimately related to the way its inhabitants live. Cooking, serving meals to a family, or supervising children can be pleasurable or difficult, depending on the facilities available. Similarly, the functionality provided by software and its ease of use- that is, its usability...strongly affects users' lives online.

One way to go about this is to increase the channels of interaction. CoFIND's very simple chat room is one attempt to do this, but it is a poor implementation. I have also attempted to implement a system which indicates online presence, but the stateless nature of the HTTP protocol means that it is difficult to know for sure whether someone is logged in, so it can be a bit discouraging to find listed users are unavailable, and the chat system is clunky at best. It would be a lot better to incorporate a mechanism akin to that of ChatCircles (discussed in Chapter five). This would not only allow for self-organisation of messages to occur, but might also be linked to specific topics, perhaps even specific qualities within topics, so that focussed discussion could take place on a given area. Similarly, the sort of collaborative touring found in systems described in Chapter five such as Nestor or Footprints might be used to great effect and could even help to provide better paths through resources.

Reflective practice

CoFIND is the embodiment of reflective practice, adapting and developing according to the needs and wishes of its users, thus meeting the need for evaluation discussed in Chapter three (Marton & Ramsden 1988; Moore & Kearsley 1996). Evaluation is enabled by CoFIND in many ways. The mechanism of qualities provides a range of possibilities, allowing criteria for evaluation to be entered as qualities and thenceforth used to provide feedback. The option to add free text comments allows for a more sophisticated level of evaluation. Going one step further, conversations can develop around resources, allowing for two-way feedback and the scope for development. Even the system for topics provides near-instantaneous feedback on where the group has decided it would be interesting to investigate next.

Matching CoFIND with Gagné's nine instructional events

Gagné's nine instructional events were identified in Chapter three as the foundation of a theory of instructional design which is sufficiently abstracted from the contingent features of teaching to provide a useful framework for the design of a self-organising system. It will therefore be informative to look at how close CoFIND comes to conforming with them.

Gaining attention

CoFIND provides assistance with *gaining attention* through the topic mechanism, which provides stigmergic guidance about the topic of most current interest. This influences users to follow what the group as a whole has identified as currently significant, even though it may not be a topic that would otherwise have been selected. The ease with which 'Simon's Clients and Severs' insinuated itself illustrates this well, albeit not in the service of learning.

Informing learners of the objective

Apart from the influence of topic labels, CoFIND does not provide any explicit support for informing learners of the objective, although I work on the assumption that these goals will arise from the educational resources which learners will find on the Web, which CoFIND supports by (in Gagné's sense) presenting the stimulus. This is not entirely satisfactory, inasmuch as there is no place in the structure of CoFIND to support, say, the instigation of problem-oriented exercises. A student using the system confirmed this, saying:

> "There is little guidance, it would help if there were more cues supplied about topics/keywords/values. Using it would be less problematic if a problem solving exercise or specific task were set."

Certainly the discussion and chat mechanisms could be used effectively once a decision to address a particular problem has been made and could somewhat support that decision-making process by enabling communication between its users, but this is not at all the same as the kind of exercise that might be set by a flesh-and-blood tutor. It is possible to conceive that the topic and/or quality mechanism might be used to organise a set of problem-related resources which might include those generated by the group, but without a tutor or some other leader to guide them there is no great likelihood that this would occur. A further development of CoFIND ought therefore to include some specific ways of dealing with the ongoing processes of constructing learning experiences. This could for instance take the form of group scheduling, with tasks collaboratively decided, but given the fact that learners will not know enough about what is to come (by definition, for they have not yet learnt it) this could remain a sticking point. For now we must fall back on the knowledge that there will be appropriate tasks and exercises available on the Web and that learners may use CoFIND to discover them, or that it should be used within a conventional learning environment where it is one of the armoury of tools available to teachers in a conventional setting (the approach adopted in the case studies described in the previous chapter).

Presenting the stimulus

CoFIND performs the role of presenting the stimulus very effectively. Through it, learners can identify the contents of a body of instruction, resources that are of use and (through qualities) do so in a manner appropriate to those who wish to use them. The development of qualities seen in the first assignment described in quality study 4 (the comparison of qualities used in different topics) shows this clearly. Through the stigmergic topic mechanism the learner is guided to what the collective will of the group thinks is important. Through the stigmergic quality mechanism the learner is able to select a way of perceiving the value of resources and is then presented with resources that best match the needs expressed.

