# KNOWLEDGE ACQUISITION AS A SOCIAL PHENOMENON

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## ABSTRACT

The acquisition of knowledge, the development of the individual's knowledge bases, does not occur in a vacuum. The social context, both social structure (the perceived regularities in the social network) and social knowledge, appears to be related to the individual's acquisition of knowledge. In this article, the relationship between the social world and individual knowledge acquisition is explored. A general theory is postulated and then formulated as a model. The basic theory is predicated on the assumption that social interaction is the driving force behind knowledge acquisition.

A selection of results pertaining to social learning will be presented. These include, but are not limited to the following:

- Social structure affects knowledge acquisition; e.g., individuals in tightly knit social groups develop similar cognitive structures, but not necessarily similar evaluations of those structures.
- Social knowledge evolves slowly and relative to shared experience.
- Individual knowledge acquisition is limited; e.g., individuals and groups talk past each other because of the lack of critical paths in their respective knowledge bases.

## Introduction

The acquisition of knowledge, the development of the individual's knowledge base, does not occur in a vacuum. The social context, both social structure — *the perceived regularities in the network of ties between individuals in the society* — and social knowledge — *that information which is known by "everyone" in the society* — appears to have an effect on the individual's acquisition of knowledge. Briefly, the conjecture is that the social world and the world of the individual are being continuously constructed as individuals move through the series of tasks that constitute daily living, interacting, communicating, and hence acquiring knowledge. The acquisition of knowledge, and hence cognitive development, becomes a by-product of human interaction: the individual's cognitive structure is continuously constructed as the

individual moves through a series of tasks interacting with others, communicating, and hence gathering information. The development of the social world involves tacit consensus among the individuals in the society over perceived regularities; in this way, social knowledge, as shared cognitive structure, is also a by-product of human interaction. Social knowledge affects future interaction/communication; in part, because it provides a basis for analyzing/interpreting particular tasks. Social structure and the individual's propensity to interact develop reflexively. As individuals' knowledge bases co-evolve, their propensity to interact changes, social knowledge evolves, and social structures change. It is to the elaboration and exploration of this conjecture that this work is addressed.

Concept development is the vehicle class used to motivate this theory; the specific vehicle used to test the tenets of this theory is the development of the concept *tutor* by a group of MIT undergraduates as they move through the task of selecting a new tutor for their living group, Third East.

The importance of the social context to the individual's reasoning process and his ability to acquire knowledge through his interaction with others has come to be more accepted by researchers in general. And yet, as Cicourel (1974: 11) notes:

> It is commonplace in sociology for writers to acknowledge the ultimate importance of the interacting situation between two or more actors. The assumed relationship between structure and process, however, is often no more than an expression of faith rather than the integration of social process with social structure...

By an expression of faith Cicourel seems to be referring to the fact that explicit cognitive procedures and a theory of meaning are absent from such formulations of social interaction; e.g., the work of Davis (1949) on status, Parsons (1951) on role expectation, Homans (1961) on social stimulus, and Blau (1967) on social status.

Despite of the lack of an explicit cognitive model for the relationship between the social world and the individual world, a variety of arguments have been forwarded on the nature of this relationship. Social position affects mobility, career chances, and who one knows (Breiger, 1978, 1979; White, 1970; Granovetter, 1973, 1974, 1982). Culture affects learning processes and behavior (Mead, 1962, 1964, 1978; Luria, 1978; Vygotsky, 1962, 1978).

In other words, there is evidence that the social world affects what we know, what information we store, even if it does not affect the cognitive mechanism for storing, retrieving, and manipulating that information. These works point to the existence of a relationship between the social and the individual world; they do not provide a mechanism for movement from the individual to the social, a model of this relationship. But they do place con-

dicative of the type of analyses that are needed to test the model. This article is not about tutor selection or what it means to be a tutor. The findings presented are not meant to be a comprehensive analysis of the learning behavior of MIT students. A complete description of these students, and their social world can be found in Carley, 1984. Nor is this article about a new methodology. Admittedly, the methodology used, frame technology, is novel in that it permits the researcher to directly relate social to cognitive data. However, the purpose of this article is not to elucidate the use of these techniques nor the algorithms on which they are based. An overview of these techniques can be found in Carley, 1985b, and a more comprehensive treatment in Carley, 1984.

## 1. Constructuralism − Theory and Model

Individuals do not acquire knowledge in a vacuum nor is the acquired knowledge independent of the individual's current knowledge. Constructuralism is the theory that the social world and the personal cognitive world of the individual continuously evolve in a reflexive fashion. The individual's cognitive structure (his knowledge base), his propensity to interact with other individuals, social structure, social meaning, social knowledge, and consensus are all being continuously constructed in a reflexive, recursive fashion as the individuals in the society interact in the process of moving through a series of tasks. As the individuals move through the set of tasks that constitute daily life, they interact and, in doing so, they acquire knowledge. What knowledge they acquire and whom they interact with are factors which are intimately related. Central to the constructuralist theory are the assumptions that individuals process and communicate information during interactions, and that the accrual of new information produces cognitive development, changes in the individuals' cognitive structure. What follows is an elaboration of various assumptions and ideas underlying this theory.

KNOWLEDGE ACQUISITION IS DONE IN THE CONTEXT OF PERFORMING TASKS

The individual's life is viewed as the performance of a set of tasks, some sequentially performed and some simultaneously. These tasks run the gamut from going to a movie, to selecting a president, to choosing a toothpaste, to interpreting questions on a test. The individual's performance of a task is dependent on his evaluation of the information he knows about some aspect of that task. The information that the individual knows relative to some task is his frame of reference for that task. When an individual performs a particular task that task's frame of reference becomes the individual's current

general theory presented in section 1, a representation scheme for knowledge is needed. This representation scheme is presented in section 3. Using this representation scheme, a model of individual and social knowledge is presented in section 4. Following this, in section 5, a more specified, albeit simple, model of knowledge acquisition, and the evolution of social knowledge as a function of social interaction is proposed. The interrelationship between individual knowledge and social knowledge is critical to this model. And finally, in section 6, a set of hypotheses about the nature of individual knowledge acquisition and social knowledge based on the foregoing models is proposed and then tested.

DATA

The data base is drawn from an in-depth study of the relationship between the social structure of a group of undergraduates at MIT and their cognitive conception or structure of the concept *tutor* as the students moved through the task of selecting a new tutor or graduate resident, for their living group, Third East (Carley, 1984). This living group, Third East, at the time of this study was composed of 45 undergraduates, male and female, freshmen through senior, all living in one section of a particular dormitory — the third floor in the east parallel of the East Campus dormitory. Physically, Third East is a block long hallway, in a dormitory, East Campus, formed of ten such hallways, five each in two parallel buildings.

The data used are non-experimental and are based on a rich ethnographic study of this group. The data include subjective interaction data, personality profiles, interviews with each student separately on their perception of the concept *tutor* and their perception of the entire tutor selection process at several different stages, voting procedure information, transcripts of meetings, actual votes, decision time frame data, and historical and cultural information on the living group.

The interaction data were analyzed using network tools to extract the underlying social structure, e.g., the block modeling program CONCOR was used to locate structural groups (Breiger et al., 1975). The students were interviewed several times throughout the tutor selection process as to their perception of the concept *tutor*, as well as on other facets of the selection task. These interviews were then coded as knowledge bases, one base per person per time period (Carley, 1985a). A set of procedures, collectively referred to as *Frame Technology*, that allows the researcher to relate social structure to cognitive structure was used to analyze this data (Carley, 1985b). Herein, the structural groups extracted from the interaction data and the maps [4] of the student's perception of the concept *tutor* are used. Again, these maps are the result of coding the interviews with the students using a set of techniques
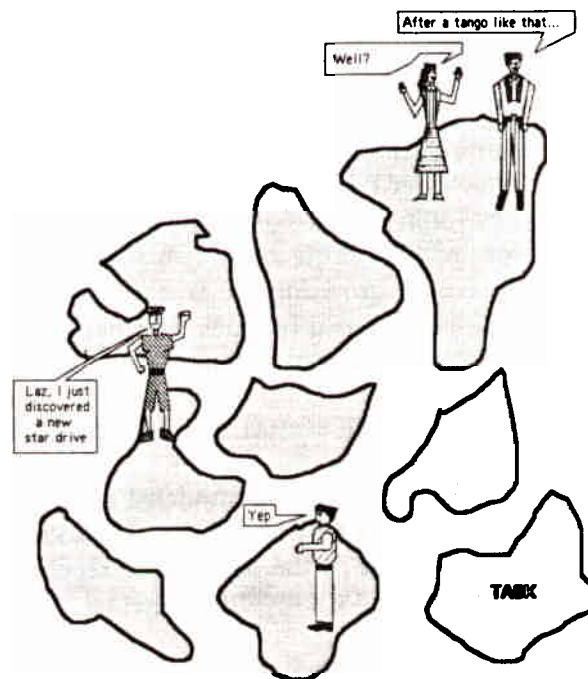
In the process of everyday life individuals move through a series of tasks , interact, and communicate. These tasks set the context for what information is communicated.

Fig. 1. Everyday life. The individual's life is viewed as the performance of a set of tasks, some sequentially and some simultaneously. These tasks run the gamut from going to a movie to selecting a president to brushing one's teeth to interpreting questions on a test. The individual's performance of a task is dependent on his evaluation of the information he knows about some aspect of that task. The information that the individual knows relative to some task is his frame of reference for that task. When an individual performs a particular task, that task's frame of reference becomes the individual's current frame of reference. As the individuals move through the set of tasks that constitute daily life, they interact, and in doing so, they acquire knowledge. What knowledge they acquire and whom they interact with are factors which are intimately related.

frame of reference. As the individual moves through his daily life he performs these tasks and interacts with other individuals performing the same or different tasks.

When individuals interact information is exchanged. The task currently being performed sets the context for what information is communicated and acquired. Individuals are most likely to communicate information in their current frame, or a frame that is tightly linked to their current frame. Further, they will accept information only if it is related to information in their current frame. The individual's performance of future tasks will be affected if

the information exchanged bears some relationship to the frames for those tasks.

There are several points here. The first is that the acquisition of knowledge is dependent on interaction and is done while the individual is moving through the performance of various tasks. The second is that the acquired knowledge can affect the individual's task performance on future tasks. The final point is that this article is not about task performance; hence, no model is provided for the way in which the performance of the task depends on the known information. It is enough for the current purpose to note that performance is a function of what information is available, and that information is acquired within the context of performing these tasks.

RELATING THE SOCIAL TO THE INDIVIDUAL

The individual is modeled as a node connected to a set of other individuals by a network of ties. The social world is modeled as a wholistic entity perceived as the patterns of regularities in the network of ties between individuals. As individuals interact, they and the social world co-evolve — see Fig. 2.

The individual has two defining characteristics that uniquely identify him vis-à-vis all the other individuals in the society. These are his propensity for interaction with the other members of the social unit [6] and his cognitive structure (his knowledge base) [7]. Presumably there are factors other than cognitive structure and interaction propensities that comprise a human being — e.g., motives and emotions. However, herein the concern is with these characteristics only to the extent to which they are articulatable, and hence communicable.

The individual's interaction propensities and his cognitive structure change as the individual participates in everyday life, performing tasks, interacting, and hence communicating and acquiring knowledge.

Note that some of the information that is communicated may be social knowledge; i.e., knowledge that is shared by members of the society. In fact, assuming that, for a particular individual, all pieces of information are equally likely to be communicated, then social knowledge is, throughout the society, the most likely information to be communicated as it is shared by "everyone." An individual can only communicate information that he knows, that is currently a part of his cognitive structure. An individual can only acquire information if it is comprehensible, given his current cognitive structure. I would suggest that there are two ways in which the individual can acquire knowledge, independent discovery or via communication. It is assumed that knowledge acquisition via discovery is relatively rare in comparison with acquisition via communication. Note that if neither new informa-
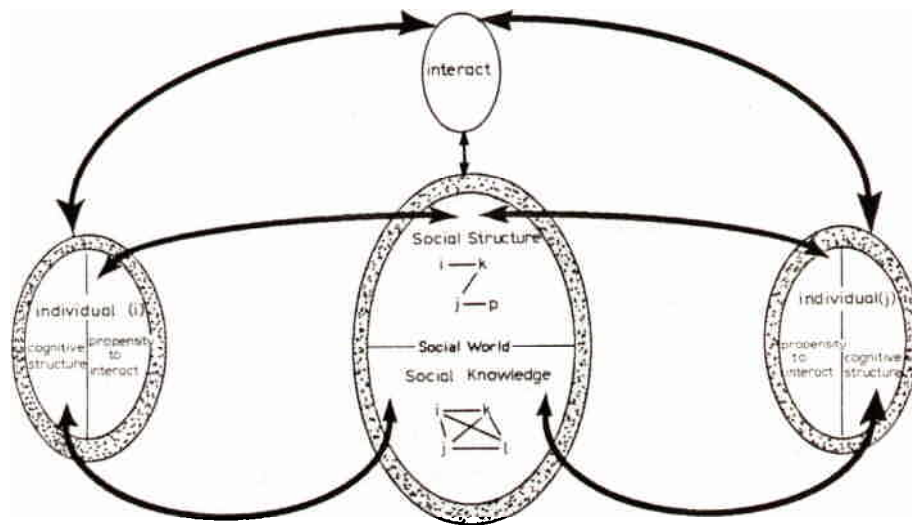
Fig. 2. Relating the social to the individual. The social world is viewed as being composed of two parts — social knowledge and social structure. The individual is modeled as having a set of propensities for interaction with each of the other members in the society and a knowledge base. As the individuals interact, they change — they acquire new knowledge and so their knowledge base changes and they change their propensities for interaction. As individuals interact, the social world changes — social knowledge evolves as individual knowledge bases co-evolve and social structure develops reflexively as interaction propensities change.

tion is discovered nor the composition of the society is changed — the individual's interaction propensities and his cognitive structure will asymptotically approach an equilibrium. Once equilibrium has been reached, the individual is static, his pattern of interaction remains unvarying, his cognitive structure is fully developed, and learning stops. Herein, the concern is only with knowledge acquisition via communication; i.e., interaction-bred information flow.

Since the individual's position in the society, his position in the social structure affects with whom he interacts, it also affects what information is communicated to him. Thus, the evolution of the individual's knowledge base is affected by social structure and his current knowledge base, as well as by the task that he is performing.

The social world is modeled as a dynamic wholistic entity, composed of a set of individuals and the network of ties between them, and perceivable as regularities in this network. The social world is divided into two parts, social knowledge [8] and social structure [9]. Social evolution becomes a heuristic artifact of social life. The social world evolves simply because all of the individuals in the social unit are simultaneously going through the proc-

ess of interaction and consequent knowledge acquisition even though they are performing different tasks. The co-evolution of individuals has social evolution as a by-product.

Interaction is the driving force which produces change in the social world and in the individuals who are members of the social unit. Changes occur because, due to this interaction, knowledge is acquired by the individuals and each individual's propensity to interact with others is reinforced. Social structure, regularities in the pattern of interaction between the members of the social unit, evolves reflexively as the individual's propensities to interact evolve. Social structure affects the cognitive development of each individual separately, by constraining interaction [10]. Similarly, social knowledge, knowledge shared by members of the social unit, evolves reflexively as the individual's cognitive structures evolve. As knowledge is acquired, individuals reposition themselves cognitively vis-à-vis other members of the society. As changes occur in who shares what information, cognitive repositioning, the individual's propensity to interact with the other members of the social unit changes. Hence, social structure and social knowledge co-evolve.

### Individuals as information processors and communicators

Individuals are viewed as joint information processors and communicators subject to time and effort constraints. As the individuals perform tasks they are constantly gathering, storing, manipulating, retrieving, and communicating information. Admittedly, individuals may also be doing other things than simply processing and communicating information, e.g., they may be reacting emotionally to some event or they might be trying to exert control over some situation or individual; however, for the purpose at hand the information processing view is sufficient. While the proposed view of the individual as an information processor and communicator is perhaps an oversimplification, I suggest that this view is useful in that it promotes an examination of the relationship between the social world and the individual cognitive world in terms of information flow, and hence knowledge acquisition. Further, if the individual is subject to time and effort constraints then task performance is important, not because of the feat but because it directs and constrains the information gathering and communication process.

### Initial cognitive structure

What knowledge the individual acquires is predicated on his current cognitive structure; i.e., individuals do not begin with a blank slate [11]. Rather, they start out with some knowledge, some set of preconceived notions about a variety of topics including ideas about the task being performed, the society in which they live, and the individuals with whom they interact. This set of ideas or knowledge forms a knowledge base. The initial knowledge

base is the set of pieces of information that the individual knows when we begin to observe his behavior. Note that this knowledge base includes the frame of reference for each of the particular tasks that the individual performs. Further, at any point in time we can think of the individual as focusing on, as having immediate recall of, that part of the knowledge base, that frame, that refers to the tasks currently being performed.

The current knowledge base is used to direct the gathering of new information, and hence the further development of the knowledge base. This recursive process of *knowledge-base-development information-gathering knowledge-base-development* continues regardless of the particular task the individual is performing, or the state the individual is at in performing that task. For example, let's say that the individual is involved in the task of choosing a president. Regardless of whether it is the beginning of the election process, e.g., prior to the primaries, or at the end of the process, e.g., when you pull the lever at the voting booth, the individual will be collecting information and adding it to their knowledge base in the same fashion. When it comes down to the wire and it is time to make a decision the information-gathering knowledge-base-development process does not halt; rather, the individual simply makes his decision on the basis of the information he has available to him at that time [12]. The point here is that the information-gathering process may be directed by what task is currently being performed, but it continues regardless of specific task.

*Cognitive structure is articulate*

The individual is continuously constructing his knowledge base, his cognitive structure. This continual construction involves the adaptation of the existing framework, the existing knowledge base, to comprise the lessons of a new experience. As Polanyi (1962: 105) notes what is meant by this process gains a more precise meaning when the framework in question is "articulate":

> The distinction between assimilation of experience by a fixed interpretive framework and the adaptation of that framework to comprise the lessons of a new experience, gains a new and more precise meaning when the framework in question is articulate. The first represents the ideal, of using language impersonally, according to strict rules; the second relies on the personal intervention of the speaker, for changing the rules of language to fit new occasions... The first is a routine performance, the second a heuristic act. A paradigm of the first is counting, which leaves its interpretive framework — the numbers used in counting — quite unchanged; the ideal of the second is found in the originality of poetic phrasing or of new mathematical notations covering new conceptions. Ideally the first is strictly reversible, while the second is essentially irreversible. For to modify our idiom is to modify the frame of reference within which we shall henceforth interpret our experience; is to modify ourselves.

In the constructuralist perspective all knowledge is articulatable [13],

therefore, it is potentially communicable. The individual's cognitive structure, his knowledge base, is an articulate structure. The modification of this structure requires the intervention of the individual to change the rules of the language [14] to fit the new occasion; i.e., if the individual is to accept new information that is communicated to him, he must adapt his knowledge base. As will be discussed in section 4, the alteration of the individual's knowledge base implies a change in the rules of language, a change in what information is related to what, a change in the meaning of various concepts. Cognitive development, the evolution of the knowledge base, is thus a heuristic act which is irreversible.

## 2. Interaction and Social Structure

In order to make some predictions from the previous theory a more precise model of social structure and the relationship between individual interaction and social structure is required. Recall that the notion of social structure presented rested on the propensity of individuals in the society to interact. Each individual has a certain propensity to interact with each of the other individuals in the society. For a particular individual, this set of propensities can be modeled as an array containing his propensity for interacting with all other individuals in the society — see Fig. 3. Collectively, these arrays, the interaction propensities for all individuals in the social unit, form a matrix. Recall that the social world is modeled as a network where the individuals are the nodes and the connections are the relationships between these individuals. One type of relationship is the propensity to interact. The proposed matrix is a representation of that part of the social world where the network ties are propensity to interact: each individual is connected to all other individuals by an interaction propensity. Within this matrix there are particular patterns; i.e., some of the individuals will have similar patterns in their interaction propensities vis-à-vis all of the other individuals in the society. As the individual's interaction propensities shift, these patterns change, and the pattern of actual interaction changes.

The propensity of one individual to interact with another individual is a function both of the level of past interaction and the degree of shared knowledge. Since interaction leads to knowledge acquisition, as individuals interact more, they share more knowledge and so are more likely to interact. This is a case of positive feedback. A consequence is that patterns of interaction will tend to change slowly, barring forces outside of the social unit [15]. Another consequence is that actual interaction becomes a fairly accurate predictor of future interaction, of the individual's propensity to interact.

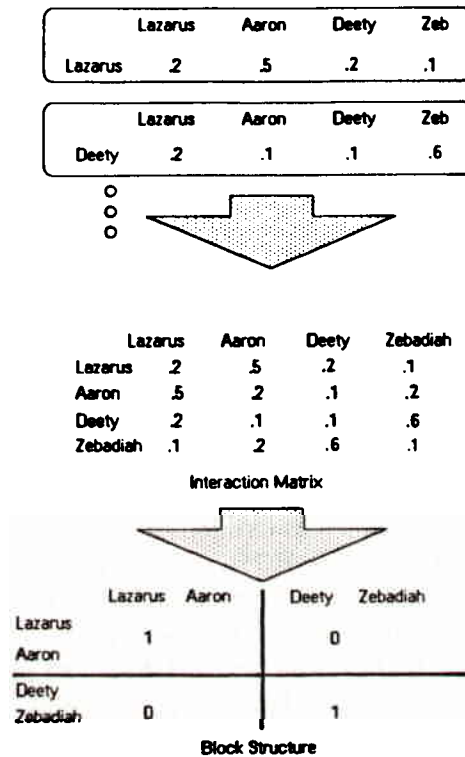Social structure, as the perceived patterns of regularities in individual's

|  | Lazarus | Aaron | Deety | Zeb |
|---|---|---|---|---|
| Lazarus | .2 | .5 | .2 | .1 |

|  | Lazarus | Aaron | Deety | Zeb |
|---|---|---|---|---|
| Deety | .2 | .1 | .1 | .6 |

○
○
○
○

|  | Lazarus | Aaron | Deety | Zebadiah |
|---|---|---|---|---|
| Lazarus | .2 | .5 | .2 | .1 |
| Aaron | .5 | .2 | .1 | .2 |
| Deety | .2 | .1 | .1 | .6 |
| Zebadiah | .1 | .2 | .6 | .1 |

**Interaction Matrix**

|  | Lazarus Aaron | Deety Zebadiah |
|---|---|---|
| Lazarus Aaron | 1 | 0 |
| Deety Zebadiah | 0 | 1 |

**Block Structure**

Fig. 3. Individuals' propensity to interact collectively forms social structure. Each individual has a certain propensity to interact with each other individual in the social unit. These propensities can be thought of as the probability that the two individuals will interact. Collectively, these probabilities for all individuals can form patterns; i.e., a group of individuals exhibits patterns of propensities that are similar, these are seen in the matrix. Such groups are structural groups. The matrix shows, in a collapsed format, the interaction between the structural groups. The 1's indicate a high level of interaction and the 0's a low level. This collapsed matrix shows that there are two groups, each of whom has a high level of intra-group interaction, and low levels of inter-group interaction.

propensities to interact, can thus be modeled as the underlying pattern in the set of ties that reflect actual interaction levels. If there is a pattern to these ties, then the members of the social unit will be divisible into groups according to shared patterns of interaction. Such groups are structural groups (Breiger, 1978; White et al., 1976) – a group of individuals who exhibit the same pattern of behavior, vis-à-vis the other members of the society, e.g., all of the individuals who interact with no one in the society including themselves. Social structure can thus be re-defined in terms of a set of these groups and the interrelationships between these groups – see Fig. 3 [16]. For example, in Fig. 3, we see that the interaction propensities for each individual

separately, collectively form two groups. Each group has a fairly high level of intra-group interaction (0.5 and 0.6, respectively) and a low level of inter-group interaction. We could think of these groups as opposing cliques.

## 3. The Representation Scheme

To further increase the precision of the model presented in section 1 a specific model of knowledge/information is required. As previously noted, knowledge is assumed to be articulatable. I propose that knowledge is not only articulatable, but composed of distinct pieces that are communicable [17]. The representation scheme used for knowledge/information [18] is based on the notion of a network of concepts. A variety of similar representation schemes have been forwarded for the representation of information in memory; schemes (Anderson and Bower, 1973; Bobrow and Norman, 1976), frames (Minsky, 1975), transition networks (Collins and Loftus, 1975; Clark and Clark, 1977; Wyer and Carlston, 1979), semantic nets (Simmons, 1973; Schank and Colby, 1973), and scripts (Schank and Abelson, 1977; Abelson, 1976; Abelson and Reich, 1969). The proposed schemes all share the notion of an ideational kernel, e.g., concepts, arranged in a network. Purely as a representation scheme, the proposed scheme is quite similar to several of these other schemes, especially augmented transition networks. The primary difference is the underlying notion that all knowledge/information, regardless of source, is articulatable and hence can be represented using the same scheme.

FACTS AND KNOWLEDGE BASES

Knowledge/information is viewed as a discrete entity composed of pieces — see Fig. 4. A piece of knowledge, a piece of information, is modeled as a fact — two concepts and the relationship between them (Carley, 1985b) [19]. Some examples of facts are *a Third Easter would be a good tutor*, *Gnerds aren't friendly*, and *Someone who fits in with the hall won't insist on quietness*.

I will refer to a collection of facts as a *knowledge base*. The individual's knowledge base is that collection of facts that are known by the individual — see Fig. 4. The knowledge base, in this case, can be thought of as a representation of the individual's cognitive structure, an articulation of the individual's perception of all his previous experiences. The social knowledge base is that collection of facts which serve as background information presumably known by "everyone" in the society. Social knowledge is that knowledge to which there is tacit consensus among the members of the social
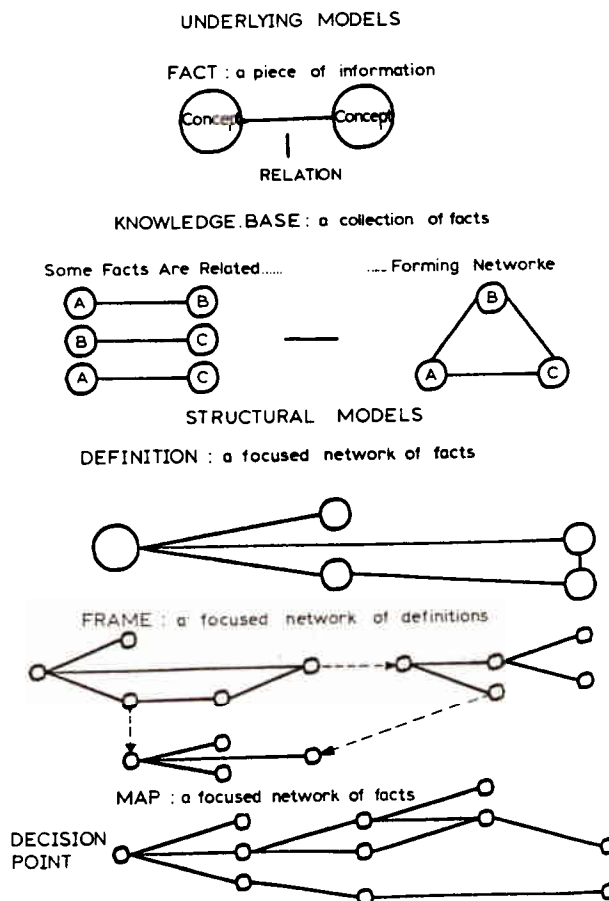
Fig. 4. Facts and knowledge bases. A fact is defined as two concepts/nodes and a connection between them. A collection of facts forms a knowledge base. Within this knowledge base it is expected that some of the facts will interrelate (share concepts) and thus form networks. Some of these networks are more important than others; e.g., the definition, the frame, and the map. Each of these networks represents a hierarchical structure of facts formed through the procedure of embedding or generalization. A definition is a focused network of facts. Note, concepts can only be defined by their relationship to each other. A frame is a focused network of definitions. A map is a focused network of facts, a slice of frame at a particular level of complexity as defined by the particular problem or topic on which the map is focused.

unit. The knowledge base, in this case, can be thought of as a representation of a standardized system of implicit signals and coding rules shared by the members of the society, an articulation of the social culture. As Cicourel (1974: 56) notes, without such a base "everyday interaction would be impossible for nothing could pass as 'known' or 'obvious', and all dialogue would become an infinite regress of doubts."

INTERNAL STRUCTURE

Within a knowledge base, we expect to find that some of the facts will interrelate; e.g., Jay loves Ann, Ann loves Greg, and Jay and Greg hate each other. Facts can interrelate forming a network simply by sharing concepts — see Fig. 4; i.e., pattern matching on concepts leads to the knowledge base being replete with implicit networks. Networking is not always the result of pattern matching; i.e., some networks are directed or have a hierarchical structure.

Individuals as information processors subject to time and processing constraints have a tendency to generalize, to categorize. The result of categorization is new information, new facts. These new facts have the old facts embedded within them; e.g., a new concept or category can be formed which serves as a handle for all of the generalized or embedded information. Generalization thus becomes a process of embedding one set of knowledge, e.g., a frame, within a particular concept or fact. Embedding is powerful as it provides a general framework which can be used to interpret outcomes, and which accurately predicts the general or average nature of those outcomes. Because of this tendency to generalize, the set of facts in the individual's knowledge base is not random but is interrelated, forming networks which have a hierarchical structure.

*The definition*

Some hierarchical networks of facts are more interesting, or have special interpretations; e.g., the definition. A definition is a focused network of facts such that the focus is the concept being defined and the other concepts in the network serve to define the focus by their relationship to it and each other.

The fundamental idea is one of relative definition:
- Concepts are ideational kernels that in isolation are devoid of meaning.
- Concepts can only be defined by their relationship to each other.
- Meaning is a function of the interrelationships between concepts in the knowledge base, and not the concepts per se.

In terms of social usage, general communication, there are no absolute definitions only relative ones — we do not go to the dictionary to understand a word, but understand it through the context in which it is being used. Even the definitions in the dictionary are transient and dependent on the perception of tacit consensus to a set of information that collectively constitutes the meaning of a particular concept.

## Frames and maps

These hierarchical networks of facts can be represented using a variety of structural models. Frames are one such structural model; maps are another (Carley, 1985b). Both frames and maps are networked knowledge bases with a hierarchical structure imposed on the network of facts. Frames and maps can be thought of as focused networks of definitions where the focus is the thing to be decided upon. Unlike the definitions previously discussed, frames and maps are complex and contain within them multiple definitions. Such structures may be interconnected, in that they can share concepts and/or facts — see Fig. 6.