Stimulating the recall of prior learning

CoFIND relies largely on the resources themselves to stimulate the recall of prior learning. Through its evolutionary mechanism it weeds out those which are not useful to this process. Resources which do not stimulate the recall of prior learning are unlikely to appear near the top of the list for a learning need expressed through qualities. In the sense that qualities allow the learner to self-diagnose current needs and find matching qualities, CoFIND supports the stimulation of the recall of prior learning fairly well, as long as appropriate qualities have been entered. Examples such as the second assessed exercise discussed in the fourth quality study of the effect of topics on the use of qualities (where qualities of dubious pedagogical merit developed) might provide little help to learners, whereas the first exercise discussed in that study (where pedagogically relevant qualities were used) would allow it to fulfil the role effectively.

Providing learning guidance

There is little explicit support for the provision of learning guidance within CoFIND, but this is not necessarily a limitation as such guidance may be among the resources shared through the system.

Enhancing and promoting retention and transfer

Because CoFIND allows learners to find resources which match the learning niche expressed through a combination of topics and qualities it can provide a range of rated resources which address a range of needs and provide a selection of approaches to learning about a topic. This increases the likelihood of a learner finding resources which most closely suit his or her needs and thus promote retention and transfer, in the same way as it assists the stimulation of recall of prior learning.

Because it places resources into competition then it is likely that those which reach the top of the list for a given context will provide a range of possible views appropriate to learners' needs. Several of the students' comments previously quoted seem to confirm this, although it is not always clear that the use of qualities adds a great deal to this process.

Providing feedback and assessing performance

Although Gagné separates the two events of providing feedback and assessing performance I have taken the liberty of treating them as two sides of the same coin. Certainly this is how CoFIND treats them and in an environment designed to encourage learning rather than the ossification of existing systems they are too similar to separate.

Feedback is built into the system at many levels and the uses of CoFIND described in the study of CoFIND 1 and quality studies 3 and 4 show ways in which this might be utilised in a blended environment.

Eliciting performance

Gagné's notion of eliciting performance may be split into two distinct aspects. In the first place it is concerned with providing appropriate tasks, something which CoFIND is explicitly designed to help with through the quality mechanism which allows learners to identify relevant resources for their specific learning needs. The second aspect is in providing motivation.

Motivation

In Chapter three I observed that a large part of the requirement to implant a predisposition toward learning relates to the process of encouraging motivation. My own studies point strongly to the importance of motivation of the right kind in allowing a self-organised learning environment to emerge. Notably, the establishment of an academic community will have a large role in enabling this. As discussed mainly in Chapters one and three, this is expressed by a wide range of educational theorists, including Piaget (1970), Vygotsky (1978), Pask (Pask 1976; Pask & Lewis 1972; Rocha 2000), Houghton (1989) and Dewey. CoFIND enables the establishment of an academic community through its various communication mechanisms, with communication explicitly centred around the resources and topics of interest to the community.

No matter how entertaining we might make our system, it is possible that it will not substitute for a real teacher when it comes to communicating a love of a subject or enthusiasm for a topic. However, it is important to note that CoFIND (at least in design) is currently competing with other online environments where some of this function may already be diminished. Bearing this in mind, there are at least three separate ways in which CoFIND can with improving motivation:

? it can provide a range of resources that are more relevant and appropriate to learn from than would be the case were other means of seeking them employed. It allows the learner to avoid less useful resources and thus may make learning a more pleasurable experience. As with all pleasurable experiences, there is an incentive to get more of the same.

? it provides a means to communicate with other users and to benefit from their experiences. The act of participating in a learning community provides greater motivation than working alone, helping to reduce one of the demotivational pressures identified by Herzberg, that of isolation (Herzberg 1966). Moore & Kearsley write “increasing the level of participation in a class supports motivation as well as learning” (Moore & Kearsley 1996, p. 133). There are many other benefits of being in a learning community, including sparking ideas, inciting competition and co-operation and providing a ‘play-space’ in which to experiment with ideas. All of these features are helpful in encouraging a predisposition towards learning by enhancing motivation.