For each task that an individual performs, he has a particular frame. This frame, in a hierarchical fashion, contains all of the knowledge that he knows to relate to this task. There are frames other than task-related frames. A map is a slice of a frame at a particular level of complexity. For example, in section 6 Fig. 12 is a map of the students' general perceptions of the concept *tutor*. It is not a frame, because there are other things the students know about tutors; e.g., specific information about their current tutor or past tutors.

## 4. Individual and Social Knowledge

Given the foregoing representation scheme, the relationship between individual knowledge and social knowledge can now be explicated. Knowledge is represented as a fact, regardless of whether that information is individual knowledge or social knowledge. The difference between social and individual knowledge is the level of consensus to that fact.

INDIVIDUAL KNOWLEDGE

Each individual has a knowledge base which contains all of the information that he has acquired. Within this knowledge base there is a set of frames, some of which share some of the same pieces of information. Different frames are associated with different tasks. The knowledge base and the set of interlocked frames are thus representations of the same information. In the first case we are looking at facts as facts and in the second at the structural relationships formed by sets of facts.

## Individuals as rational beings

Individuals are presumed to be rational. Rationality is defined in terms of the use and coherency of known information. Individuals are considered rational in the sense that they use primitive logical operations and optimiza-

tion to make decisions based on the information currently in their frame of reference. Rationality is thus bounded by what information the individual knows and the amount of time available to process that information.

The individual is rational if he uses his frame of reference for a task to perform that task. The individual is rational if he incorporates into his frame of reference that information which is communicated to him which is related to information currently in his frame of reference. The individual is behaving irrationally if he makes a decision or comes to a conclusion, that is not based on the information he knows; e.g., deciding to farm in the desert even though one frame concerns desert farming and includes facts such as *water is necessary for farming* and *there is nor water in the desert*. The individual is behaving irrationally if he rufuses to accept new information which is related to information he already knows, given processing constraints; e.g., refusing to accept the fact *a dog is a mammal* even though his current frame concerns animals and includes the facts *mammals are characterized by having body hair and bearing their young live and so are dogs*.

### Coherent knowledge base

An aspect of rationality is that the individual's cognitive structure, his knowledge base, is presumed to be coherent on a frame by frame basis; i.e., it does not contain a piece of information A and its logical opposite, not A, at the same time in a single frame. To an observer the individual's knowledge base may appear to be incoherent because the observer does not perceive the entire set of frames in question. For example, a mathematician might say that *the sum of the angles of a triangle is always 180 degrees* and then at another time that *the sum of the angles of a triangle need not be 180 degrees*; thus, seeming contradictory to the listener. In the first case the mathematician's current frame, his frame of reference, might be Euclidean geometry, and in the second case his current frame might be a frame for a non-Euclidean geometry, like spherical geometry. The hierarchical nature of frames, due to levels of generalization/categorization, may make it difficult for individuals to see the inconsistencies between different frames in their own knowledge base; i.e., if the top levels of the frames deal with extremely different types of information (involve different concepts) the individual may never access both frames simultaneously or sequentially and so realize that pieces of information contained at lower levels in the frame are actually contradictory.

### Intelligence

Intelligence is defined in terms of the manipulation of sets of information. The individual's level of intelligence is a function of his ability to cross-relate and manipulate the facts in his knowledge base, forming new networks (frames) and altering old ones. It may be difficult to distinguish between irra-

tional and intelligent behavior because in order to distinguish between the two it is necessary to observe the actors frames of reference.

## SOCIAL KNOWLEDGE

Polanyi (1958: 216–219; 264–266) in his discussion of the pursuit of science implicitly defines social knowledge as "tacit knowledge" resulting from "tacit consensus," itself a by-product of the articulation of "common experience," and, more importantly, a product of the transitivity of appraisal across a continuous network of critics. The concepts 'majority', 'relevant', and 'availability' are now redefined as relative phenomena, products of one's position in the social network. For example, if constructing the social knowledge for students in the social sciences: the piece of information that *Piaget is a developmental psychologist* might be considered a piece of social knowledge because it is known and consented to by most students of psychology, some in anthropology and sociology, and only a few in political science and organizational theory; and at the same time, the piece of information that *Garfinkle founded ethnomethodology* may also be considered to be social because it is known and consented to by most students of sociology and anthropology, some psychologists and political scientists, and only a few organizational theorists. Note that in both cases there is a locus (or loci) of consensus, and that it differs from case to case, for each piece of information.

In keeping with Polanyi, and given the foregoing representation schema, I define social knowledge in terms of shared facts. Two individuals may share information; i.e., the same piece of knowledge may be in both of their knowledge bases. In general, for any two individuals the intersection of their knowledge bases contains the knowledge which is social vis-à-vis those individuals. The more members of the social unit who share a particular piece of information the more social that knowledge. Thus, tacit consensus to a fact produces social knowledge. There is no need for explicit acknowledgement of the sharing of that information to confirm the information as social. However, each time the information is reiterated its presence as a piece of social knowledge is reaffirmed.

### Social validity

Each piece of information has a particular level of social validity. The level of social validity is a function of the number of individuals in the social unit who share that piece of information. The social knowledge base is formed at a particular level of validity by taking the intersection across a set of individuals' knowledge bases for each piece of information separately.

The social knowledge base contains those pieces of information that are

shared by some portion of the members of the society. It is a research decision as to what level of consensus produces "social knowledge" and hence what information is in the social knowledge base. A social knowledge base produced by taking the intersection of the knowledge bases of all of the members of the social unit contains only that information which is socially the most valid. In effect, the social knowledge base is formed by taking the intersection across the knowledge bases of all of the members of this social unit — see Fig. 5. In general, whether the social knowledge base is formed by taking the intersection across all of the members of the social unit or just some sub-unit within the larger, the larger the social unit the smaller the social knowledge base. For example, the amount of information shared, on average, by two individuals in the United States is smaller than the amount of information shared, on average, by two students living on Third East.

The level of social validity chosen when constructing the social knowledge base leads to different predictions. For example, if the level of validity desired is tacit consensus by the simple majority of the individuals in the social unit then there may be no individual in the society whose knowledge base contains the entire social knowledge base — see Fig. 5. Whereas, if all individuals in the social unit are expected to consent then all individuals will share all of the information in the social knowledge base.

## Loci of consent

I suggest that different members of the society will have different perceptions of what knowledge is social, in part because of their structural position in the society and in part because of differences in the level of tacit consensus to a fact expected by that individual in order to attach the label "social knowledge." In the first case, for different structural groups in the society, different information will be considered to be social knowledge; e.g., on Third East it is a piece of social knowledge that *if someone makes a pun they are thrown in the shower* whereas on other parts of campus making a pun was not such a capital offense, and in still other parts, the offender might be thrown in the moat. Each piece of information has a different locus of consent. In the second case, one individual might consider a piece of information to be social if he can presume it to be shared by the average man on the street, e.g., if he has seen it on t.v., whereas a different individual might consider a piece of information to be social only if he has personal experience and if all of his acquaintances have communicated this piece of information. I would suggest that most individuals probably have a naive notion of social knowledge as that information shared by "everyone" where "everyone" is the vast majority of members of their current group. Together, these notions are similar to Polanyi's notion of consensus across a network of critics.
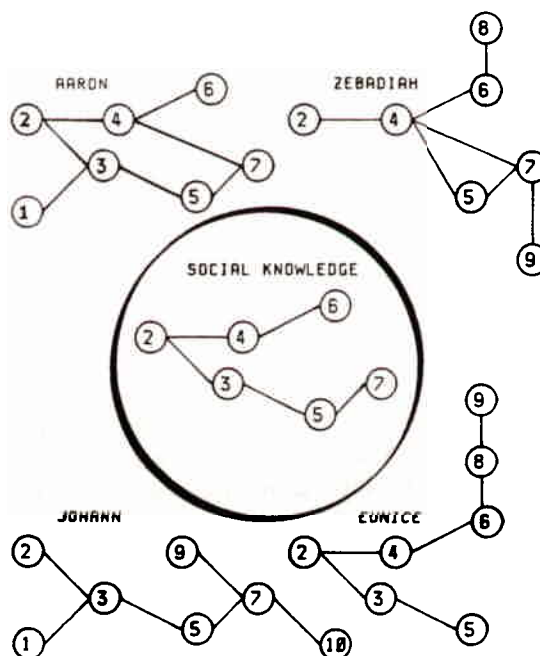
Fig. 5. Social knowledge: shared facts. Social knowledge is based on tacit consensus to a set of facts, on a fact by fact basis. The more individuals in the society who have a particular fact in their respective knowledge base the higher the level of social validity attained by that fact. Social knowledge exists at different levels of social validity, different levels of agreement to the fact by the members of the social unit. In this example, simple majority has been used as the level of social validity, a piece of knowledge is in the social knowledge base just in case it is in the majority of the group members individual knowledge bases.

Social knowledge has a dualistic nature — it is known and consented to by individuals who share a social tie and each piece of social knowledge is in itself a social tie. Individuals can speak of everybody knowing 'x' because, within a particular mapping of the social network (when looking at particular ties) most of the individuals who are tied to that individual do in fact know and consent to that fact [20]. Further, that social fact, that piece of social knowledge, in and of itself becomes a defining characteristic of that social structure, it is a tie which connects individuals in that social unit. Social knowledge thus serves to reflect social structure and both knowledge and structure evolve reflexively.

*Potentially available knowledge*

For the society, at any particular time, there is a set of potentially available information — the set of facts formed by taking the union over the knowledge bases of all of the members of the society. This set includes any

information that is known to at least one member of the social unit. All individuals are assumed to have potential access to the same information. However, what knowledge they actually acquire, when they acquire it, how they value that knowledge, and whether or not they even accept it and incorporate it into their knowledge base is affected both by their current frame of reference and their position in the social network. It is the co-development of the knowledge bases of all of the members of the social unit that leads to the development of the social knowledge base and the alteration of the social network.

### Acritical knowledge

Since the social knowledge base is built upon a piece by piece basis, the resultant internal networks are not formed by generalization, and so do not necessarily have a hierarchical structure. Hence, there is no such thing as coherency on a frame by frame basis, only coherency in the knowledge base in its entirety. Recall, that the individuals' knowledge bases are coherent in a frame by frame fashion, but not necessarily in entirety. Consequently, regardless of the level of social validity used, it is possible for the social knowledge base to be incoherent. The social knowledge base may contain pieces of information that are in direct contradiction to each other. For example, the social knowledge base may contain both the fact that *the tutor must be able to help freshmen with their course work*, and that *the tutor does not need to be able to help freshmen with their course work*. The incoherency/inconsistency of the social knowledge base is exacerbated if the level of social validity required is based on the tacit consensus of fewer members of the social unit than a majority. For example, typical cases of inconsistent social knowledge with low levels of social validity are clichés. Thus, by virtue of its social existence external to any one individual, social knowledge is acritical.

## 5. Knowledge Acquisition — A Model

The foregoing models of social and individual knowledge make it possible to provide a mechanism by which the associated knowledge bases evolve. The proposed mechanism centers around the reconstruction of meaning as the individuals acquire knowledge. Recall that concepts are defined by their relationship to other concepts. Each time the individual acquires a new piece of information, incorporates it into his knowledge base, the meaning of the concepts linked by this information changes. No mechanisms for deleting information are proposed. Thus knowledge acquisition becomes a heuristic act which irreversibly alters the meaning. Social meaning, shared facts relative to

a single concept, evolves, is reconstructed, as the social unit moves through a series of tasks and the individuals communicate information. Shared experience leads to shared knowledge because it provides an opportunity for interaction, hence communication, focuses all individuals on frames that, while not identical nor even concerned with defining the same topic, all contain a great deal of information relative to the experience and hence have a higher degree of overlap (share more facts) than would any random set of frames.

ACQUISITION OF KNOWLEDGE BY THE INDIVIDUAL

Interaction/communication leads to cognitive development. The individual's knowledge base, specifically his current frame of reference (i.e., the frame for the task he is performing) affects what information he chooses to communicate and whether or not he incorporates that information which is communicated to him into his knowledge base. In the following discussion, the concern is with what *can* be accepted and what *can* be communicated; not, what *will* be. The difference between what *can* and what *will* be may be a function of emotional state, intelligence, physical handicaps, etc. Whether or not this is true, is beyond the scope of the current article. One possible interpretation of the following work is that factors such as intelligence and emotions are "noise" in the system, with a probability distribution, such that the following model is a model of what happens not only on average, but in general (e.g., Gaussian).

*Processing demands on knowledge availability*

As an information processor with limited time and resources, the individual at any one time, in order to accomplish a task, is focused on, has immediate access to, only part of his knowledge base. The requirements of task performance limit the individual, such that, while performing that task he has immediate access to that part of his knowledge base that focuses on that task, i.e., the task frame is his current frame. The level of access he has to other frames in his knowledge base is directly a function of the degree to which those frames are similar, share facts, with his current frame. Recall that the individual's knowledge base at a structural level contains a set of interlocked frames. The degree of interlock is the number of facts the two frames share − their intersection. We can imagine a network of frames − see Fig. 6, such that two frames are linked if they intersect in terms of facts. In this network, there exists a path between two frames if the two frames intersect or if they are linked to frames which are linked together. The individual's current frame limits what information the individual can communicate and accept at that point in time by limiting access. Specifically, if we think of access
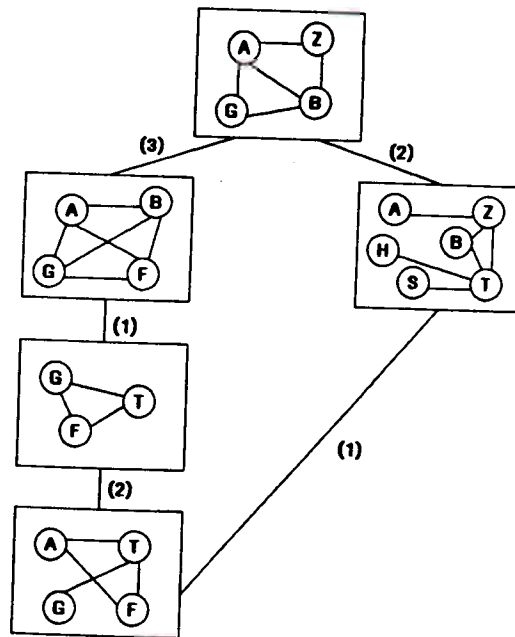
**ACCESS A FUNCTION OF SHORTEST PATH**



Fig. 6. Network of interlocked frames. In the individual's knowledge base there are a set of frames; e.g., one for each task. Two frames are said to interlock to the degree to which they share the same facts. These interlocked frames form a network within the knowledge base, which is in and of itself information for the individual. That is, each frame has a particular handle, or concept, that serves to denote it and these concepts are linked by a relationship indicating the degree of overlap between the frames. Here, each square box represents a frame, and the network within it the facts out of which it is based. The numbers in parentheses are the degree of interlock between the connected frames. At any point in time, the individual is focused on a particular frame, is at a particular position in the network of interlocked frames. This position inhibits and directs recall of information and movement to other frames.

as a probabilistic function then the level of access that the individual has to facts in a particular frame is inversely proportional to the path between the current frame and the desired frame. The strength of the path would be a function of both the length and the degree of interconnectedness between frames for each link in this path [21].