? feedback and assessment can provide motivation through positive reinforcement. The ability to discuss and publish combined with a feedback mechanism that gives a fairly precise and anonymous evaluation of what is discussed and published may provide senses of what Maslow describes as *belongingness and esteem* (Maslow 1954). Of course there is always the danger that the opposite may occur. CoFIND is not the embodiment of tact.

Alan Kay puts the kind of motivation that might be provided by CoFIND rather succinctly:

> one’s own interests provide the motivation to journey through an environment that is full of learning opportunities disguised as toys
>
> (Kay 1996).

Papert’s view is similar:

> the reason you need all those heavy-handed instructional methods is because you’re trying to teach people something they don’t want to learn. When they want to learn it, if you create the right intellectual environment, they learn it quickly and easily.
>
> (Papert 1987)

CoFIND does not yet have an effective way of dealing with demotivational factors such as the problem of flaming mentioned in Chapter four, apart from the ability to contribute anonymously. Unfortunately, this in turn can lead to problems of trust and a reduced sense of community (Preece 2000, p193). The solution to this kind of problem probably lies in building effective communities. Within an electronic community, members may take a variety of roles. In a group of adult learners it would be improbable that some of those roles would fail to overlap with the kind of things teachers do in discussion fora. A problem of building effective communities is one of providing a suitable space for them to grow. What is sought is a method of participatory design that provides sufficient flexibility that the community itself can decide how it is controlled, for example like that of the Peckham Experiment discussed earlier (Goodwin 1994). CoFIND does not yet provide explicit support for such processes.

Conclusions to this chapter

CoFIND was originally designed as a means for a group of like-minded learners to collaboratively though not necessarily co-operatively (Brown & Duguid 1995) discover appropriate resources from which to learn, a role which remains central to this day. With a design philosophy grounded in evolutionary theory and principles of self-organisation, CoFIND seeks not only to improve the ability of learners to select relevant resources, but also gives those resources some structure and form as a result of the interactions of its users. It is thus tailored to the specific needs, classification schema and understanding of the community which forms it.

CoFIND has grown beyond its original remit to make it easier to select educational resources, and now exhibits some of the qualities of a virtual learning environment (VLE), optionally including synchronous as well as asynchronous discussions and a means of file upload as well as its core functionality of organising and structuring resources. Because of its core functionality and these VLE-like features, the system (by which I mean the combination of, and interactions between, the computer programs, their users and their environment) is able to act in some ways as a guide, or controller of the learning process. It would be foolish to suggest that it could in its current form be used as a replacement for a teacher, but there is now sufficient functionality in the system to provide a useful support tool for groups of learners.

Many problems have occurred in the development of the CoFIND systems, often related to interface issues or lack of functionality within a specified area, and their development continues. The CoFIND systems have been helpful in pointing the way towards the kind of system which could potentially help to remove some of the strain from the process of teaching or even, perhaps, to replace most of the roles of a teacher altogether. If our universities insist upon continue to employ subject experts without regard to their abilities to teach, then a system which builds upon approaches taken by CoFIND may help their students, directing them instead to better sources of subject knowledge.

CoFIND's self-organisation is based around the reification and use of metadata. Taken to the limits, a system that could reify all and any metadata used by learners could have the potential to help organise and influence their interactions with each other and resources available on the Web to any degree. The emergent structures that would result may or may not have educational benefits but, with a sufficiently focussed body of mature learners driving them there would at least be a chance that they would be organised around educational needs. Currently the most successful way I have accomplished this is through the skyhooks of extrinsic motivators. In the next chapter I will attempt to extrapolate some principles from the lessons learnt and will be envisaging a more complete self-organising environment for learning which might break free from these constraints.

Chapter 8 : Towards a theory of self-organising network-based learning systems

About this chapter

This chapter attempts to pull together and summarise the various themes that have been explored throughout this thesis. By the end of this chapter I hope to have distilled the essential features which might characterise a self-organised networked learning environment and suggested a representative set of mechanisms which might assist in the development of such environments. I conclude with a description of an environment (currently in early stages of development) that draws upon and extends the work performed so far.

Where are we now?

This thesis began by examining the nature of educational systems, suggesting that it is the nature of all systems to be both dictated by and to dictate the behaviour of their components. In traditional forms of education, this has led to systems that can occasionally be harmful to the goal of effective learning. A part of the reason for this lies in the centralised control which underlies such systems, with hierarchies being controlled from the top down by individuals and small groups rather than emerging from the needs of the learners to learn. Although these are designed environments, each designer sees only a part of the whole system. Local interactions lead to complex behaviour in the system as a whole, which may lead to consequences quite different from those intended. There are opportunities afforded by distance learning, especially through networked learning environments, to reinvent educational systems without a designer or team of designers in control.

Through an investigation of ways in which self-organisation is achieved in natural and artificial systems common features which could be exploited to inform the development of self-organised environments were identified, such as evolution and stigmergy. In an educational context, the structures that might emerge were identified as being those usually imposed by a facilitator of learning, most commonly embodied in the form of a teacher. There are many different roles performed by teachers and many different ways they affect the ease with which learners learn. By abstracting the non-contingent features of these roles a framework was provided which could be used to generate and validate a self-organising educational system. This framework provided a means of benchmarking success that was largely independent of the need to measure learning outcomes.

The strengths and weaknesses of networked environments which had no obvious support for self-organisation of learning were examined and found wanting, largely through lack of support for the emergence of structure. This lack of support may be manifest either in too rigid an existing structure (such as the threads of discussion fora) or in a lack of structure to differentiate messages or resources. It was discovered that self-organising network-based systems (such as collaborative filters) which make explicit use of the combined individual efforts of their users often use layers of metadata, either explicit or implicit. Other successful ploys include the implicit application of stigmergy, together with techniques to apply negative feedback. However few if any address the dynamically changing needs of learners.

Lessons learnt from looking at other self-organising networked environments combined with theories of self-organisation and an abstract instructional framework informed the construction of the CoFIND series of systems. Through stigmergy, natural selection and manipulation of layers of metadata, CoFIND has been able to achieve some measure of self-organisation with an educational purpose by reifying learners' preferences and needs in the form of qualities.

The remainder of this chapter summarises the main lessons learnt and explores what would be required in a system that could truly offer an alternative to existing educational systems.

Guidelines and hypotheses for the construction of self-organising network-based learning environments

We have looked at a variety of issues in the course of this thesis surrounding network-based learning and self-organisation. We have seen that self-organisation is a common property found in a wide range of circumstances, and that (despite a range of issues to which I have yet to find a good resolution) it can be encouraged to occur by the creation of an appropriate environment. We have seen that educational systems contain a wide range of interacting subsystems. Those that are essentially educational in character seem to revolve around the roles of the teacher as a mediator of learning. With this in mind I have developed systems which attempt to embody some of those roles as an emergent property of the interactions of their users. The result of these developments suggests the following set of hypotheses and rules of thumb to identify and perhaps even to generate network-based learning support systems which encourage self-organisation to occur and which exhibit emergent properties akin to the roles of a teacher.

Foundations

The following assertions are hopefully self-evident:

? the Internet contains a large body of instructional/educationally useful resources is readily available, mainly (though not entirely) in an unorganised form. There are many ways of finding out about these resources though few give more than a hint as to the value of the resources as an aid to learning

? a group of adult learners brings a range of experience, knowledge and learning strategies to any new learning experience and some of that experience, knowledge and learning may be communicable to other adult learners.

Growing self-organised systems

Self-organising systems have a number of characteristics and there are several ways that they can be encouraged to develop:

? for any system to spontaneously speciate, one condition is that there must be a means to generate information or form and some kind of constraint to limit its growth

? most (if not all) systems will behave dynamically when driven by positive feedback and constrained by negative feedback

? stigmergy provides a powerful model for driving positive feedback by enabling group communication through artefactual processes

? natural selection provides an effective model for building negative feedback into systems

? a system should be capable of creating (or procuring from its environment) variety and novelty

? a system should be sufficiently flexible that unanticipated behaviours resulting from side-effects of other features can be capitalised upon

? a system should exhibit parcellation yet allow limited traffic between parcellated areas

? a system should be viewable at more than one scale, the slower moving parts dominating the development of the faster moving parts

? for a community to dynamically adapt, communication in as many ways as possible should be enabled between its participants although (following the principle of parcellation) competitive processes should be allowed to ensure that relatively few of those communication methods are actually employed on a regular basis.