*What information can be communicated*

An individual can not communicate a fact that he does not know. The individual can only communicate information in his cognitive structure; i.e., the fact to be communicated must be in his knowledge base. Whether or not

dividuals interact the larger the intersection of their knowledge bases. This will lead to a situation where the two individuals have not only a set of shared facts, but shared networks of facts; in other words, it becomes possible for them to have shared meanings, shared definitions.

As two individuals' knowledge bases become more similar, the propensity of one individual to accept the facts communicated by the other increases [25]. That is, it is more likely that the communication will be successful because both individuals will share both concepts (consequence of immediate comprehension) and due to shared networks of facts, shared meaning. As these internal or shared meanings develop, the ability to communicate is enhanced. If two individuals share a structure of facts (e.g., the definition of a particular concept) then the communication of a fact that entails this concept evokes the entire shared structure. To the extent that accomplishing a task requires knowledge acquisition or communication, the individual as an information processor subject to time and effort constraints is thus more likely to interact with individuals with whom he shares more facts, due to the rapidity with which knowledge can be extracted and the need for only minimal education.

EVOLUTION OF SOCIAL KNOWLEDGE

The development of social knowledge, social learning, involves tacit consensus over perceived regularities. Social learning occurs as individuals' cognitive structures co-evolve. As individuals interact the number of facts that they share increases. Social knowledge evolves as more and more of the members of the society share the same facts. Social knowledge evolves on a fact by fact basis. As more individuals in the society share a particular fact, that fact increases in social validity, and becomes a piece of social knowledge. A potentially available fact becomes a social fact as more individuals acquire it. Thus, social knowledge, as shared cognitive structure, is also a by-product of human interaction. However, because social knowledge requires tacit consensus among individuals, it will evolve more slowly than will the individual's knowledge base.

Since there is no mechanism at the individual level for "un-acquiring" information, social knowledge will continue to grow if membership in the society is fixed and there is at least one path connecting everyone in the social unit in terms of propensity to interact.

Since social knowledge requires tacit consensus by the members of the society, if the society's membership changes, social knowledge may actually decrease. For example, at one time, all of the members of the society may share a particular fact and so it has a high level of social validity. However, several years later, the society may have many new members who do not share

this fact with the original members of the society and so this fact has a lower level of social validity. Thus, social knowledge is continuously constructed as members enter and leave the society. The longer a group of individuals are together, the more they interact, the more similar their knowledge bases become, and the more social their knowledge.

*Social consensus*

Social knowledge becomes a problematic and continuously renegotiated data base because who knows (and hence tacitly consents to the existence of) what information is dependent on one's position in the continuously changing social structure. A fact is considered to be a part of social knowledge if it has a certain level of social validity. The social validity of a piece of information is a function of the level of tacit consensus. For each piece of social knowledge, tacit consensus to that fact by members of the society, which implies at least an implicit agreement to the value/existence of that piece of information, is not an artifact, but a necessary prerequisite for that fact to be a part of the social knowledge base. Consensus to a set of information, which is seen to imply at least an implicit agreement to the meaning of the included concepts, under a constructural framework, is again not an artifact but a product of consensus over each piece of information, each fact, separately. Since each individual has a different knowledge base, at the social level concepts can only be defined probabilistically [26]. Further, since the social knowledge base is continually constructed on a piece by piece basis, meaning becomes a negotiated dynamic phenomenon that changes as the structural makeup of the social unit changes.

The pervasiveness of a piece of information, the extent of its social validity, is thus a function of the length of chains in the social network along which that information is known. In this case, as one moves along the social network, as one moves from one social group to another, concepts gradually shift in their social meaning, and the set of shared facts changes. Consensus to a set of facts thus serves, implicitly, to define group membership.

*Incomplete social knowledge*

Social knowledge, as a function of shared individual knowledge, is not necessarily complete. For social knowledge to be complete, at a particular level of validity, there must not be a piece of information which is not shared by a "majority" of the individuals in the society. Where absolute validity is required, complete social knowledge would occur only if the union of the knowledge bases is equivalent to the intersection.

*Inaccessible social knowledge*

The lower the level of social validity attached to a particular fact, the

less likely it is that that fact will be accessible to the individual. Because immediate comprehension is required for acquiring knowledge, and since "social knowledge" is not necessarily shared by everyone, a particular member of the social unit may not only not have a particular piece of social knowledge in his knowledge base, but he may be unable to directly access it because he does not have other information that relates to this piece of information. Even though, "everyone else" in the society may have access to this fact. Because of the way the social knowledge base is constructed on a piece by piece basis, some individuals may use only part of the base, and others may use a different part.

The basic idea is that if the individual is in a particular sub-group his individual knowledge base may be so different from the majority knowledge base which forms the social knowledge that he 'literally' can't comprehend it. In this case one might want to question whether or not he should even be considered a member of the social unit. The degree of overlap between the individual knowledge base and the social thus becomes a measure of socialization, and social membership.

The principle of immediate comprehension implies that the individual can only access a social fact in which at least one of the concepts also occurs in his current set of active concepts – those concepts in the current cognitive structure. Socialization thus becomes an incremental process during which the new member is acquainted with a new set of concepts by creating new connections between old concepts and then thus redefining old concepts in terms of new ones. And then, the new member is acquainted with those facts that can only be related in terms of the new concepts.

*Social existence*

Social knowledge maintains an existence independent of any particular individual precisely because that knowledge is shared by many individuals. A single individual can enter or leave the society with little direct impact on social knowledge. His propensity to communicate while a member of the society will affect the development of social knowledge, even though social knowledge exists independently of groups of individuals. The social world is maintaned as a perceptual entity due to the wholistic effect of reflexive consensus; i.e., social knowledge is a function of group membership, and group membership is a function of social knowledge. As groups develop and dissolve, social knowledge changes.

*Educational process*

Education is defined as the process of successfully communicating a chain of facts – see Fig. 9. For example, if the communicator and the receiver have facts $a$ —— $b$, $a$ —— $c$, $a$ —— $d$, and $c$ —— $f$ in common, and the

TEACHER/COMMUNICATOR     STUDENT/RECEIVER
        TIME 1                    TIME 1

IF THE TEACHER WANTS TO COMMUNICATE
THE FACT E—G, THEN B—E or C—E
HAS TO BE COMMUNICATED FIRST ...

STUDENT  TIME 2          STUDENT  TIME 3
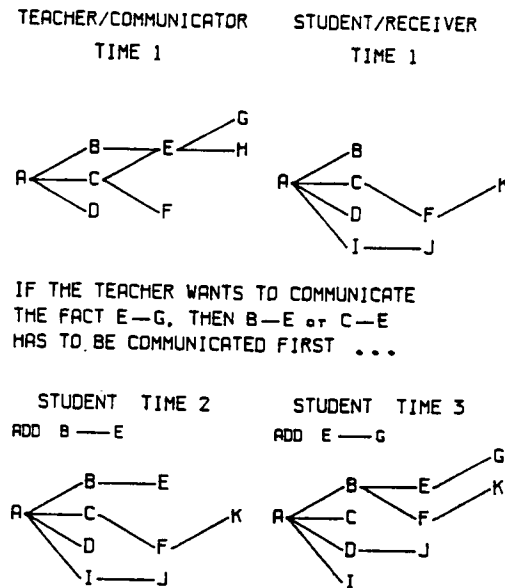ADD  B —E               ADD  E —G

Fig. 9. The educational process requires the sequential communication of facts such that the concepts chain from one to the next.

communicator wants the receiver to know fact $c$ —— $g$, then, if the communicator's knowledge base looks like that in Fig. 8 he will first have to communicate fact $b$ —— $e$, or the fact $c$ —— $e$, and then the fact $e$ —— $g$. The principle of immediate comprehension, when applied to the educational process, suggests that education must proceed in an incremental step-wise fashion.

The greater the common frame of reference, the less likely it is that one individual will have to 'educate' the other in order to communicate a particular fact. Thus, if the individuals start out with a larger common frame of reference, the need for this educational process in order to communicate becomes unnecessary as the requisite facts will already be shared. Within the social unit, education serves to increase the set of shared knowledge, and to decrease the need for explicit communication.

## 6. Knowledge Acquisition – Results

The foregoing model rests on the theory that social knowledge and individual knowledge co-evolve as individuals interact. There are a variety of

Further, each time an individual has a particular fact communicated to him he has a chance to accept it, to incorporate it into his knowledge base. Thus, the more a particular fact is communicated, the more likely it is that the individual will eventually acquire it. The individual's propensity for accepting a particular piece of information is thus proportional to the frequency with which that fact is communicated to him.

WHEN TWO INDIVIDUALS INTERACT

Under the constructuralist theory, previously posited, the driving force behind knowledge acquisition is interaction. Interaction between individuals leads to communication; hence, to the transmittal of information, of facts, from one individual to another — see Fig. 7. As the individuals interact,
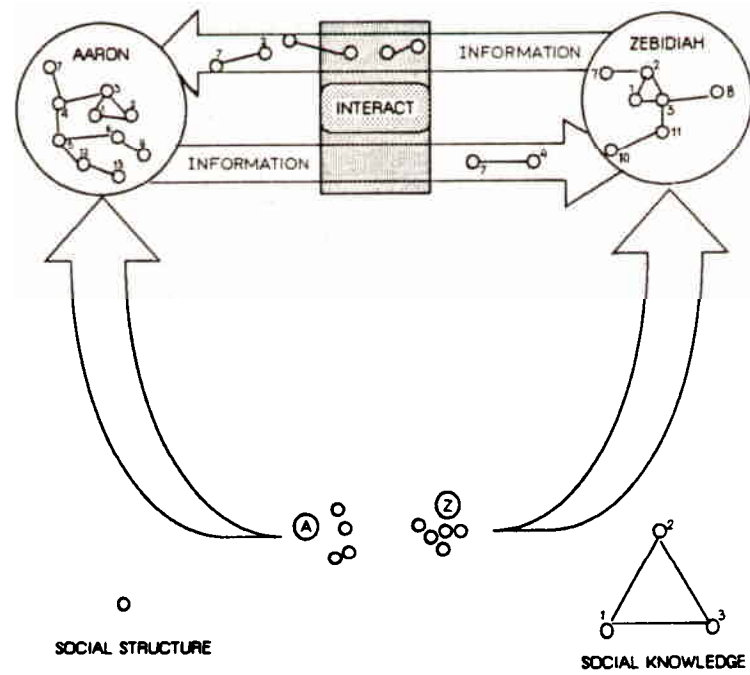


The Social World, via the social structure, affects whom one interacts with and here modulates what information is communicated, the rate of information flow when information is communicated and the value of information.

Fig. 7. As two individuals interact information flows. Individuals can only communicate information which is in their knowledge base. They can only acquire information if that information is immediately comprehensible. Each time period, each time they interact, one piece of information flows from Aaron to Zebadiah, and from Zebadiah to Aaron. Facts in both Zebadiah's and Aaron's knowledge bases are vis-à-vis these two individuals, social knowledge.

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some of the facts in one individual's knowledge base may be communicated to the other individual who may then incorporate those facts into his knowledge base. In each time period each individual may interact with another individual, and communicate and/or acquire one fact to/from the individual with whom he is interacting, subject to the constraints on fact communication and acquisition previously described.

Communication is considered successful if the individual to whom the fact is communicated actually adds it to his knowledge base. Recall that the communication of a fact does not guarantee its acquisition; rather, the individual has a certain propensity to accept that fact, given that it has been communicated. Hence, the more often a particular fact is communicated to a particular individual the more likely he is to accept it, to incorporate it into his knowledge base. On average, it is expected that since the individuals are interacting, hence communicating, that each of their cognitive structures will develop. In this way, social interaction through the process of communication leads to cognitive development – see Fig. 8. Hence, the more two in-
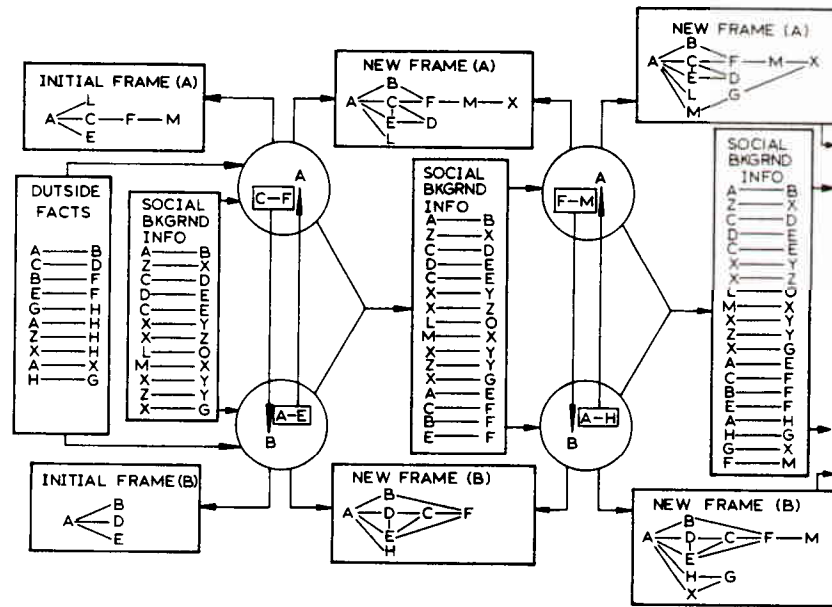


Fig. 8. Development of the knowledge base. Individuals' knowledge bases change over time through the incorporation of some of the information that is communicated from other individuals in the society. The principle of immediate comprehension, when applied to individual knowledge base construction, results in the individuals incorporating a communicated fact into their knowledge base, acquiring knowledge, only if at least one of the concepts that comprise that fact is already in their knowledge base. Social knowledge changes over time as individuals' knowledge bases co-evolve.

meaning of those concepts has been altered. Given that there is no mecha-
nism for deleting facts, knowledge acquisition is thus a heuristic act which
is irreversible. Cognitive development becomes an incremental process, the
result of a gradual construction process (like putting tinker-toys together):
what one learns, how one interprets information, is dependent upon one's
previous understanding, one's previous knowledge base. The principle of im-
mediate comprehension leads to the result that knowledge acquisition occurs
one fact at a time. A fact can be added to the individual's knowledge base
only if it shares a concept with at least one other fact already in the knowl-
edge base. Given that there is no mechanism for "un-acquiring" facts, there
will be no fact in the individual's knowledge base that is not connected to
at least one other fact. Moreover, since frames are hierarchical structures
built up out of facts through the process of generalization, there will be no
frame in the individual's knowledge base that is not linked to at least oth-
er frame. Hence, between any two frames, there will always be a path; howev-
er, the path may be long (number of intervening frames) and it may be very
weak (the links between any two frames may be based on very few shared
facts). Further, the only way to acquire new concepts, to increase one's
vocabulary, is by relating the new concept to one currently in one's cognitive
structure; i.e., by adding a new fact that contains that new concept.

The principle of immediate comprehension limits what the individual
*can* accept; however, it does not guarantee acceptance. The individual, as an
information processor subject to time and effort constraints, is more likely
to acquire knowledge if that knowledge is immediately relevant. That is, if
a piece of information is communicated, an individual is more likely to add
that information to his knowledge base, given that he can add it, if that infor-
mation directly relates to information which is easily accessible. Basically, the
internal structure of the knowledge base, the network of interlocked frames,
serves to inhibit knowledge acquisition.

The principle of immediate comprehension applies on a frame by frame
basis; e.g., the individual will not add a communicated fact to his current
frame unless that fact shares a concept with at least one fact in the individu-
al's current frame. The individual's propensity for accepting a particular
piece of information is inversely proportional to the ease of accessing those
facts which share a concept with the new fact. Given the network of frames,
the individual's propensity to accept a particular piece of information into
a particular frame is inversely proportional to the length of the path connect-
ing the current frame and the frame in which the new piece of information
is to be added. In a literal sense, the individual's current frame acts as his
frame of reference — that body of knowledge that admits understanding and
interpretation of new information — which, at the same time, allows him to
understand any information that is directly related and inhibits him from un-
derstanding information that is not directly related.

the facts in a particular frame can be communicated is dependent on the de-
gree of access that the individual has to that frame at that time. All facts
within a particular frame are equally likely to be communicated vis-à-vis that
frame. The propensity to communicate a particular fact is thus proportional
to the number of frames that contain that fact and the degree of access to
those frames at that point in time. Thus, the individual can not communicate
a fact unless it is both in his knowledge base and he has access to it, given
his current frame [22]. Secondly, given time and effort constraints on com-
munication, the individual is most likely to communicate those facts which
are currently being reinforced (occurring in many frames) and easily accessi-
ble (occurring in the current frame or one connected by a strong path).

## What information can be accepted

Cognitive development is seen as the alteration of the existing cognitive
structure via the acquisition of knowledge. Under normal conditions, it is as-
sumed that individuals can only acquire knowledge; i.e., they can not "un-
acquire" knowledge [23]. A simple, but powerful principle that I would argue
is necessary for defining mechanisms of knowledge acquisition is *the princi-
ple of immediate comprehension:* Individuals will utilize new information to
alter their cognitive structures if they can directly relate that information to
information currently in their cognitive structures.

Given the model of cognitive structures as a collection of facts, a knowl-
edge base, then immediate comprehension [24], the ability to immediately re-
late new information to information currently in one's cognitive structure,
can be redefined in terms of the co-occurrence of concepts in the new fact
and the facts in the current knowledge base. A fact is modeled as two con-
cepts and a connection between them, and two facts are linked if they share
a concept. This is simply a matter of pattern matching on the concepts (their
symbols). Thus the individual can acquire information and yet have no un-
derstanding of what the communicators mean by the concepts involved.
Thus, a fact can be added to the individual's knowledge base just in case that
knowledge base contains at least one fact to which the new fact will link. If
one of the concepts in the new fact is *understood* by the individual, occurs
in that individual's cognitive structure, then the individual can relate that new
fact to at least one other fact currently in his cognitive structure, and so can
add the new fact to the knowledge base.

Recall, that all concepts acquired meaning only by their relationship to
other concepts (the principle of relative definition). Acquisition of knowl-
edge via the principle of immediate comprehension leads to the development
of the cognitive structure by modifying the meaning of the concept(s) which
are contained in the new fact. When a new fact is added to the knowledge
base it serves to link together two previously unlinked concepts. Hence, the

implications, predictions, that follow from this theory. A few of these implications relating to the evolution of individual and social knowledge bases will be explored. Further, the specific models of information and knowledge bases presented herein allow the researcher to explore a variety of issues relative to the nature of knowledge acquisition. Herein, tools based on these models are used to look at two social communication issues – miscommunication and persuasion. These tools are described in Carley (1985b).

## INTERACTION AND TASK SOLUTION PROMOTE KNOWLEDGE ACQUISITION

According to the model, as individuals perform tasks in the course of pursuing everyday life they acquire knowledge by acquiring new facts. In the process of acquiring new facts, they may acquire new concepts, however, the potential number of facts increases faster than the number of concepts [27]. In the proposed data set, it was found that during the three months of tutor selection the cognitive structures of the students on Third East did increase. Moving from the beginning to the end of the process, the average number of concepts increases from 49.27 to 52.87 and the average number of facts increases from 194 to 233.8. Further, as individuals within the group interact, it is expected that the more the individuals interact the more chances there are for communication and hence a transferral of information. Thus, over time it is expected that the cognitive structures of the members of the society will become more similar. And, in fact, on Third East, the standard deviation in number of concepts/facts used decreases over time: for concepts from 16.81 to 15.76, and for facts from 89.15 to 86.36. These trends indicate that shared experience and interaction during the tutor selection process, led to not only an increase in individual knowledge; but, to an increase in shared knowledge. It is important to note that, even though new information was available to the individuals during the tutor selection process, knowledge acquisition through interaction dominated knowledge acquisition through independent discoveries – if this were not the case the standard deviation would not have decreased.

## SOCIAL STRUCTURE AFFECTS KNOWLEDGE ACQUISITION

In a social unit whose existence is not defined by the task in question one would expect that the established pattern of interaction, the extant social structure among the members of the social unit, would affect the behavior of the members of the social unit. One might even argue that the more established the group, the greater the potential for the underlying social structure to affect behavior vis-à-vis a particular task. When cognitive development is seen

as the result of social interaction, then the social structure of the social unit (as defined by the interaction pattern) will be reflected in the socio-cognitive structure (as defined by shared knowledge).

In Table I the relationship between structural position and shared knowledge is presented. The members of Third East were broken down into structural groups using CONCOR (Breiger et al., 1975; Carley, 1984). Joint maps were constructed for each of the structural groups. These joint maps were formed by taking the intersection of facts that occurred in all of the group members' individual knowledge bases [28]. The level of intra-group interaction and shared knowledge are both recorded. Note, the extant social

TABLE I

Social Structure and Consensus

| Structural group | Intragroup interaction | Intergroup interaction | Consensus over concepts | Consensus over facts |
|---|---|---|---|---|
| Gnerds: | | | | |
| Lowell, Hazel, Gay* | 1.00 | 0.17 | 91.58 | 261.45 |
| Heads: | | | | |
| Johann, Eunice, Jake* | 1.00 | 0.12 | 61.47 | 153.97 |
| Laidback: | | | | |
| Lorenzo, Jaques, Jubal | 0.67 | 0.33 | 59.69 | 158.34 |
| Freshmen: | | | | |
| Ted*, Thorby*, Castor, Sam* Tamara*, Hank*, Pollox* | 0.67 | 0.11 | ? | ? |
| Socially Active: | | | | |
| Ian, Maureen, Meade*, Frederico* | 0.50 | 0.11 | 56.97 | 111.56 |
| Sideliners: | | | | |
| Edith, Manni, Jimmy*, Joe* | 0.33 | 0.13 | 44.29 | 102.36 |
| Doers: | | | | |
| Slayton*, Hilda* Zaccur, Ernest, Minerva* | 0.20 | 0.31 | 100.80 | 327.71 |
| Self Defined: | | | | |
| Deety, Lafe*, Roger*, Justin* | 0.17 | 0.13 | ? | ? |
| Loners: | | | | |
| Zebadiah, Woodie, Noah* | 0.00 | 0.03 | 49.40 | 73.46 |
| Non Hall: | | | | |
| Aaron, Ishtar, Lazaraus* | 0.00 | 0.04 | 38.50 | 89.62 |
| Non Structural: | | | | |
| Zebadiah, Deety | 1.00 | ? | 71.74 | 175.25 |

This table is based on time 3 interviews.
* Coded interview was not available at the time of this analysis.

structure, as measured in terms of structural groups, is reflected in the socio-cognitive structure, as measured by social knowledge.

### Shared position leads to shared knowledge

The first point is that social knowledge and social structure are somewhat reflexive; i.e., individuals who share similar structural positions will tend to have similar knowledge bases. For example, Zaccur and Ernest are members of the same social structural group (have similar interaction patterns), and they tend to occupy the same socio-cognitive space vis-à-vis the concept *tutor* (share facts relating to this concept). The confluence of structural and cognitive ties creates a shared reality, a consensus. Despite rare direct interaction these two individuals construct their formulations of the concept *tutor* in the same way — they both utilize non-hall-based information and evaluate information on the basis of their off-hall experiences.

The second point is that, if consensus was merely the result of social training, of shared experience, and not the result of interaction, then we would expect that, in a group where the individuals did not interact with each other and yet were in similar structural positions and shared a large number of external social ties (hence experiences), that there would be a high level of consensus. However, this is not the case. Referring to Table I, we see that the Loners, specifically Zebadiah and Woodie form such a group. They have an intra-group interation level of 0 at the close knit level — both said that they rarely interacted. And they share a large number of external social ties; e.g., they are both in R.O.T.C., don't like to drink, are violently opposed to drugs, and conservative. On the basis of shared ties we would expect these individuals' knowledge bases would exhibit a high degree of consensus; but, they don't — chi squared for the facts is only 73.46. However, they do exhibit a high degree of concepts in common (45.24%). This suggests that: shared social ties (similar experience) result in shared vocabulary, and not necessarily shared meaning. However, given that all concepts are defined only by their relationship to other concepts, the fact that shared position leads to only a similar vocabulary means that individuals who occupy similar positions may use the same words (perhaps even with the same frequency) and yet mean something very different by the words that they use.

And a third point is that structural position indicates a particular level of connectedness [29] which in turn affects not the exact information in the knowledge base, but its structure and the amount of knowledge. Note, those individuals who did not have strong ties with the hall, who did not spend a lot of time interacting with hall members other than perhaps those in their own group (e.g., the Loners and the Socially active) tend to have highly elaborated maps at the onset of the process (large knowledge bases: average number of concepts is 68.5 and average number of facts is 295.5) and as the

process continues their knowledge bases appear to shrink. Whereas, the more hall-dominated students (Laidback and Doers), those who have strong ties and interact with hall members outside of their own structural group tend to have less elaborate knowledge bases at the onset (concept average is 43.5 and fact average is 164.3) and as the process continues their knowledge bases appear to increase. This behavior is probably a function of social ties. That is, both the Loners and the Socially active do not rely on the hall for social life – they maintain, albeit for perhaps different reasons, only weak ties with the hall. Whereas the Doers and the Laidback spend a larger overall fraction of their time socializing on the hall, have strong ties with the hall.

Self-dominated individuals, those with only weak ties with the hall will tend to have a wider range of social contacts, more interactions with non-hall members. This will give them a wider base of information to draw on and hence a more diversified knowledge base. Whereas, hall-dominated individuals will spend more time interacting on the hall, have a more narrow range of social contacts, and so will have a more narrow base of information to draw on. For a task that is specific to the living group, as in the case of the tutor selection, individuals with predominantly weak and inter-group ties will actually be acquiring less information about the task than will those with strong inter-group ties: their base of potential knowledge is wider and hence less focused on the local group's task. Thus, although their non-hall oriented activities may actually give them a head start in so far as having elaborate initial conceptions about the problem, in the long run this wider base of interaction may actually serve to inhibit the flow of task-specific information. On the other side of the coin, hall-dominated individuals, those with predominantly strong inter-group ties will at the onset have access to only social knowledge, previously agreed to rules. Without the influx of new information, this group could in fact stagnate. However, given that there will be some new knowledge, the group with strong ties will actually learn new information faster as they will start out with a larger initial set of shared knowledge and they will be interacting with more individuals in the social unit. Individuals are more likely to acquire a piece of information if it is already shared by a high percentage of the individuals in similar structural positions. This is a direct result of the previous rules for communication and knowledge acquisition. Individuals in similar structural positions interact with the same set of individuals to the same degree. Consequently, on average, they are likely to receive the same information. If a high percentage of the individuals in similar structural positions already share a particular fact then it must be the case that many individuals who communicate with this set of individuals have this fact in their respective knowledge bases. The more individuals who have a particular fact in their respective knowledge base, the more likely that fact is to be communicated. And the more often a fact is communicated to an individual, the more likely he is to acquire it.

*Level of interaction determines level of shared knowledge*

When members of the social unit interact there is a chance for communication; and hence, a chance that the communication is successful, that information is transferred. In the simplest model, *ceterius paribus,* the greater the degree of interaction between two individuals, the greater the amount of information that is transferred, the greater the degree of convergence in their cognitive structures. In this way, interaction leads to the conversion of individual cognitive structures into a similitude of the general conception of reality — i.e., socialization. Note that in Table I, as the level of intra-group interaction decreases, so does shared knowledge. Where the interaction levels are not homogeneous — the members of the social unit can be arrayed on the basis of the degree of interaction — interaction may actually force destabilization — divergence of shared cognitive structures. That is, it is possible for the paths by which individual's cognitive structures converge to a shared cognitive structure for the social unit as a whole to differ according to the patterns of interaction. This imbalance is augmented by the fact that it is possible for the rate of convergence in shared cognitive structure for any particular sub-group to be higher than the rate of convergence for the social unit as a whole. Differences in the patterns of individual interaction propensities across the group form structural groups whose existence is reinforced as individuals' knowledge bases within the sub-group converge while the knowledge bases of individuals in different sub-groups diverge.

In Table I we see that those cases where structural similarity breeds cognitive similarity are exactly those cases where structural similarity and shared interaction paths merge. That is, the higher the level of intra-group interaction the higher the level of shared knowledge. The model suggests that the tighter the social sub-group (the higher the internal interaction among the members of the sub-group relative to the amount of external interaction) the greater the pressure toward shared knowledge among the members of the sub-group. Further, given two tightly structured groups with little cross-interaction the result should be divergent conceptions across sub-groups. Specifically, in sub-groups that are tightly internally structured — where the members of the sub-group spend the majority of their time with each other with little external contact (e.g., cliques) — one would expect that the members of such sub-groups would portray not only similar knowledge bases, but particular facts that are not shared by non-clique members. And, in fact this is the case. For example, the Gnerds and the Heads represent opposing cliques with high intra-group interaction levels and low inter-group interaction levels (as in Fig. 3). If we look at the joint maps formed by taking the intersection of the group members' respective knowledge bases relative to the concept *tutor* we see that in fact there is some overlap between the two groups; but, they also have different facts — Figs. 10 and 11 [30]. For exam-
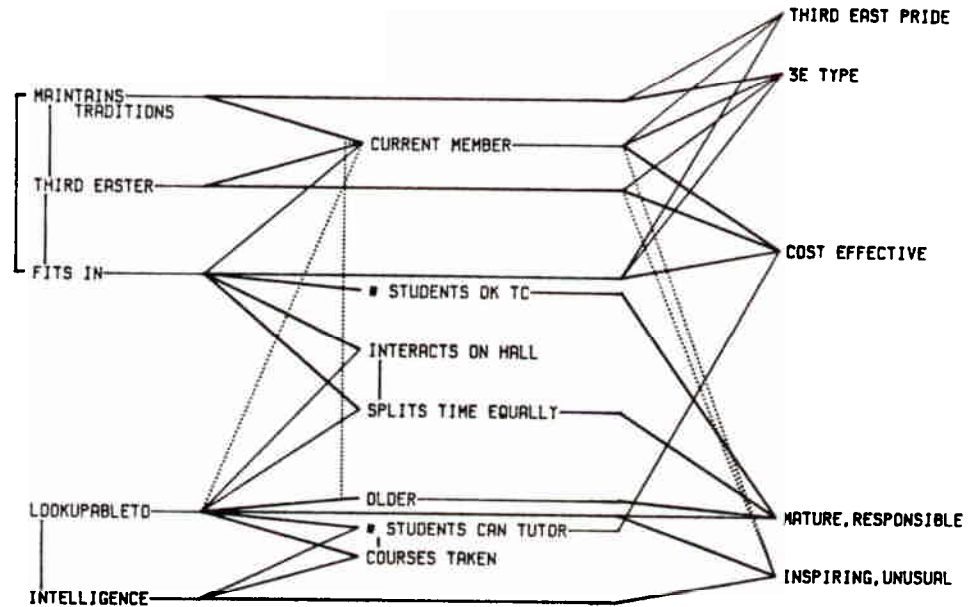
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MISCOMMUNICATION:   GNERDS



Fig. 10. Gnerds' perception of the concept *Tutor*. This map was formed by taking the intersection of Lowell's and Hazel's maps of the concept tutor at time 3, the end of the tutor selection process. Then, the shared structure that did not directly relate to the concepts *Third Easter* or *Lookupableto* was deleted. If part of the structure had not been deleted, the density of the shared map would have made it illegible. The dotted lines indicate an inverse or negative relationship; whereas, the solid lines indicate a positive relationship. All of the concepts on the left hand side can be thought of as requirements for the job of being a tutor. That is, the concept *tutor* is not shown, and there is a positive relationship between this concept and all of those concepts listed on the left.

ple, the Gnerds share the fact that a *current hall member is not lookupable to as a tutor* which is not shared by the Heads, and the Heads share the fact that a *tutor who has knowledge of MIT is cost effective* which is, in turn, not shared by the Gnerds.