Creating structure through metadata

Metadata provide mechanisms for achieving structure within a self-organising environment:

? organisation of any large body of resources involves a process of abstraction which may be understood and explained using metadata, whether created by a designer, emergent, explicit or implicit

? by definition, organised data must be categorised by some form of metadata. Raw data have no meaning, no relationships, no structure

? one of the distinguishing features of an educational experience as opposed to a random learning event is that it brings structure to learning

? a solution to the problem of self-organisation of learners and their learning is to bring about structure by enabling the self-organisation of metadata

? if shared metadata emerge through the actions or design of the users of the system then that part of the system which is shaped by those metadata may or may not be self-organised

? if metadata are solely imposed by a central authority or designer, then those parts of the system affected by this will *not* be self-organised. However, the data values of those metadata may lead to self-organisation of the relationships between them which could then be abstracted using different metadata.

? if a system is to self-organise, some or all of its metadata should not be imposed by an authority, but should be generated from the use of the system itself, either explicitly or implicitly from the actions of its users.

? to make a system self-organising, both data and metadata entered (implicitly or explicitly) by one user of the system must be capable of having some material effect on the actions of one or more other users

? the usage of all metadata must be capable of being affected in some sense by the usage of all other metadata in the system. These effects might not be direct and might be infinitesimally small, temporally separated, or stigmergic

? to reach a degree of order implies that some dynamic adaptation must occur

? the values of metadata must be able to change, but so too must their structural schema

? metadata should adapt to the task at hand, both in the values they hold and their schema

? typically, metadata adaptation will occur through an evolutionary process

Helping learners to learn

The previous assertions suggest a way of building systems that structure themselves by the interactions of learners, resources and metadata. For these systems to reach pedagogically useful states:

? systems should exhibit one or more features of an instructional system- I have identified Bruner’s framework and its surrounding preconditions and assumptions as one plausible basis for identifying such features, but this is not the only possible framework

? metadata, learners and resources should exist within a landscape that makes it probable that the pedagogically useful will be selected or will survive preferentially

? landscapes which result in pedagogically useful features are most likely to occur when learners seek to learn and are aware of the system's role in enabling that to occur

A self-organised system

I have begun to build a truly self-organising system for learners, based on the precepts given above. It is still in an early stage of development, but this is what it might be like to use it:

When users first enter the system, they are faced with a range of subject titles, some more prominent than others. Drawn by interest in the subject itself as well as by stigmergy to subjects already deemed useful by large communities of users and with sufficient current interest shown (perhaps by size, list position or some other visual indicator) users select subjects of interest to them, or they might supply their own, hoping to build a learning community around them.

On entering a subject area, the users provide some profiling information to supply information about themselves, using metadata such as current level/ability within the subject, preferred learning styles, nationality, sex, previous experience and so on. These metadata are not quite like those used on other sites which employ user-modelling, inasmuch as they have been generated from those used by other users to describe themselves. In a manner that the users will soon become accustomed to, these metadata are arranged stigmergically, with the more frequently used metadata more easily selectable.

Having entered profiling information and entered a subject area, users see something that would not be too unfamiliar to someone who had already used a VLE or MLE. Amongst other things, a user sees:

? topics, listed in a meaningful sequence based upon a matching of metadata with those of existing users, with a clear indication of which topics are most popular at the moment

? a discussion forum, with an area set aside for each topic as well as other user-definable areas. Messages within the discussion achieve prominence according to how much they have been read, as well as being rateable according to user-defined qualities, these ratings being shown in the message listings. Relationships other than simple hierarchies of replies can be expressed and used to change the display of messages. These relationships may be defined by the users

? a calendar/schedule. Users can see the numbers of individuals who have subscribed to any given event, thus allowing more popular events to be discovered through stigmergy

? news and announcements, including current events from the schedule and invitations to form groups or participate in some form of assessment/group exercise. This is an essential mechanism to allow communication between users and groups of users

? a list of participants, with stigmergic indicators of levels of activity within the system and the means to send individual messages, thus self-organising into a web of trust, with the key species highlighting themselves by making their activities visible. Perhaps there is some indication of those who have a similar profile to that of the learner viewing the list

? a group list. This may be arranged around patterns found in user profiles, or self-selected. Users can send messages to a specific group and arrange group schedules

? a chat room, perhaps a variant of ChatCircles, allowing users to manage interactions in real time. This is also related to indicators of others online now, allowing self-organisation of synchronous sessions to develop.