Further, ongoing interaction serves to increase the degree of shared cognitive structure. Overtime, as cognitive structures are elaborated through the influx of new information. Specifically, over the course of a decision-making process, as new information comes in, it is natural that some of this information is acknowledged by the individuals and accepted into their cognitive structure. This elaboration is not random but specifically defined by the structure of the social unit, and the flow of information from external
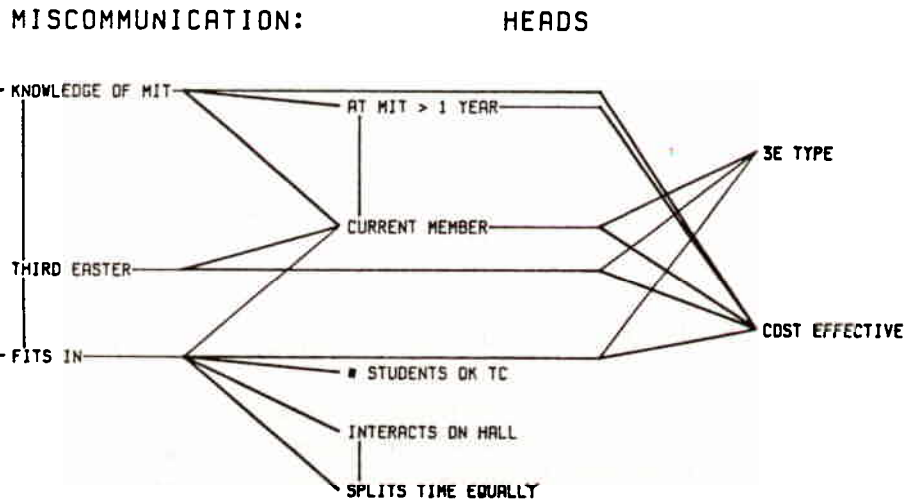
MISCOMMUNICATION:                    HEADS



Fig. 11. Heads' perception of the concept *Tutor*. This map was formed by taking the intersection of Eunice's and Johann's maps of the concept tutor at time 3, the end of the tutor selection process. Then, the shared structure that did not directly relate to the concepts *Third Easter* or *Lookupableto* was deleted. If part of the structure had not been deleted, the density of the shared map would have made it illegible. The dotted lines indicate an inverse or negative relationship; whereas, the solid lines indicate a positive relationship. All of the concepts on the left hand side can be thought of as requirements for the job of being a tutor. That is, the concept tutor is not shown, and there is a positive relationship between this concept and all of those concepts listed on the left.

sources throughout the decision-making process. Where there is a great deal of internal pressure, high intra-group interaction, one expects that over time the members of the clique will develop more similar cognitive structures. For both of the cliques there was an increase in consensus over time; i.e., the maps for the members of the group became more alike — an increase in similarity of 32.5% for the Gnerds and 30.0% for the Heads [31]. And, finally, shared cognitive structure is enhanced not just by having a high level of interaction within the group, but by all members of the group having the same pattern of interaction with non-group members. Note, that the only available data for the Heads and the Gnerds is that for two of the members, in both cases, a couple. If a high level of interaction with another individual was sufficient to produce shared cognitive structure, then we would expect that other couples would also exhibit increasing cognitive similarity as the process continued. However, this is not the case. Another couple in the living group is Zebadiah and Deety. In Table I we see that they are members of different structural groups; i.e., although they spend much of their time interacting with each other, unlike Hazel and Lowell (the Gnerds) or Eunice and Johann

(the Heads) they do not have the same pattern of interaction with other hall members. By the end of the tutor selection process, their maps actually decreased in similarity (−13.6%).

The foregoing findings suggest the following ideas:

- Shared social structural position is sufficient for shared vocabulary.
- Interaction is necessary but not sufficient for shared knowledge.
- Coupling shared position and interaction increases the propensity for shared knowledge.

## SOCIAL KNOWLEDGE EVOLVES SLOWLY

Given that the amount of interaction that can occur between the members of the social unit is predicated upon the amount of time that the individuals have to interact, when time is a scarce resource, the potential for divergence of shared cognitive structures is at its highest. That is, given enough time, the knowledge bases of the members of the social unit will converge, barring the continual influx of new information, and barring changes in group membership and assuming at least one chain of interaction that connects every individual in the society. The rate of that convergence is dependent on the social structure. Given enough time, even the most unlikely interaction will occur and all knowledge will eventually be transferred. However, under normal limited conditions, time is a scarce resource, and extant social structure, for the most part, determines interaction, thus limiting information flow.

Consequently, social knowledge should evolve slowly since tacit consensus is required to produce social knowledge, and such consensus will not occur if the extant social structure inhibits interaction and hence communication and the acquisition of knowledge by individuals in different structural groups. In order for a fact to be added to the social knowledge base there must be tacit consensus to this fact. The level of tacit consensus increases as more individuals acquire a particular fact. Given that structural position limits whom one interacts with, and that interaction is necessary for knowledge acquisition, it will generally be the case that social knowledge will evolve slowly. The more segmented the society, structurally, the slower social knowledge will evolve, etc.

These processes are further exacerbated by the fact that in pursuing their daily lives, the members of the society are not necessarily working on the same task and hence are not guaranteed to even be using the same set of concepts, let alone facts. This phenomenon is also exacerbated by a dynamic social membership. That is, the level of tacit concensus changes as individuals enter and leave the society and as the members of the society garner new
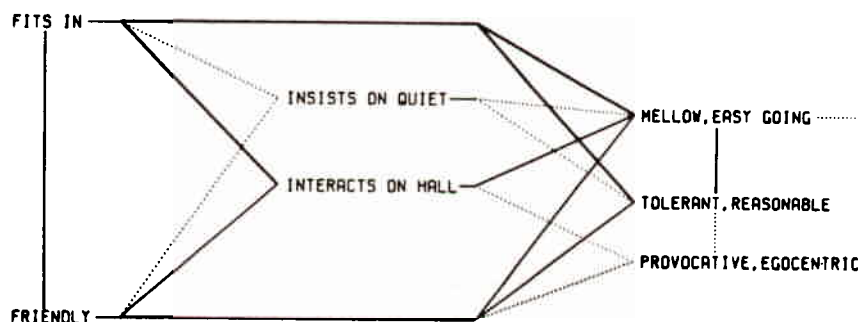
Fig. 12. Social knowledge: beginning of the process. This map was formed by taking the available knowledge bases for the students at time 1, the beginning of the process, and forming their intersection. There were 20 such available knowledge bases. Note, this map is robust in the sense that were any randomly chosen 17 knowledge bases chosen from this same period no other facts would have been included. This map represents the social knowledge about the concept *tutor* at the beginning of the tutor selection process. This can be thought of as the social definition of that particular social position. The dotted lines indicate an inverse or negative relationship; whereas, the solid lines indicate a positive relationship. All of the concepts on the left hand side can be thought of as requirements for the job of being a tutor. That is, the concept *tutor* is not shown, and there is a positive relationship between this concept and all of those concepts listed on the left.

knowledge; consequently, social knowledge is transient. Social knowledge can decrease, a fact can be deleted from the social knowledge base, only if membership in the society changes. In the short run, membership changes are expected to be rare; hence, in the short run it is expected that social knowledge will increase. In the long run, an increase in social knowledge is dependent on mechanisms for education, reiteration, and continual communication of both old and new information.

Fig. 12 shows the social knowledge relative to the concept *tutor* at the beginning of the tutor selection process on Third East. This figure represents the social meaning of the term *tutor*. It was constructed by taking the intersection of the set of 20 maps coded from the interviews done with the students at the beginning of the process (time 1). In Fig. 13 the shared conception of the concept *tutor* at the end of the tutor selection process is presented. This figure was constructed by taking the intersection of the set of 19 maps coded from the interviews done with the students at the end of the process (time 3) — (Carley, 1984). Note, only one concept, *students ok TC*, is added and three facts, over time.

The tutor selection process was less than three months in length. During that time, membership in the social unit did not change. Consequently, we would expect social knowledge during this period to have increased. Compar-
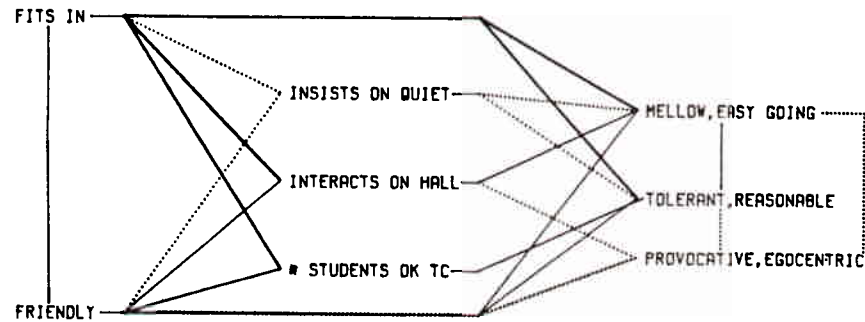
Fig. 13. Social knowledge: end of the process. This map was formed by taking the available knowledge bases for the students at time 3, the end of the process, and forming their intersection. There were 19 such available knowledge bases. Note, this map is robust in the sense that were any randomly chosen 17 knowledge bases chosen from this same period no other facts would have been included. This map represents the social knowledge about the concept *tutor* at the end of the tutor selection process. This can be thought of as the social definition of that particular social position as affected by the students actually having to select someone to fill this position. The dotted lines indicate an inverse or negative relationship. All of the concepts on the left hand side can be thought of as requirements for the job of being a tutor. That is, the concept *tutor* is not shown, and there is a positive relationship between this concept and all of those concepts listed on the left.

ing Figs. 12 and 13 we see that social knowledge at the end of the process includes all facts available at the beginning of the process, and more. Given, that all of the students were involved during this time with the same task, tutor selection, we would expect some development of the social knowledge base. Note that three facts have been added, and that these facts all relate to the new concept *students ok TC.*

Some of these facts were in some of the individual's knowledge bases at the beginning of the process. For this fact to have ended up as part of the social knowledge it would need to have been extensively communicated. It is interesting to note that during the tutor selection process one of the candidates, after his interview, chose to go into one of the students' rooms to smoke. This incident caused a great deal of commotion on the floor, and became the topic of many conversations over the course of the next few weeks. Some students argued that such behavior was immature, others that it was a friendly act, and so on. They could not agree on the interpretation of the event. However, as evidenced by the intersection of their maps at the end of the process, they all did end up agreeing that regardless of what it meant that he chose to smoke with a particular set of individuals, the important thing, vis-à-vis the job of being a tutor was that the *tutor* be someone whom all of the students could agree to. In other words, it doesn't matter what the tutor

does do, but it does matter how the fellow students feel about this behavior. This event, and the measured changes in social knowledge, suggest that not only does social knowledge evolve slowly, but that it evolves relative to shared experience.

A final point, information gathered from an individual who lived on Third East during the late 60's and early 70's, indicated that, in their maps of the concept *tutor*, they all included the fact that *a tutor should be mature and stable* and that a *mature stable person can prevent suicides*. These facts, and others like them were part of the general social knowledge at this point in time, due to events on campus and in the dorms around this period. However, by the early 1980s these facts were no longer part of the social knowledge base vis-à-vis the concept *tutor*. It was no longer the case that being a tutor meant the monitoring of potential suicide victims to the other students. Membership on the hall was completely different, and social knowledge had changed, facts had been deleted from the social knowledge base.

## SOCIAL KNOWLEDGE ADMITS RAPID COMMUNICATION

Within a group with a substantial common frame of reference, substantial amounts of social knowledge, the communication can proceed at what appears to be a rapid rate due to the large number of shared facts. The larger the number of shared facts the more disjoint the communication may appear to an outsider as much of the communication is implicit. Recall that individuals with a substantial shared frame of reference can immediately comprehend any fact that is related to any of their shared knowledge. Hence, for a member of the group to communicate a particular piece of information to the outsider may take a substantial amount of education; whereas, to communicate it internally takes virtually none. This suggests that, what to the outsider may appear as rapid communication among group members, is simply a result of communicating highly context-specific information; i.e., of communicating information connected to the shared-knowledge base. To the extent that a shared body of knowledge, a shared frame of reference, can be thought of as culture, the foregoing argument has the interpretation that culture, simply by being a broad common-knowledge base, admits apparent rapid communication among the members.

In Fig. 14 the explicit knowledge shared by Hazel and Lowell is presented. In Fig. 15 this map has been expanded to include the implicit knowledge. Implicit knowledge is that set of facts that both individuals shared by virtue of being members of the same socio-cultural environment. In conversations with other members of the social unit individuals do not need to reiterate shared social knowledge, as it is understood. This does not mean that these individuals won't reiterate shared knowledge, just that they are less likely to.
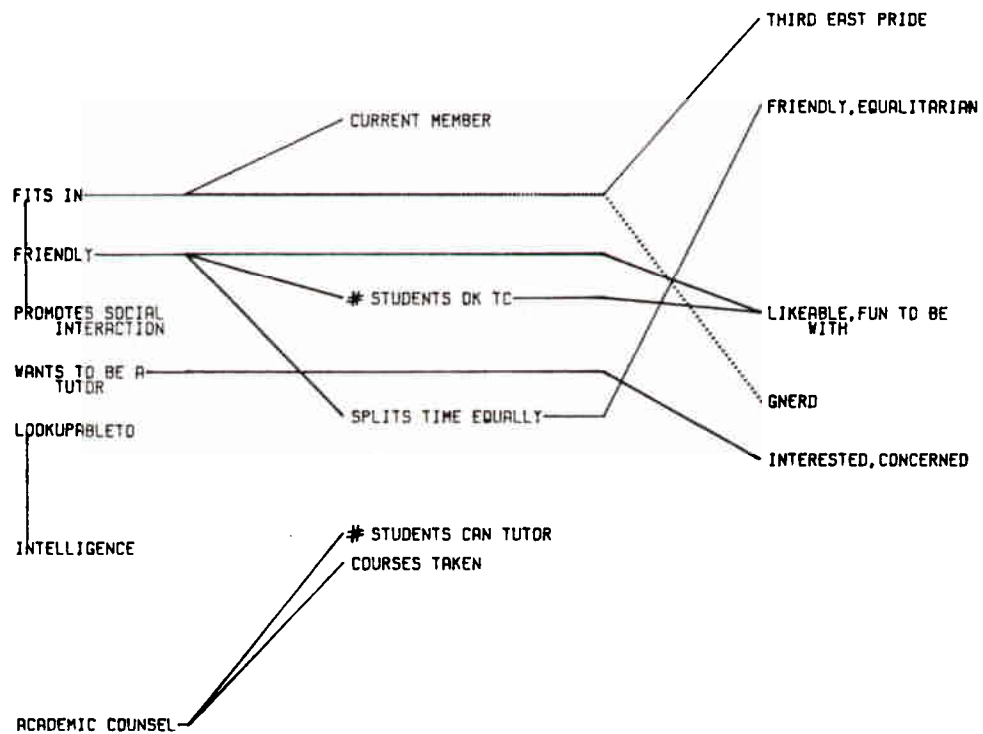
Fig. 14. Gnerds: explicit knowledge base. This map contains the complete intersection of Lowell and Hazel's time 3 knowledge bases prior to the explication of implicit knowledge. That is, this map shows the set of facts that both individuals explicitly mentioned in their interviews about the concept *tutor*. The level of agreement is fairly high.