Along with the system itself there are many support tools (e.g. video conferencing, whiteboarding, remote control, word processors and so on) which are needed to deal with the mechanics of online learning.

Following from the principle of clustering and developing hierarchies, within each topic, there are:

? relevant news/announcements etc

? a set of appropriate resources from which to learn, in an order based on selectable qualities. Users may rate these resources according to those qualities. Relationships between resources can be specified and used as a filter and/or to shape the format of the display.

? a discussion area for the topic (see above)

? a chat room for the topic (see above)

? a set of relevant tasks. Learners are able to see the work of others here, and to rate them. They may propose new tasks if they wish

? a means to create subtopics, exhibiting a similar structure

Each system is capable of communicating with other similar systems using a set of protocols which allow different resources, topics and qualities to “invade” other systems across narrow bridges, making it possible for new and novel systems to arise.

A sufficiently usable system with this functionality, embodying the principles identified earlier, fuelled by a sufficiently motivated group of learners, could develop complex and intricate structures to assist the process of learning. These structures may be thought of as a distillation and amplification of the group’s abilities rather than the effects more commonly found in group behaviour of either a small number of individuals’ dominance or of a dilution of the collective talents of the group.

Conclusions

Self-organising behaviour of groups of learners is common in traditional learning environments. In a computer network our ability to create virtual spaces which adapt and change opens up a range of new opportunities. In particular the possibilities afforded by systems which capitalise on stigmergy combined with an appropriate negative-feedback mechanism are immense, allowing effective use of the sheer scale of the Internet in ways that would be unimaginable in either traditional teaching environments or earlier computer assisted learning systems.

For those seeking to build self-organising network-based collaborative learning systems, the overriding principles from which all others follow are that there should be positive and negative feedback loops which are driven by the combined behaviours of their participants, whose goals should be to use the system to help them to learn. These loops should determine the form and structure rather than the content of the learning experience, through the use of implicit or explicit metadata. There is still a lot of work needed to identify ways in which this might occur, especially for sequencing and temporal features of the structure. The structure may never be as rich or as valuable as that provided through management by a traditional teacher. If further research should show this to be an insurmountable problem then it is worth noting that such a system may (as we have seen in my earlier studies) be incorporated to form a hybrid within a traditional educational structure.

Perhaps the most interesting outcome of this research is a deeper insight into the ways that virtual networked environments can enrich the processes of communication, providing a meta-level of structure established by indirect communication and stigmergy. Networked computers are able to provide the means to amplify relationships between people and things, even to provide new forms of sensory apparatus that perceive and enhance patterns of interactions between individuals. This is an exciting new field, an evolutionary leap which begins to exploit the unique features of networked computers rather than simply mirroring or improving ways we already communicate.

Appendix 1: original contributions to knowledge

Independent and original contributions to knowledge

The central contribution to knowledge made by this thesis is the proposal of a principle of evolving metadata as a means to engender self-organisation of a body of knowledge through the interactions of more than one participant. This has not been rigorously demonstrated but the studies and research that I have performed suggest strongly that it is worth further study.

Within an educational context, the analysis of weaknesses in existing self-organising systems (such as collaborative filters) and the arguments for the particular application of the principle of evolving metadata to an educational setting are also original.

Other original contributions

? analysis of educational systems in terms of hierarchical structure and scale, especially the recognition of the levelling effect of multiple inheritance and the identification of the role of the teacher as the key structurally determining factor

? analysis of effects of structure in discussion groups on the ability of those groups to support self-organisation

? analysis of existing networked computer systems to support learning in terms of evolution, stigmergy and self-organisation

? the application of stigmergy to the explicit self-organisation of metadata

? the explicit application of certain key principles of evolution (including survival of the fittest, reproduction with variation, parcellation of populations) to the self-organisation of data and metadata

? the development of a system embodying the principles of self-organisation of metadata

? the discovery of effects of different purposes on the selection of 'quality' metadata

? analysis of the importance of motivation (most notably the desire to learn from the system) in determining the structure of a self-organised educational system

? analysis of ways that visual cues can create stigmergic effects which influence the behaviour of users of adaptive systems

Appendix 2: related publications

This thesis integrates and builds upon research published or to be published in the following proceedings and journals (included with this thesis):