Further, given a broad set of shared knowledge, these individuals can continue to communicate facts that are disjoint (not connected into a network) and yet be understood by another member of the society because each fact is related to a piece of shared knowledge.

*Decreased explicit communication*

Ironically, the greater the common frame of reference, the less need there is for explicit communication. That is, given that there are a limited number of facts, the more facts the individuals share, the fewer they 'need' to communicate. The increased likelihood of the other individual already knowing that fact decreases the need of the first individual to communicate it. If we assume that the only facts communicated are those that are not shared, and that there is a limit to the number of facts, then as the common frame of reference increases, fewer facts will be communicated. Regardless of whether
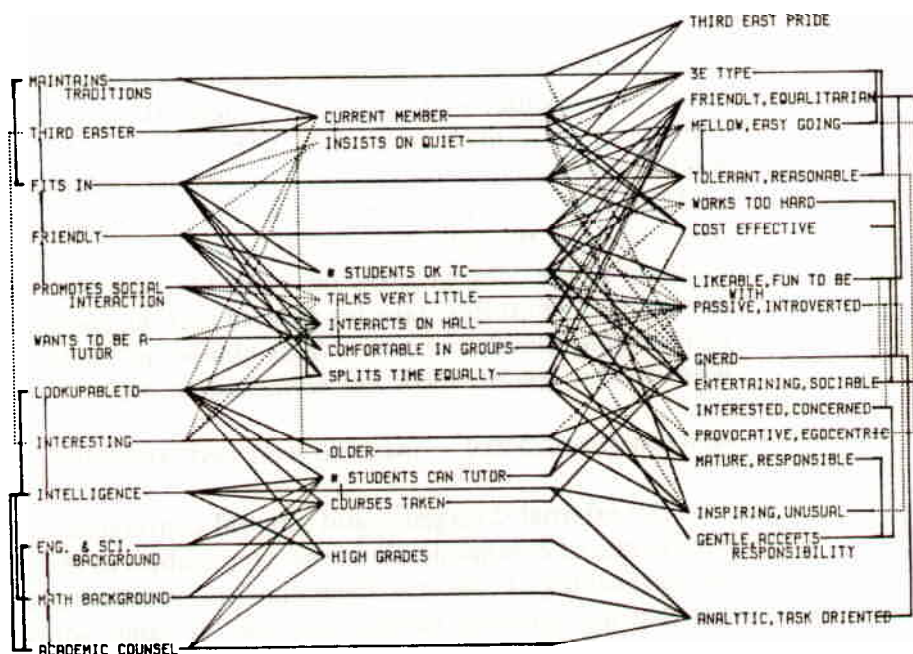
Fig. 15. Gnerds: explicit and implicit knowledge base. This map contains the complete intersection of Lowell and Hazel's time 3 knowledge bases after they have been modified to include the implicit social knowledge that they each, separately communicated. This figure, when compared with the last shows extensive agreement when implicit knowledge; i.e., shared social knowledge is taken into account. Social knowledge thus admits rapid communication; i.e., although Lowell and Hazel were explicitly agreeing to just that set of facts presented in Fig. 14 they were implicitly agreeing to the set of facts in Fig. 15.

or not we assume that there is a limit to the number of potentially available facts, the more facts the individuals share, the more knowledge that is implicit in their communication. Notice, that Fig. 15 is over twice the size of Fig. 14.

*Increased context sensitvity*

As fewer facts are communicated, the sensitivity of those facts to the local context, to the shared frame of reference increases. Consider the case where we have a group of individuals with a large shared-knowledge base, and a virtual outsider — someone who shares relatively few facts with the groups' members. In this case, if a fact is communicated by a member of the group, the outsider will stand little chance of comprehending that fact; i.e., it will be quite unlikely that one of the concepts that comprise that fact will be in his knowledge base [32]. Basically, the tighter the group, the less likely

it is that an outsider will be able to comprehend communication between group members. The outsider does not have the context (the shared frame of reference formed out of the set of shared facts) to understand the communicated information; and, the more context there is (the larger the shared frame) the more likely it is that internally-communicated information will not be immediately comprehensible to outsiders. For example, a non-member of Third East can read, in interviews with the students, the fact that *a gnerd won't fit in on the hall.* However, the non-member is not privy to the shared meaning of the concept *gnerd* on Third East, and so won't know facts that members of Third East take for granted such as *gnerds are not entertaining and sociable, gnerds can tutor a large number of students, gnerds have taken hard courses, gnerds work too hard*, and so on.

## MISCOMMUNICATION – TALKING PAST ONE ANOTHER

The external divergence and internal convergence of sub-groups modifies the rate of communication between members of the social unit by affecting the meaning of concepts. Consequently, members of the groups can think that they are agreeing, because they use the same words (concepts) and yet they are actually miscommunicating. Again, if we assume that there are a limited number of facts, then, the larger the common frame, the less likely it is that individuals will talk past each other, will miscommunicate. If we define miscommunication as the incorporation of the communicated fact into a chain of facts other than the chain expected by the communicator, then as the size of the shared frame increases, relative to the size of the non-shared frame, the likelihood is decreased that a particular fact is embedded in a chain that is 'unexpected' by the communicator. Such a chain of concepts, such a network of facts is considered a "critical path" [33].

The communicator's expectations will be based on his frame. If, for example, there are only 3 chains of facts in which the fact $b \underline{\quad} c$ is embedded in the communicator's frame (A's frame), and there are 4 such potential chains in the communicatee's frame (B's frame) then clearly the likelihood of miscommunication is going to depend on the relative size of the shared frame, the set of shared knowledge.

Miscommunication occurs when a fact is communicated and shared, but the meaning of at least one of the concepts is not shared. Recall, that this is possible as concepts are only defined by their relationship to other concepts. Miscommunication will be worse, in the sense of less expected, if the level of consensus to the meaning of the concepts that compose the fact is high.

Let me illustrate this with an example of miscommunication that occurred on Third East. One of the individuals applying for the tutorship posi-

tion was in fact a current Third Easter. Referring back to Figs. 10 and 11, the Gnerds' and Heads' maps of the concept tutor, you can see that both groups acknowledge the fact that a *Third Easter would be a good tutor*, and that *a Third Easter would fit in on the hall*. A Third Easter actually applied for the tutorship position. The Heads expected that the Gnerds would rank this candidate high when it came time for the vote; however, they did not, and the Heads were confused.

This confusion is due to miscommunication. Miscommunication is particularly unexpected in this case because, in the social unit as a whole, there is a dense socially-accepted meaning for the concept *Third Easter* i.e., many of the facts that serve to define what a Third Easter is, are part of the social knowledge base. In Fig. 16 the shared social meaning of the concept *Third Easter* is presented. Because of the high level of shared meaning to the concept *Third Easter* the Heads don't expect the Gnerds' behavior. However, if you refer to Fig. 10 you will see that for the Gnerds there is a negative relationship between the concept *current hall member* and the concept *lookupableto*, and that *lookupableto* is an important requirement of a tutor. The path — *Third Easter* —— *current member* —— *lookupableto* — is not shared by the Heads, it is part of a critical path whose existence leads to miscommunication. The Gnerds do not accept a current Third Easter as a tutor because, although he is a Third Easter and therefore fits in with the hall, he is not lookupableto. And for the Gnerds, lookupableto is a strong requirement.
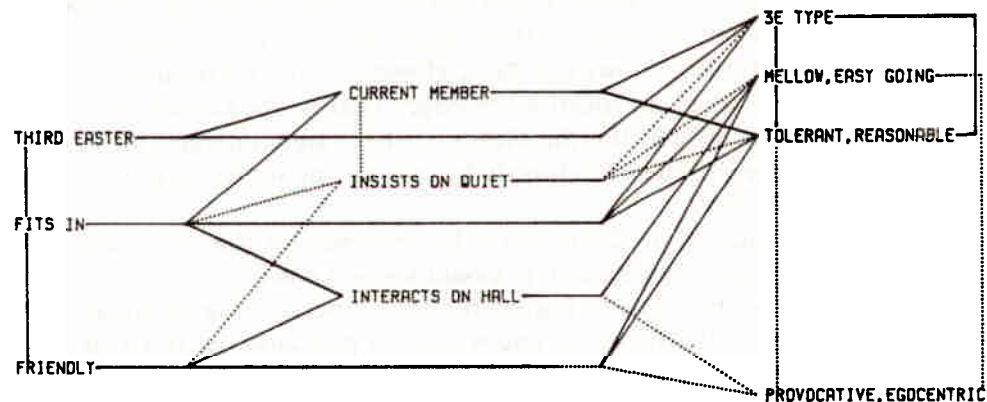


Fig. 16. Third East — social meaning. This map is the focused network of facts in the social knowledge base that represents the social definition, or shared meaning, of the concept *Third Easter*.

PERSUASION – THE USE OF SOCIAL KNOWLEDGE

Now, let's say that the Gnerds, Hazel and Lowell, want to convince the Heads that it is important that the tutor be someone who is lookupableto. To do this, the Gnerds would have to go through a process of educating the Heads. They would first have to successfully communicate a fact that ties the concept *lookupableto* to a concept currently in the Heads' knowledge base, specifically, in the Heads' frame for the concept *tutor* and then a fact that ties *lookupableto* to the concept *tutor*, e.g., they could communicate the fact *someone who splits their time equally among the students is lookupableto* and then the fact that *a tutor should be lookupableto*. In other words, they could try to persuade the Heads by communicating the facts that form the critical path. In principle, such communication could be successful; i.e., it does not counter the principle of immediate comprehension. However, I would suggest that such an approach will not be successful because it will not be reinforced by the social world.

We have already seen that persuasion is more likely to succeed if individuals are members of the same structural groups and have a high level of interaction; i.e., individuals in such groups have similar cognitive structures. In that case, shared structural position reinforces communication and increases the likelihood of persuasion. Gnerds and the Heads as opposing cliques; their structural positions are so different that they reinforce the lack of communications, i.e., both groups have high levels of intra-group interaction (1.00 – see Table I) and relatively low levels of inter-group interaction, especially with each other. The members of these groups rarely interact, and so stand little chance of successfully communicating, persuading the other, if they rely on making their arguments by communicating just any critical path in their knowledge base. However, such persuasion could be enhanced if they relied on social knowledge. That is, the Gnerds have little chance of directly influencing the Heads as they rarely interact; however, they can influence the Heads indirectly by influencing individuals who do interact with the Gnerds.

Indirect influence is further enhanced if the persuader ties the fact he wishes to communicate to extant social knowledge. Social knowledge can be used to reinforce an argument and so increase the likelihood of persuasion. By tying the fact that one wishes to persuade the other of to a previously agreed upon set of knowledge, the persuader is using social knowledge to increase his likelihood of success. This point is illustrated in Fig. 17. Let's say that Aaron wants to persuade Zebadiah of either fact *1* —— *2*, or *4* —— *5*. Both facts are potentially communicable; i.e., both facts are immediately comprehensible by Zebadiah. Aaron will have more luck communicating fact *1* —— *2* than fact *4* —— *5* because, even though neither of these facts is
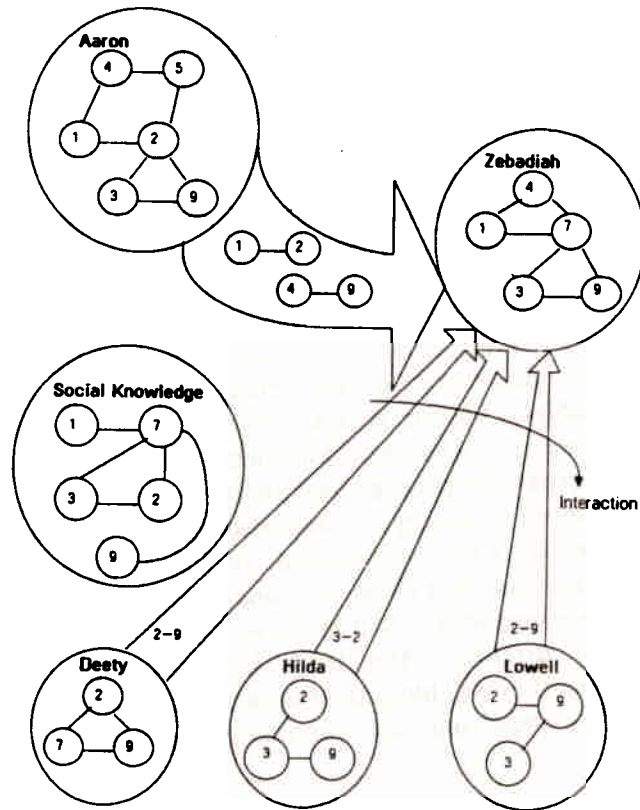
Fig. 17. To convince another. Persuasion is more effective if it is done by tying the new fact to previously accepted information, by tying it to social knowledge. Aaron will have more luck convincing Zebadiah of fact *1* ——— *2* than of fact *4* ——— *5*, because the first is related to extant social knowledge. Moreover, since Aaron is not the only individual who will be interacting with Zebadiah, if he tries to persuade him of fact *1* ——— *2* then some of the other individuals in the process of interacting with Zebadiah will actually help him out as they will communicate facts that have concept *2* in them, simply because each of the facts in their knowledge bases are equally likely to be communicated on a frame by frame basis.

part of the social knowledge base, the first, were it to become accepted by the members of the social unit and so become a part of the social knowledge base, it would be only a minor modification in current shared knowledge, whereas the second would require more extensive modification of social knowledge. Note, that both concepts *1* and *2* are part of the social knowledge base but neither concept *4* nor concept *5* are part of this base. Hence, for the fact *1* ——— *2* to become part of the social knowledge base no education would be required. It just needs to be communicated enough. Further, since there are several facts in the social knowledge base that already utilize the

concept *2*, as individuals other than Aaron interact with Zebadiah, they will communicate facts that include this concept. Thus, in communicating the fact *1* —— *2* to Zebadiah, Aaron only needs to convince him to add the connection, not the concept and connection. In this way, social knowledge can be used to abet persuasion.

Now return to the case of the Gnerds and the Heads. If the Gnerds want to convince the Heads that *a tutor should be lookupableto* and that *a current hall member is not lookupableto* they could utilize social knowledge relative to the concept *lookupableto*. On the Third East, it turns out that there is no accepted definition of the concept *lookupableto* in the social knowledge base; i.e., most students have their own idea about what it means to be *lookupableto*. So, the Heads can't rely on a shared definition.

However, in the social knowledge base, there is a set of facts relating to how to evoke the concept *lookupableto*; i.e., there is a set of facts such that if the anterior concept is accepted by the student the posterior concept (*lookupableto*) will be accepted. In Fig. 18 all of those facts in the social knowledge base that evoke *lookupableto* are shown, as are all of those facts that evoke concepts which evoke *lookupableto*. Note, that none of the concepts are currently in the Heads' knowledge base. Thus, if the Gnerds want to succeed they will have to set up a situation such that many of the individuals in the social unit are communicating facts containing one or more of
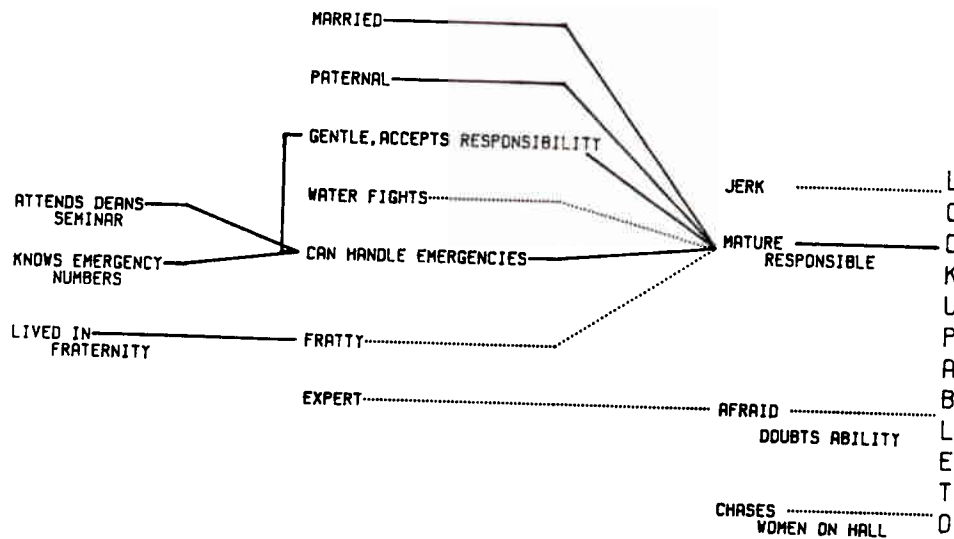


Fig. 18. Evoking *Lookupableto.* This map was drawn from the social knowledge base by extracting all of those facts that evoked *lookupableto*, had *lookupableto* as the posterior concept. Note, there were no facts in the social knowledge base in which *lookupableto* was the anterior concept; i.e., there was no socially agreed to meaning for this term.

these concepts, and then the concept *lookupableto* will be evoked. For example, if they create an emergency, or start a water fight, etc. while a potential tutor candidate is on the hall, then those concepts will be evoked and so will the concept *lookupableto*. As more members of the society accept facts that contain the concept *lookupableto*, more individuals in the society will communicate facts that contain *lookupableto* to the Heads. Consequently the Heads will eventually add the concept *lookupableto*. Once the Heads have the concept *lookupableto* in their map, persuasion becomes a matter of linking the concepts.

It is interesting to note that, at MIT, tutor candidates often complain that the students do crazy things during the interviews, almost as if they were trying to test the candidates; e.g., staging water fights, asking outrageous questions, etc. The foregoing analysis suggests that what the students are doing is not so much testing the candidate as creating a situation that is known, via social knowledge, to evoke particular concepts that they want all of the members of their social unit to have in their knowledge bases. That is, the students are engineering situations by staging water fights and asking outrageous questions as a means to increase group consensus.

At any rate, one's ability to persuade another is thus enhanced if one can rely on extant social knowledge to do the education, and then make a minor modification in this social knowledge. This idea coupled with the principle of immediate comprehension suggests that persuasion will be the most successful if it relies on communicating a fact that links two well-established maps together. Moreover, one can make the prediction that the longer the chain of facts that is to be communicated, and the more removed the facts are from the extant social structure, the less likely the communication will succeed, the less likely that the receiver will be persuaded.

## 7. Synopsis

The constructuralist theory was briefly presented. This theory posits that the world of the individual and the social world are constructed as individuals interact while performing the set of tasks that constitute daily life. Interaction leads to communication and thus to knowledge acquisition. Cognitive development, knowledge acquisition at the individual level, is the direct result, perhaps even a by-product of social interaction. Since interaction is part of everyday life, the individual's cognitive structures are continually constructed and updated. The co-development of the individual's knowledge bases produces social knowledge. Shared knowledge, social knowledge, changes individuals' propensities to interact. And, individuals' propensities to interact develop reflexively with social structure.

Constructuralism serves as the backdrop for an extended look at the relationship between social knowledge and individual knowledge. In the foregoing discussion little attention was paid to specifically modeling the way in which changes in knowledge affect interaction or to the relationship between interaction and social structure. These topics, while germane to the theory, are beyond the scope of the current paper, and so, tended to be glossed over. Rather, herein, the goal was to elaborate that part of the constructuralist theory that spoke to the case of knowledge acquisition at the social and individual level. In this vein, several propositions and a few specific models were forwarded; e.g., articulatable knowledge, immediate comprehension, relative definition, tacit consensus, and the knowledge acquisition model. Based on these ideas, a few predictions were made and explored using the Third East data; e.g., increased interaction leads to increased shared knowledge, social knowledge is transient but evolves slowly, miscommunication occurs if critical paths are missing, and effective persuasion requires minor social modification.

No claim is being made that the data prove the theory. Nor is there any claim that the findings are unique. Rather, the point of the foregoing analysis is that the proposed model of knowledge acquisition is not only simple, but leads to consequences that are in fact observable. Further, the proposed model has valuable implications for the process of knowledge acquisition and the analysis of this acquisition; e.g., the whole notion of utilizing social knowledge to abet persuasion. A final point is that the representation scheme for knowledge − facts and knowledge bases − is particularly useful in locating specific instances of particular communication behavior, and hence in increasing the researchers' analytical power.

Although this paper has been about the way individuals acquire information, not the way they perform tasks, some implications can be drawn about tasks. Tasks require the formulation of a problem and a solution; they require the individual to acquire knowledge and to define when the acquired knowledge constitutes a solution. For the individual, task performance is a heuristic act if it is dependent on the acquisition of knowledge, and not exclusively on the use of previously acquired knowledge. As more members of the society go through the process of formulation vis-à-vis a particular task, the task becomes a social task. The task becomes a social task in which the task formulation, the set of requisite knowledge, is negotiated by those performing the task. As multiple individuals pursue the same task, social knowledge vis-à-vis the task increases. Now, consider the limiting condition − every piece of information relative to the task has a high level of social validity. A piece of information at the individual level acquires the impact of a rule if that piece of information exists independent of the individual by virtue of being social, shared by others. In this case, the task can be thought of as cul-

tural. The task, its formulation and solution are part of the culture because the formulation no longer requires negotiation; i.e., the formulation has been established by previous social encounters over the same or similar tasks. Cultural tasks are, in a sense, solved social problems. The establishment of rules vis-à-vis the task is thus indicative of the degree of culturalization of the task.

Culturalization of information decreases the degree of individual formulation necessary and increases the ease of information transmittal within the society. Culturalization can also be seen as making the knowledge acquisition, and hence tasks, easier from the individual point of view as it decreases the need for analysis. To use a rough analogy, task solution can be seen as involving processing, storage, retrieval, and correlation; here, culturalization can be thought of as obviating the need for correlation, decreasing the processing costs, and thus reducing the task from one of formulation to one of memorization. Games have a high level of culturalization, the presidential election less so, and the Third East tutor selection even less.

A final point. Given that one's understanding of another's behavior is predicated upon the belief that similar cognitive conceptions will produce similar behavior, then control of cognitive development becomes equivalent to control over social outcome. If, as postulated, cognitive development is the direct result of social interaction, then control over that interaction becomes the keystone to the establishment and maintenance of a particular social world. Limiting the individual's interactions serves to direct his cognitive development by inhibiting knowledge acquisition to just that knowledge communicated by his contacts. At the societal level, limitations on the member's patterns of interaction can serve to create a stable social environment, and a stagnant one.

## Notes

1 Some researchers have gone so far as to argue that the social environment not only constrains, but determines (dominates), not just the individual knowledge acquisition process but the associated reasoning process (Blalock, 1967; Durkheim, 1951; Luria, 1978; Vygotsky, 1962, 1978).

2 Note, Cicourel (1974: 27) makes an argument similar to the one above stressing the point that: "The social analyst's use of theoretical concepts like role actually masks the inductive or interpretive procedures whereby the actor produces behavioral displays which others and the observer label 'role behavior'. Without a model of the actor that specifies such procedures or rules, we cannot reveal how behavioral displays are recognized as 'role taking' or 'role making'."

3 As these pieces of social background information increase in social acceptance the task becomes more highly defined relative to that society, and thus becomes more of a cultural task.

4 A network representation of the knowledge base – refer to section 3.

5 As will be seen, the representation schema is extremely general and can be mapped into, as a database, many of those previously mentioned. In some ways, it bears the highest degree of similarity to Minskian frames and to augmented transition networks.

6 The individual's propensity for interaction can be thought of as an array containing his propensity for interacting with all other individuals in the society.

7 The individual's cognitive structure is the set of information known by the individual, his knowledge base.

8 Social knowledge can be thought of as social background information (Carley, 1985b), that information which everyone knows.

9 The perceived patterns of regularities in the interaction behavior of the individuals in the society.

10 Note, as the population changes, as individuals enter and leave the social unit the social world changes. As the composition of the society changes the possibilities for interaction change and as a consequence the social world is altered. If the composition of the society is fixed, the social context will change as long as new information is being communicated. Similarly, new information; e.g., discoveries lead to changes in social knowledge. With neither new information nor changes in the composition of the society, the social world will asymptotically approach an equilibrium. Once equilibrium has been reached, the society is static, no changes will occur in either social knowledge or social structure. In this sense, culturalization becomes a process of choice reduction, a process in which the individual's interaction propensities and knowledge base become increasingly constrained by a fixed social world.

11 The process and theory of knowledge acquisition described are presumed to be relevant to adults gathering information. The early cognitive development of children may actually follow a different process.

12 The proposed relationship between the information-gathering and decision-making aspects of behavior are discussed further in Carley, 1985b.

13 All knowledge is viewed as articulatable. The idea in this paper is that all knowledge is articulatable and hence interrelated. One could argue here that the acquisition of language is not the acquisition of independent concepts or words, but the acquisition of a potentiallly articulatable structure. For example, a child's utterance of the word *food* is really a communication of the piece of information *I want food* and learning the term *strawberry* is learning that *object x is a strawberry*. And so on. In this case, the acquisition of language becomes just a special case of general knowledge acquisition. The implication for education would be that teaching a new language by teaching a set of words independent of context will be less successful than teaching a language by teaching phrases, or paired concepts.

14 The rules of the language are viewed as being capable of being represented in the same manner as information in the language. And, like the information, the rules are dynamic; i.e., they can change over time and across individuals.

15 Such forces include changes in membership; e.g., due to migration, and changes due to discovery.

16 To extract social structure data on the level of subjective interaction data was analysed using the block modeling program CONCOR (Breiger et al., 1975). A complete report on the social structure of Third East is presented in Carley, 1984, ch. 11.

17 The proposed representation scheme was originally posed in Carley, 1984. For a more detailed presentation of this scheme than that presented herein, the reader is referred to Carley, 1985b. For a discussion of using this scheme to code verbal protocols the reader is referred to Carley, 1985a.

18 Note, the term knowledge and information are being used interchangeably. In part, be-

cause no claims are being made about differences between the two. And, in part, to stress the idea that under the proposed model there is no such thing as an absolute value for knowledge; i.e., there are no absolute truths, and validity is a function of the degree of shared tacit consensus to that fact.

19 This model follows from the notion of a fact, forwarded by Minsky (Minsky, 1975, pp. 181) — "a fact is a relationship together with a few things the relationship ties together in a meaningful way." Note, the general notion of a linked pair of concepts as the representation of information is used by a wide variety of researchers both prior and subsequent to the Minskian articulation.

20 What I mean by know and consent is that the piece of the information is in the individual's cognitive structure, the fact is in the knowledge base.

21 A link between two frames is a piece of information, a fact in the knowledge base. The strength of the link is the number of facts shared by the two connected frames. A path is a set of frames and the links between them.

22 As will be explained in the next section, barring trauma, the individual can potentially access any piece of information from any frame; however, the access path may be so long and the various links so weak that, given his time and effort constraints, the individual may actually not have the time to process the path to retrieve the desired information.

23 The loss of memory is viewed as the result of trauma, or biological dysfunction which actually serves to block off or destroy stored information. The inability to recall information, barring memory loss, is viewed as a function of access given that access is a function of the location of the desired information vis-à-vis in the network of frames given one's current frame.

24 In terms of education, the principle of immediate comprehension suggests that the Socratic method, or any other method in which new knowledge is built by reliance on old, rather than memorization, will be more effective.

25 This might be subject to some types of limiting conditions. For example, if there is a limit to individual's knowledge bases then, eventually, there will be no need for communication; however, this seems unlikely.

26 In contrast, if complete information is assumed then the available information does not have varying probabilities of truth or importance for different individuals. Consensus to a fact, which is seen to imply at least an implicit agreement to the value of a piece of information, is under classical decision theory, an artifact. Since, the value of the fact is "fixed" across individuals, and consensus results by default. Consensus to a set of information, which is seen to imply at least an implicit agreement to the meaning of the included concepts, under classical decision theory, is also an artifact. Again, because everyone knows everything, all concepts are defined in absolute terms: social meaning is fixed within the social unit. Social knowledge becomes a non-problematic absolute standard, not a negotiated dynamic phenomenon.

27 Assuming uni-directional connections, if the number of concepts increases as $N$, the number of facts increases as $N^2 - N$.

28 CODEF was used to code the interviews to produce individual maps (Carley, 1984, Carley, 1985b). These maps were then modified using an expert system which aided the coding process CarleySKI. Then the program JOINT was used to locate the social knowledge base for the group.

29 One measure of connectedness is the number of ties; e.g., weak ties or strong ties (Granovetter, 1973, 1974, 1982).

30 These figures are not the full maps extracted from the interviews regarding the concept tutor, rather they are only a portion of those maps. For the full maps the reader should turn to Carley, 1985b. Portions of maps are presented, in this case, rather than full maps,

as the lower level of complexity aids in exhibiting the point about miscommunication in a later sub-section.

31 This is the percentage increase in the chi-squared for the concepts.

32 The probability that an individual immediately comprehends a fact is a function of the ratio of the number of facts that he shares with the members of the group, and the number of facts shared by the members of the group.

33 Imagine the chain of facts $a — b — c — d$. This chain is a critical path if $a — b — c$ is known by one individual and $b — c — d$ by the other. In this case miscommunication occurs when $b — c$ is communicated.

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