? (Dron, Mitchell & Siviter 1998) Journal article in *Education and Training*. This paper describes the first of the studies of discussion groups discussed in Chapter four

? (Dron et al. 1999) Conference paper for *WebNet 99*. This paper describes the first study of CoFIND 1, reported in Chapter 7. It won a top paper award

? (Dron et al. 2000a) Conference paper for *WebNet 2000*. This paper deals with the ways that CoFIND might replace a teacher

? (Dron et al. 2000b) Conference paper for *ISKO 6*. This paper looks at the ways that CoFIND evolves metadata

? (Dron et al. 2000c) Conference paper for *WWW9*. This poster paper discusses CoFIND's role as a replacement for a teacher

? (Dron et al. 2000d) Conference paper for *WebNet 2000*. This short paper describes the Website Evaluation System used in the HCI study of Chapter 7

? (Dron et al. 2000e) Journal article in the International *Journal of Network and Computer Applications*. This paper was an extended version of that delivered at WebNet 99, and introduced CoFIND 2

? (Dron, Boyne & Mitchell 2001) Conference paper at *UKAIS 2001*. This paper looks at a number of ways that structure can emerge in CoFIND

? (Dron, Mitchell & Boyne 2001) Conference paper at *WebNet 2001*. This paper discusses the role of stigmergy in the organisation of the Web and of CoFIND in particular.

Glossary of terms

Beer game

an extended example of systems behaviour invented by Forrester and described by Senge where latencies within a system lead to unwanted behaviours despite each individual within the system responding rationally to local events.

CAS

Complex Adaptive System, one which reaches metastability, though in a constant state of flux, usually accommodating of minor perturbations but which may slip to a different metastable state with sufficient stimulus.

Cold-start phenomenon

a problem affecting collaborative filters where the system is only useful once ratings have been given, leading to a vicious circle where the system is not used because it has no ratings so is not useful, so no ratings are given.

Constructivism

a range of theories of and approaches to education which focus on the construction of knowledge by the learner rather than the transmission of knowledge by the teacher.

Edge of chaos

a state of systems where change occurs, balanced between Stalinist and Red queen regimes.

Exaption

used by Gould to describe the sort of adaptation seen in spandrels, where a side-effect of another process leads to an evolutionary advantage.

Lamarckian evolution

from Lamarck, a predecessor of Darwin whose evolutionary theory relied upon the inheritance of acquired characteristics. Although the theory is discredited as a mechanism driving biological evolution, it appears to be the mechanism behind other sorts of evolution, notably that of memes.

Meme

used by Dawkins to describe an infectious concept, idea or cultural artefact, which spreads through a population and replicates. Memes compete and evolve in a Lamarckian manner.

Metastability

A pseudo-stable state, where a system which is constantly in flux remains apparently stable in its configuration, adapting to perturbations.

Parcellation

the separation of evolutionary environments leading to accelerated evolution (according to many evolutionary theorists).

QOI

Quality of Information – a measure of how useful, relevant, timely or appropriate any given piece of information might be.

RBL

Resource-based learning - used to describe a method of learner-centred teaching which encourages learners to research a topic themselves, usually involving a set of resources selected or created by a teacher.

Red Queen Regime

a system which has fallen into chaos, never reaching stability.

Self-organised criticality

the state of a metastable system balanced on the edge of chaos.

Sky hook

a term coined by Daniel Dennett to describe a “deus ex machina” which is extrinsic to a system (used derogatively in the context of evolution to describe a mechanism to accelerate evolution which does not itself evolve).

Spandrel

a term used by Gould to describe a feature of a system which is a side-effect of something else but which serves some unexpectedly useful function.

Stalinist Regime

from the chaos theorists, a system which falls into a fixed pattern of behaviour with no novelty and only cyclical change at best.

Stigmergy

a form of artefactual communication via the environment leading to self-organised behaviour, first described by Grassé.

Symbiotic evolution

a concept introduced by Margulis where the “invasion” of one organism by another can lead to evolutionary advantage without immediately changing the genetic make-up of either organism, classically seen in the mitochondria which inhabit the cells of non-bacterial organisms.

Teachback

a concept used by Pask to describe a method of enabling learning by teaching, leading to positive feedback loops of benefit to tutor and tutee.

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